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Is the trend in new introductions of marine non-indigenous species a reliable criterion for assessing good environmental status? The case study of Greece

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Abstract

This study presents the updated status of marine non-indigenous species (NIS) distribution in Greece and investigates trends in new NIS introductions, at both national and subnational level, during 1970-2017. The overall picture shows an increase in new introductions from the 1970s to 2017. The number of unaided introduced species (mainly Lessepsian immigrants) followed an upward trend in the South Aegean Sea until 2017. Similarly, the number of NIS associated with transport-stowaway (NIS introduced mainly via ballast and boat hulls) followed an upward until 2017 in the South Aegean Sea, but also in the Hellenic Levantine coasts. However, these results are greatly affected by a monitoring bias, which appears to be the main factor influencing the number of new NIS introductions reported from Greece and its subnational areas. This monitoring bias, as well as the continuous influx of Lessepsian NIS into the Aegean Sea, constitutes a challenge for Greece as regards setting exact boundaries for areas with or without Good Environmental Status (GES), based on Descriptor 2, primary criterion C1 (D2C1), of the Marine Strategy Framework Directive (MSFD). Dedicated monitoring of marine NIS should be established and be constant in space, time and across taxonomic groups. Prioritization should be given to hot-spot areas of new NIS introductions, such as ports, aquaculture units and marine protected areas. This should be a prerequisite for applying the primary criterion D2C1 of the MSFD properly, at both national and subnational level. Finally, as regards the implementation of D2C1 of the MSDF and setting exact threshold values, we highlight the need for subregional and regional coordination in the Mediterranean.

Keywords: Non-indigenous species; biological invasions; range expansion; pathways; monitoring; Mediterranean Sea.

Introduction

Marine non-indigenous species (NIS; also called alien species) are of high relevance to a number of international and European policies (Boon *et al.*, 2020). Marine NIS are included as a descriptor of Good Environmental Status (GES) in the Marine Strategy Framework Directive (MSFD) (EC, 2008), namely Descriptor 2 (D2).

The Member States of the European Union (EU) are required to consider NIS when developing their marine management strategies, which aim to reach GES in the context of the MSFD (EC, 2017a, b). Towards this aim, an annotated list of the marine NIS of Greece was compiled by Zenetos *et al.* (2018), which included 217 NIS. Since then, new species have been recorded in the Hellenic Seas (Kondylatos *et al.*, 2018; Dragičević *et al.*, 2019; Kousteni *et al.*, 2019; Küpper *et al.*, 2019; Giovos *et al.*, 2020; Karachle *et al.* in Bariche *et al.*, 2020; Angelidis & Polyzoulis, 2018; Manousis *et al.*, 2020; Pirkenseer, 2020; Ragkousis *et al.*, 2020; Zenetos & Miliou, 2020; Zenetos et al., 2020). In addition, several NIS have extended their distribution range northwards (Aegean Sea) (Gerovasileiou *et al.*, 2017; Kondylatos & Corsini-Foka, 2017; Kondylatos *et al.*, 2017; Lipej *et al.*, 2017; Ulman *et al.*, 2017; Chartosia *et al.*, 2018; Manousis *et al.*, 2018) and westwards (Ionian Sea) (Yokeş *et al.*, 2018; Dimitriadis *et al.*, 2019, 2020; Pirkenseer, 2020). Unaided natural dispersal of NIS previously introduced elsewhere in the Mediterranean (58%) and transport-stowaway (37.1%) were identified as the major pathways of introduction for the new NIS introduced into Hellenic waters (Zenetos *et al.*, 2018), following similar patterns to those

observed in the Eastern Mediterranean Sea (Katsanevakis *et al.*, 2013; Armon & Zenetos, 2015).

The primary criterion set for D2 by the European Commission (EC, 2017b) (criterion D2C1) is: "*The number of non-indigenous species which are newly introduced via human activity into the wild, per assessment period (6 years), measured from the reference year as reported for the initial assessment under Article 8(1) of Directive 2008/56/EC, is minimized and where possible reduced to zero*". For most Member States, the reference year for the initial MSFD assessment corresponds to 2012 for marine NIS (Tsiamis *et al.*, 2019), which means that the first six-year assessment period for D2C1 is the period 2012- 2017.

In order to define GES based on D2C1 "*Member States shall establish the threshold value for the number of new introductions of non-indigenous species, through regional or subregional cooperation*" (EC, 2017b). However, setting threshold values for the new NIS introductions of D2C1 has proven to be challenging (OSPAR, 2018).

The aim of this work is to analyze the relative trends in the number of new NIS introductions in Hellenic waters during six-year periods, aiming at making recommendations for defining GES in Greece based on D2C1. In addition, we investigate the trends in new NIS introductions in association with their related pathways, at both national and subnational level. Finally, we present an updated distribution of the marine NIS of Greece at the MSFD subnational level.

Methods

Geographic areas

Five assessment areas have been defined in the territorial waters of Greece (Fig. 1), according to the MSFD Initial Assessment by the Greek Ministry of Environment and Energy (MinEnv Greece, 2012), namely the Adriatic, Ionian, North Aegean, South Aegean and Levantine Seas.

NIS updating and distribution data

Detailed distribution data of marine NIS in Greece are stored in the ELNAIS database (https://elnais.hcmr.gr/), which was established in 2007 and is continuously updated with new data from published and grey literature, new observations made by a network of contributing experts and citizen science data (Zenetos *et al.*, 2015).

The list of marine NIS of Greece by Zenetos *et al.* (2018) has been updated with new data until September 2020 (Annex 1: supplement). In addition, the status of several species was updated on the basis of new evidence. Specifically, the foraminiferan species *Amphistegina lobifera* Larsen, 1976, *Amphistegina lessonii* d'Orbigny in Guérin-Méneville, 1832, *Clavulina* cf. *multicamerata* Chapman, 1907, *Heterostegina depressa* d'Orbigny, 1826, *Triloculina* cf. *fichteliana* d'Orbigny, 1839 and *Planogypsina acervalis* (Brady, 1884), that were classified as cryptogenic in Zenetos *et al.* (2018), have been re-instated as non-indigenous following Stulpinaite *et al.* (2020). In contrast, five microalgae that were listed as non-indigenous in

Fig. 1: MSFD assessment areas of the marine territorial waters of Greece (according to MinEnv Greece, 2012).

Zenetos *et al.* (2018), have been transferred to cryptogenics following Gómez (2019); these are: *Sinophysis caniculata* J.-P.Quod, L.Ten-Hage, J.Turquet, G.Mascarell & Couté, *Prorocentrum emarginatum* Y.Fukuyo, *Prorocentrum borbonicum* Ten-Hage, Turquet, Quod, Puiseux-Dao & Couté, *Prorocentrum levis* Faust, Kibler, Vandersea, Tester & Litaker, and *Pseudochattonella verruculosa* (Hara & Chihara) Tanabe-Hosoi, Honda, Fukaya, Inagaki & Sako. Two annelid species, namely *Mediomastus capensis* Day, 1961 and *Eurythoe complanata* (Pallas, 1766), were also moved to cryptogenics following Langeneck *et al.* (2020). Finally, the nimble spray crab *Percnon gibbesi* (H. Milne Edwards, 1853) reported in Greece since 2004 (Thessalou-Legaki *et al*., 2006) was removed to crypto-expanding species as its introduction into the Mediterranean Sea is most likely due to natural spreading (passive drift of larvae with currents) from the Atlantic Ocean, as suggested by Sparrow *et al.* (2001). Unsupported records were removed before proceeding to analyze trends. For example, *ca*. 100 mostly wrong, mollusc records were deleted by Crocetta *et al*. (2017).

Based on the September 2020 updated list of marine NIS of Greece (Appendix I), the date of first collection (or first report if the date is missing) has been compiled for each Hellenic MSFD area separately. Both established and non-established species (casual records) were considered. Cryptogenic and data-deficient species have not been taken into account due to their high uncertainty. Trends were presented at both national and subnational level, per MSFD assessment area (Fig. 1).

The most plausible pathway(s) of introduction in Hellenic waters was assigned for each NIS, according to the Convention on Biological Diversity (CBD) classification (CBD, 2014).

COR = CORRIDOR: interconnected waterways/basins/seas.

UNA = UNAIDED: natural dispersal across borders of non-indigenous species that have been introduced through other pathways, as in the case of Lessepsian immigrants or otherwise transferred species (e.g. on vessels) in the Mediterranean, spreading unaided to Hellenic waters.

REL = Release in nature: aquaculture/mariculture; aquarium species; intentional (accidental or irresponsible) release of live organisms from confinement, including cases such as the disposal of aquaria kept species into the wild.

TC = TRANSPORT-CONTAMINANT: contaminated nursery material; contaminated bait; food contaminant (including live food); contaminant on animals (except parasites, species transported by host/vector); parasites on animals (including species transported by host and vector); contaminant on plants (except parasites, species transported by host/vector); parasites on plants (including species transported by host and vector).

TS = TRANSPORT-STOWAWAY: angling/fishing equipment; hitchhikers on ship/boat (excluding ballast water and hull fouling); ship/boat ballast water; ship/boat hull fouling; other means of transport.

UN = UNKNOWN.

Data analysis

We investigated the trends in new NIS introductions at national and subnational level in association with their pathways during six-year reporting cycles, in accordance with the primary criterion D2C1 of the MSFD. Considering that the vast majority of NIS in Hellenic waters has been detected after 1970 (208 NIS out of 242), we measured the rates of new NIS introductions (expressed as number of new NIS per six-year period) from 1970 to 2017, covering eight reporting cycles. Hence, data from 1970 to 2017 were grouped in six-year periods, and linear trends were estimated for the number of new NIS in all study areas. The R^2 and p-value along with the equation of each trend are presented. Statistical significance was set to $p<0.05$. The aforementioned analysis was performed on (a) the entire dataset per area, disregarding the pathway of arrival; and (b) the two major pathways, i.e. UNA and TS, separately.

The Durbin-Watson statistic was applied in order to check for autocorrelations. In all the cases under study, the Durbin Watson test was between 1.5 and 2.5, thus excluding autocorrelation. Significant changes in the number of observations (number of new NIS per six-year period) from 1970 to 2017 among the MSFD areas and the six-year periods (using one-way ANOVA), as well as between the two main pathways (TS and UNA) (using one-way ANOVA) were investigated. A one-way ANOVA was applied using the number of observations as dependent variable and MSFD areas as well as six-year periods as independent variable.

Results

Overview and updated distribution data

A total of 242 marine NIS has been recorded in Hellenic waters by September 2020 (Appendix I). Fishes is the taxonomic group with the highest number of NIS, contributing with 51 NIS, followed by 50 molluscs, crustaceans and annelids (43 and 33, respectively).

The distribution of marine NIS in the Hellenic MSFD subnational areas is presented in Figure 2. The most plausible pathway/vector of arrival is given in Appendix I. There are currently seven NIS in the Adriatic Sea, 78 in the Ionian Sea, 92 in the North Aegean, 113 NIS in the Levantine, and 196 in the South Aegean Sea. Approximately half of the NIS are found in at least two MSFD subnational areas, while 85 species occur exclusively in one MSFD subnational area (see Appendix I). The majority of the latter NIS are casual records, but >30 of them are already established in a MSFD subnational area. Such are the cases of the recently detected mollusc *Viriola* sp. [cf. *bayani*] Jousseaume, 1884 (Micali *et al.*, 2017; Ovalis & Zenetos in Stamouli *et al.*, 2017; Steger *et al.*, 2018); the bryozoan *Celleporaria vermiformis* (Waters, 1909) (Ulman *et al.*, 2017), the tracheophyte *Halophila decipiens* Ostenfeld (Gerakaris *et al.*, 2020), and the fish *Cheilodipterus novemstriatus* (Rüppell, 1838) (Ragkousis *et al*., 2020).

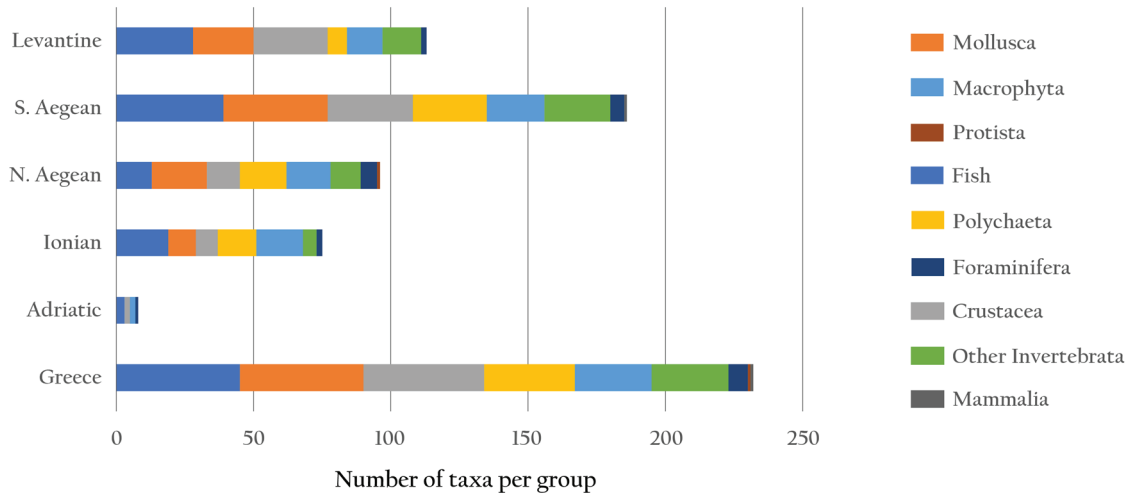

Fig. 2: Contribution of taxonomic groups of marine NIS at national and subnational level, Greece.

Trends in new NIS introductions

The overall picture (Fig. 3) shows an increase in NIS introductions from 10 new NIS in the period 1970-1975 to 42 new NIS in 2012-2017.

Figure 4 depicts the trend in new NIS introductions per MSFD area, with the exception of the Adriatic Sea where only seven species have been recorded to date. The highest number of new NIS records in the North Aegean and the Levantine was recorded in the period 2006-2011, whereas in the Ionian in 2000-2005 and in the South Aegean in 2012-2017. It should be also noted that in the South Aegean alone an increase in the number of new NIS was observed during the last analyzed six-year period (i.e. 2012-2017), while in all the remaining areas this number dropped. Finally, a general upward trend in new NIS and all MSFD areas was observed from 1970 to 2017. Nevertheless, this trend was significant ($p<0.05$) only in the South Aegean and the Levantine (Fig. 4).

The main pathways of marine NIS introductions at national level are (see also Fig. 5): 1) unaided, which correspond mainly to the Lessepsian species; i.e. natural dispersal of Lessepsian NIS already introduced in the Southeast Levantine basin (Egypt, Israel, Lebanon, Cyprus etc.), and 2) transport-stowaway, which correspond mainly to NIS introductions related with ballast water and hull fouling.

A breakdown of the pathways of introduction per MSFD subnational area (Fig. 6) revealed that the introduction of Lessepsian NIS peaked in the South Aegean (106 species) and Hellenic Levantine Seas (84 species), while more than 40 NIS have been introduced in the North Aegean and Ionian Seas (44 and 42 taxa, respectively). The second most important pathway of introduction was transport-stowaway including ballast, boat hulls and angling-fishing, for all MSFD subnational areas (Fig. 6). Release in the wild appears to be a minor pathway of introduction as observed in the South and North Aegean Sea (Fig. 6).

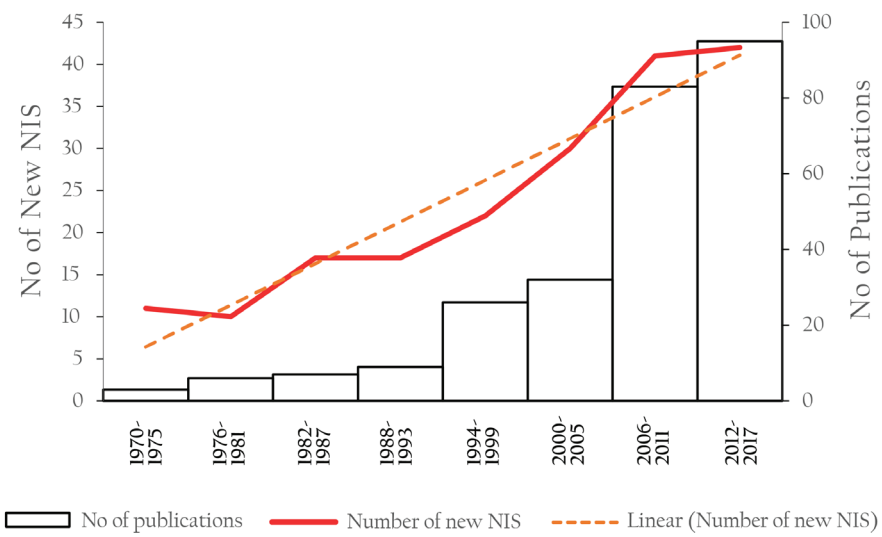

Fig. 3: Trends in new NIS introduction *vs*. scientific publications at national level since 1970.

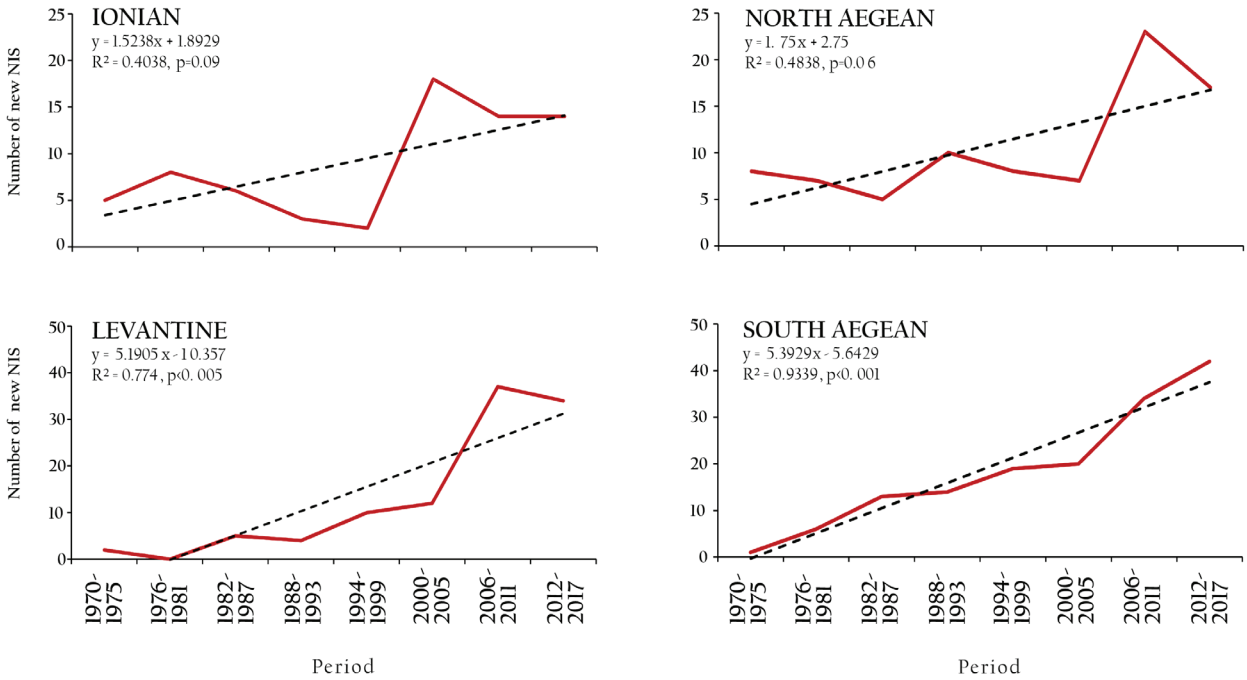

Fig. 4: Number of new marine NIS introductions per six-year periods in the Hellenic MSFD subnational areas from 1970 to 2017.

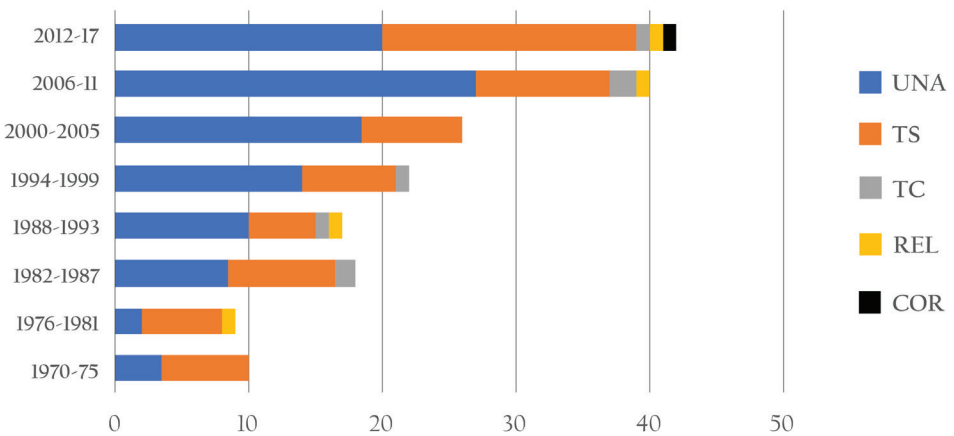

Fig. 5: Trends in pathways of new marine NIS introductions at national level of Greece since 1970 (UNA = Unaided, TS = Transport-Stowaway, TC = Transport-Contaminant, REL = Release in Nature, COR = Corridor).

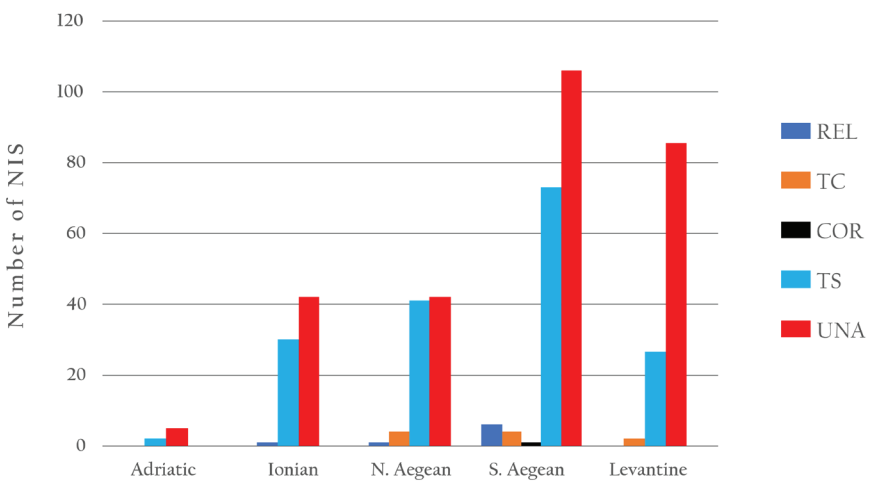

Fig. 6: Pathways of new marine NIS introductions per MSFD subnational area of Greece since 1970 (UNA = Unaided, TS = Transport-Stowaway, TC = Transport-Contaminant, COR = Corridor, REL = Release in Nature).

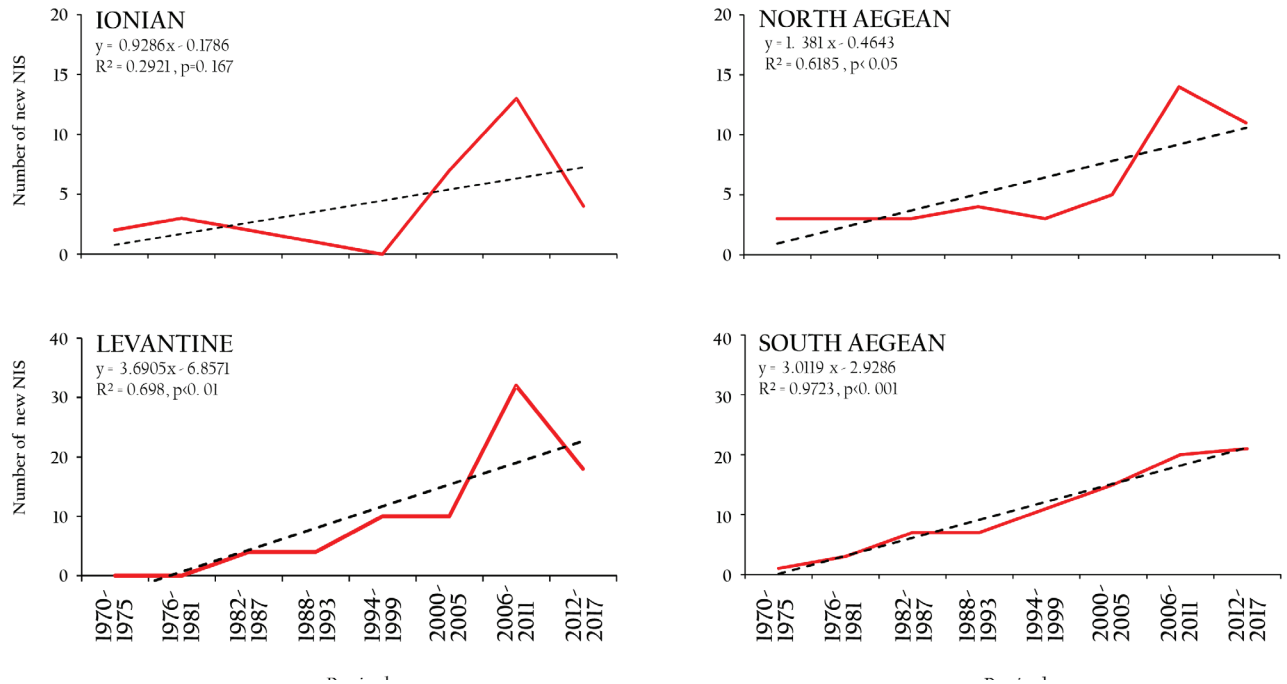

Fig. 7: Trend in unaided (UNA) associated new NIS introductions per six-year cycle since 1970 in the Hellenic MSFD subnational areas.

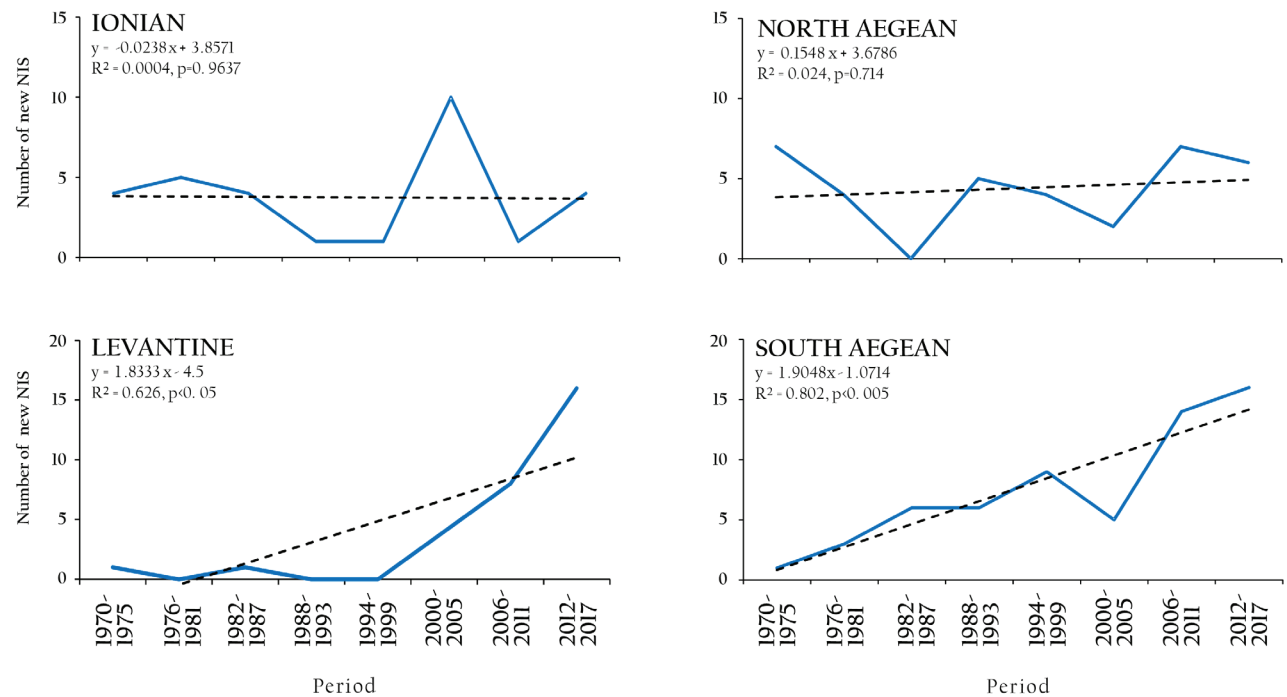

Fig. 8: Trends in transport-stowaway associated new NIS introductions per six-year cycle since 1970 in the Hellenic MSFD subnational areas.

With respect to the unaided (UNA) introduced species, on a sexennial basis, an upward trend was observed (Fig. 7), being significant in all subnational areas ($p<0.05$) with the exception of the Ionian Sea ($p=0.167$). The pattern of observations for transport-stowaway associated NIS showed a significantly upward trend in the Levantine and South Aegean ($p<0.05$ in both cases; Fig. 8). This trend was not observed in the Ionian or the North Aegean ($p=0.934$ and 0.714, respectively).

Discussion

At national scale, an upward trend in new NIS introductions during the last years is noted. This increase of new NIS introductions is probably affected –to a certain degree– by increased research on NIS during the last years (Crocetta *et al*., 2017; Zenetos, 2019). Furthermore, the introduction and wider use of underwater digital photography and visual census as tools for recording marine biota by both recreational and scientific divers, com-

bined with the launch of new publication outlets encouraging researchers to report findings of new NIS records (e.g. Dailianis *et al.*, 2016; Gerovasileiou *et al.*, 2017; Dragičević *et al.*, 2019; Katsanevakis *et al.*, 2020), have contributed significantly to the reporting of several NIS.

The analysis at subnational scale revealed a peak of new NIS introductions in 2006-2011, followed by a slight decrease in 2012-2017, for the North Aegean Sea and the Hellenic Levantine Sea. However, given the time lags in reporting introductions for several NIS, future research could reveal different trends (Zenetos *et al.*, 2019). On the other hand, new NIS introductions seem to accelerate further in the South Aegean Sea during 2012-2017. This continuously upward trend should be attributed to the increasing monitoring effort in the area, especially around the Island of Rhodes and the Saronikos Gulf. Moreover, pathway analysis at subnational scale indicated a rather constant increase of new NIS associated with the "Unaided" pathway in the South Aegean Sea, corresponding to Lessepsian immigrants and other NIS which have been previously introduced in neighbouring areas. These NIS continue to spread westwards from already established populations in the adjacent coasts of southern Turkey. On the contrary, the observed decrease in Lessepsian NIS introductions in the Hellenic Levantine Sea during 2012-2017 might be the result of less monitoring effort targeting these species in that period.

The introduction of Lessepsian NIS appears to be slowing down in the North Aegean and Ionian Seas, possibly due to the winter temperatures prevailing in these areas, which are not yet hospitable enough to receive and foster the rate of establishment of Lessepsian immigrants, as in the case of the South Aegean Sea. However, new Lessepsian NIS have been reported from these areas during the last years, such as the fishes *Pempheris rhomboidea* Kossmann & Rauber, 1877 and *Upeneus moluccensis* (Bleeker, 1855), the molluscs *Dendostrea* cf. *folium* (Linnaeus, 1758), *Septifer cumingii* (Dunker, 1855), *Syrnola fasciata* Jickeli, 1882, *Smaragdia souverbiana* (Montrouzier, 1863), *Ergalatax junionae* Houart, 2008, the echinoderm *Diadema setosum* (Leske, 1778) and the foraminiferan *Triloculina* cf. *fichteliana* d'Orbigny, 1839, which reached the North Aegean in the period 2012-2017 (Evagelopoulos *et al.*, 2015; Delliou *et al.*, 2015; Giovos *et al.*, 2019). Similarly, yet at a slower pace, Lessepsian NIS advance towards the Ionian Sea. For example, the fishes *Upeneus pori* Ben-Tuvia & Golani, 1989, *Stephanolepis diaspros* Fraser-Brunner, 1940, *Bregmaceros nectabanus* Whitley, 1941, *Torquigener flavimaculosus* Hardy & Randall, 1983, *Scomberomorus commerson* Lacepède, 1800, and *Sargocentron rubrum* (Forsskål, 1775) reached the Ionian Sea in the period 2012-2017, whereas another two, *Pterois miles* (Bennett, 1828) and *Synchiropus sechellensis* Regan, 1908 were observed in 2018 (Mitsou & Maximiadi in Yokeş *et al.*, 2018; and Teneketzis & Christidis in Yokeş *et al.*, 2018) and *Diadema setosum* (Leske, 1778) in 2019 (Pirkenseer, 2020).

An analysis of the pathway transport-stowaway (shipping) revealed an upward trend in new NIS introductions associated with that pathway for the South Aegean and the Hellenic Levantine Sea. The South Aegean Sea hosts Piraeus Port, one of the biggest ports in the Mediterranean. Based on Eurostat (2018), there is a constant increase of the commercial ship traffic in Piraeus port since its privatization in 2009. This increase agrees well with the recent sharp increase of NIS associated with transport-stowaway (shipping) in the South Aegean during the periods 2006-2011 and 2012-2017. On the other hand, the Levantine Hellenic coasts lack large ports. Still, the Hellenic Levantine coasts (as well as the South Aegean ones) constitute major tourism destinations, especially for sailing boats that might be responsible for hull-fouling NIS introductions. In addition, increased monitoring effort also explains the above pattern. For instance, the recent studies of Ulman *et al.* (2017) and Ulman (2018) focused on the marinas of Rhodes and Crete, and revealed several new NIS for the Hellenic Levantine Sea, most of which were also the first records for Greece. Less monitoring could explain the fact that new NIS introductions associated with shipping in the North Aegean and Ionian Seas have not increased, although these areas host some of the largest Hellenic ports, such as Thessaloniki port (Gkargkavouzi *et al.*, 2019).

Release in the wild comes third, but far behind, as pathway of introductions. Its increasing role as a pathway in the Mediterranean has been highlighted by Zenetos *et al.* (2016). Corridor (Suez Canal) was assigned as a direct pathway only for the fish *Acanthurus sohal* (Forsskål, 1775) (Giovos *et al.*, 2018).

Reporting on new ship-transferred NIS relies mostly on scientific research given that diving activities rarely take place near ports and marinas, while sessile fouling taxa are difficult to identify by non-experts. However, their number is expected to increase during the next years as several ports, marinas and cargo ship hulls have been targeted for focused NIS research within the framework of the national MSFD monitoring activities and other parallel projects coordinated by Hellenic research and academic institutions.

It should be highlighted that several species still remain undetected/unreported in one or more MSFD subnational areas (Table 1). The proximity to the Turkish coasts of the Levantine Sea is responsible for many NIS in the Aegean Sea, which are already established in the Levantine Sea and are progressively moving/expanding towards the Aegean Sea. Most of them were first reported from eastern Rhodes Island (Hellenic Levantine Sea), but many had already advanced to the Aegean Sea before they were observed in the Hellenic Levantine waters. Such is the case of 22 species present in Hellenic Aegean waters, yet unnoticed in Hellenic Levantine waters, either due to different expansion events or to spatial variation in research efforts. Similarly, 12 species reported from the Levantine subnational area have not yet been reported from the Aegean Sea coasts (Table 1) and, thus, they could be considered potential future newcomers for the adjacent marine areas. The above patterns could be attributed partly to the regional lack of experts. For instance, the parasite *Glyphidohaptor plectocirra* (Paperna, 1972) has only been reported from Hellenic Levantine

Table 1. Marine non-indigenous species in Greece, present in at least one MSFD subnational area, but possibly present in other MSFD subnational areas as well, pending discovery (1: to be detected/reported by scientists, 2: to be reported by divers and citizen scientists, 3: to be reported by fishers and divers, 4: to be reported by amateur shell collectors).

Lessepsian NIS present in the Aegean Sea, pending detection in the Levantine Sea of Greece	**Lessepsian NIS present in the Levantine Sea of Greece, pending detection in the Aegean Sea**	**Transport-stowaway associated NIS, expected to be discovered in additional MFSD subnational areas of Greece**
[4]*Acteocina mucronata* (Philippi, 1849)	[2]*Actaeodes tomentosus* (H. Milne Edwards, 1834)	[1]*Amphibalanus eburneus* (Gould, 1841)
[2]*Alepes djedaba* (Forsskål, 1775)	[1]*Calanopia elliptica* (Dana, 1846)	[4]*Anadara transversa* (Say, 1822)
[1]*Bemlos leptocheirus* (Walker, 1909)	[4]*Cerithidium perparvulum* (Watson, 1886)	[1]*Balanus trigonus* Darwin, 1854
[1]*Bregmaceros nectabanus* Whitley, 1941	[4]*Clementia papyracea* (Gmelin, 1791)	[1,4]*Bulla arabica* Malaquias & Reid, 2008
[4]*Bulla arabica* Malaquias & Reid, 2008	[1]*Dorvillea similis* (Crossland, 1924)	[1]*Caprella scaura* Templeton, 1836
[4]*Cerithiopsis tenthrenois* (Melvill, 1896)	[1]*Glyphidohaptor plectocirra* (Paperna, 1972)	[1]*Celleporaria brunnea* (Hincks, 1884)
[3]*Champsodon nudivittis* (Ogilby, 1895)	[2]*Hypselodoris infucata* (Rüppell & Leuckart, 1831)	[1]*Clytia linearis* (Thornely, 1900)
[4]*Diodora funiculata* (Reeve, 1850)	[2]*Matuta victor* (Fabricius, 1781)	[1]*Crisularia serrata* (Lamarck, 1816)
[3]*Equulites klunzingeri* (Steindachner, 1898)	[1,3]*Metapenaeopsis mogiensis consobrina* (Nobili, 1904)	[1,4]*Diodora funiculata* (Reeve, 1850)
[4]*Fulvia fragilis* (Forsskål in Niebuhr, 1775)	[3]*Oxyurichthys petersi* (Klunzinger, 1871)	[1]*Hypnea valentiae* (Turner) Montagne
[4]*Isognomon legumen* (Gmelin, 1791)	[3]*Sillago suezensis* Golani, Fricke & Tikochinski, 2014	[1]*Paracartia grani* (G. O. Sars, 1904)
[2]*Macrophthalmus indicus* Davie, 2012	[1,3]*Trachysalambria palaestinensis* (Steinitz, 1932)	[1]*Polycerella emertoni* Verrill, 1881
[4]*Nerita sanguinolenta* Menke, 1829		[1]*Polydora cornuta* Bosc, 1802
[1]*Ophiactis savignyi* (Müller & Troschel, 1842)		[1]*Scytosiphon dotyi* Wynne
Parexocoetus mento (Valenciennes, 1846)		[1]*Sertularia marginata* (Kirchenpauer, 1864)
[3]*Pomadasys stridens* (Forsskål, 1775)		[1]*Sphaeroma walkeri* Stebbing 1905
[4]*Pyrunculus fourierii* (Audouin, 1826)		[4]*Spondylus* cf. *spinosus* Schreibers, 1793
[3]*Saurida lessepsianus* Russell, Golani & Tikochinski, 2015		[1]*Styela plicata* (Lesueur, 1823)
[4]*Smaragdia souverbiana* (Montrouzier, 1863)		[1]*Tricellaria inopinata* d'Hondt & Occhipinti Ambrogi, 1985
[4]*Spondylus* cf. *spinosus* Schreibers, 1793		
Syrnola fasciata Jickeli, 1882		
[2]*Xanthias lamarckii* (H. Milne Edwards, 1834)		

waters (Stefani *et al.* 2012). However, a wider distribution is suspected because its hosts, the rabbitfish *Siganus luridus* (Rüppell, 1829) and *Siganus rivulatus* Forsskål & Niebuhr, 1775, are already widespread in the Hellenic seas and have developed large populations in several areas. As records of many conspicuous fish, crustaceans and molluscs are attributed to citizen scientists (Zenetos *et al.*, 2015; Crocetta *et al.*, 2017; Giovos *et al.*, 2019), their contribution in "filling-in" regional gaps of still unreported NIS in the Hellenic waters is expected to be significant, especially in understudied remote areas.

Based on the above, it is evident that the number of new marine NIS reported from Greece is greatly dependent on: a) the westward influx of Lessepsian immigrants from the south coasts of Turkey to the South Aegean, and b) monitoring effort.

Several of the Lessepsian immigrants enter the Greek seas through natural dispersal from already infested are-

as of the Eastern Levantine Sea. It has been highlighted that the introduction of NIS that are spreading exclusively through natural dispersal is impossible to control and manage. Consequently, it has been argued that these NIS should be reported in the criterion D2C1, but not be taken into account when measuring GES based on that criterion (Palialexis *et al*., 2015). Nevertheless, it is challenging to prove that these NIS are secondarily spreading exclusively through natural dispersal and not also through human-mediated pathways (e.g. fouling, fishing nets, etc.). Moreover, some of these species may have catastrophic impact on native habitats (e.g. *Siganus* spp.), while others may also be included in the Union list of the EU Regulation for Invasive Alien Species (EC, 2014), such as *Plotosus lineatus* (Thunberg, 1787). Thus, we believe that ignoring them could be controversial.

When it comes to the monitoring effort, it has been highlighted as an important factor for reporting new NIS introductions (see also Rohde *et al.*, 2017), and does not allow us to conclude with accurate remarks on the trends in new NIS introductions, and in particular the NIS associated with shipping. Monitoring efforts on marine NIS need to become more constant in space, time and across taxonomic groups. In the case of NIS found in the Hellenic seas, the existing information comes from a variety of research projects and citizen science data. Therefore, more focused monitoring on marine NIS would be essential, and should also include inconspicuous taxa that often remain understudied (e.g. parasites, microalgae). Moreover, optimization and standardization of monitoring methodologies, by prioritising hot-spot areas of new NIS introductions, such as ports, aquaculture units, marine protected areas and gateway areas of the Lessepsian influx (such as the Dodecanese islands in the south-eastern Aegean Sea), as appear to be a prerequisite for applying the primary criterion (D2C1) of the MSFD, at both national and subnational level.

The time lags in reporting should be added to the above limitations in estimating GES based on new NIS introductions of D2C1, given that they can skew the introduction patterns of marine NIS. Correction factors in assigning temporal and spatial trends in biological invasions have been proposed, thus permitting more accurate management assessments (Zenetos *et al.*, 2019).

Finally, ongoing work by the European Commission, the EU Member States and the Regional Sea Conventions on setting threshold values for the primary criterion D2C1, can serve as a basis for defining GES in terms of the MSFD (Tsiamis *et al.*, 2019). The Baltic Marine Environment Protection Commission (Helsinki Commission - HELCOM) has recently set threshold values for the HELCOM core Indicator for new NIS equal to zero, meaning that there should be no primary introductions of new NIS due to human activities (HELCOM, 2018). The Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) has not yet defined a threshold value for new NIS introductions, although it highlights that the relative change in the number of new primary NIS introductions observed over subsequent assessment periods can facilitate the assessment of GES (OSPAR, 2018). Following the OSPAR example, the current paper analyzed the relative trends in the number of new NIS introductions in Hellenic waters per six-year reporting cycles.

A suitable methodological approach for threshold values in the case of D2C1 could be the percentage reduction of new NIS introductions reported in the last assessment MSFD reporting cycle compared to the previous time-periods. However, the monitoring bias and the continuous influx of Lessepsian NIS into the Aegean Sea makes the setting of exact boundaries for GES, based on D2C1, challenging for Greece, and most likely for other Mediterranean countries, such as Cyprus, Malta and Italy. For that reason, we highlight the need for subregional and regional coordination among Mediterranean countries in implementing D2C1 of the MSFD and setting exact threshold values based on a common strategy (Cavallo *et al.*, 2018).

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Appendix I: List of non-indigenous species reported in Greece until September 2020. Species are presented in alphabetic order and the year of first record in Greek waters (all) and each subnational MSFD area is given, along with the overall establishment status (ES) and the potential pathway(s) of arrival (path). Cas = casual; est = established; inv = invasive; quest = questionable; unk = unknown; COR = corridor; UNA = unaided; REL = release; EC/REL = escape from confinement/release; TC = transport-contaminant; TS = transport-stowaway (TS-Angl/fis = angling/fishing; TS-ball = ship/boat ballast water; TS-hulls = ship/boat hull fouling); UN = unknown.

Group	Species	all	ES	path	Adriatic	Ionian	N. Aegean	S. Aegean	Levantine
Fish	*Abudefduf* cf. *saxatilis* (Linnaeus, 1758)	2020	cas	UN				2020	
Fish	*Abudefduf sexfasciatus* (Lacepède, 1801)	2017	cas	REL				2017	
Fish	*Abudefduf vaigiensis* (Quoy & Gaimard, 1825)	2018	cas	UN		2018			
Fish	*Acanthurus sohal* (Forsskål, 1775)	2017	cas	COR				2017	
Fish	*Acanthurus* cfr. *gahhm* (Forsskål, 1775)	2019	cas	REL				2019	
Crustacea/Copepoda	*Acartia (Acanthacartia) tonsa* Dana, 1849	2005	est	TS		2005			
Crustacea/Decapoda	*Actaeodes tomentosus* (H. Milne Edwards, 1834)	2013	cas	UNA					2013
Mollusca/Gastropoda	*Acteocina mucronata* (Philippi, 1849)	1991	cas	UNA				1991	
Fish	*Alepes djedaba* (Forsskål, 1775)	1960	est	UNA		1987		1960	
Crustacea/Decapoda	*Alpheus rapacida* (de Man, 1908)	1998	cas	UNA			1998		
Bryozoa	*Amathia verticillata* (delle Chiaje, 1822)	1969	est	TS-hulls		1980	1974	1969	2014
Crustacea/Cirripedia	*Amphibalanus eburneus* (Gould, 1841)	1970	unk	TS-hulls			1970		
Foraminifera	*Amphistegina lessonii* d'Orbigny in Guérin-Méneville, 1832	1974	est	UNA				1974	1974
Foraminifera	*Amphistegina lobifera* Larsen, 1976	1955-64	est	UNA		1955-64	2006	1967	1955-64
Mollusca/Bivalvia	*Anadara transversa* (Say, 1822)	1993	est	TS-hulls			1993		
Fish	*Apogonichthyoides pharaonis* (Bellotti, 1874)	1982	est	UNA				1982	2010
Crustacea/Copepoda	*Arietellus pavoninus* (G. O. Sars, 1905)	1967	est	UNA, TS				1967	
Ascidiacea	*Ascidiella aspersa* (Müller, 1776)	1901	est	UN			1967	1901	
Macroalgae/Rhodophyta	*Asparagopsis armata* Harvey	2010	cas	UNA		2010	2010		
Macroalgae/Rhodophyta	*Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon	1992	inv	TS-Angl/fis	2013	2006	1992	2006	2006
Crustacea/Decapoda	*Atergatis roseus* (Rüppell, 1830)	2009	est	UNA				2011	2009
Fish	*Atherinomorus forskalii* (Rüppell, 1838)	1986	est	UNA		2012		1986	2015
Annelida	*Axionice medusa* (Savigny in Lamarck, 1818)	1976	est	UNA		1980	1976	1985	
Crustacea/Cirripedia	*Balanus trigonus* Darwin, 1854	1970	est	TS-hulls			1970	2010	2016
Crustacea/Amphipoda	*Bemlos leptocheirus* (Walker, 1909)	2015	unk	UNA				2015	
Ctenophora	*Beroe ovata* Mayer, 1912	2004	unk	UNA			2004		
Macroalgae/Rhodophyta	*Botryocladia madagascariensis* G. Feldmann	2006	est	TS-Angl/fis		2009	2013	2006	2009
Mollusca/Bivalvia	*Brachidontes pharaonis* (P. Fischer, 1870)	1975	est	UNA, TS			1975	1975	2010
Annelida	*Branchiomma bairdi* (McIntosh, 1885)	2014	est	TS-hulls				2015	2014

continued

Appendix I continued

Group	Species	all	ES	path	Adriatic	Ionian	N. Aegean	S. Aegean	Levantine
Annelida	*Branchiomma luctuosum* (Grube, 1869)	1989	est	TS-hulls			1989	2006	
Fish	*Bregmaceros nectabanus* Whitley, 1941	2014	est	UNA		2016		2014	
Mollusca/Gastropoda	*Bulla arabica* Malaquias & Reid, 2008	1998	est	TS				1998	
Mollusca/Gastropoda	*Bursatella leachii* (De Blainville, 1817)	1975	est	UNA, TS		2003	1975	1977	2007
Crustacea/Copepoda	*Calanopia elliptica* (Dana, 1846)	1988	cas	UNA					1988
Crustacea/Decapoda	*Calappa pelii* Herklots, 1851	2005	cas	UN		2005		2005	
Crustacea/Decapoda	*Callinectes sapidus* Rathbun, 1896	1947	inv	TS	2013	1990	1947	1965	2005
Fish	*Callionymus filamentosus* Valenciennes, 1837	2003	est	UNA		2007		2003	2016
Crustacea/Amphipoda	*Caprella scaura* Templeton, 1836	2002	est	UN		2002		2012	
Crustacea/Decapoda	*Carupa tenuipes* Dana, 1851	2009	est	UNA				2011	2009
Cnidaria/Scyphozoa	*Cassiopea andromeda* (Forsskål, 1775)	1942	est	UNA		2018	2010	1942	2011
Macroalgae/Chlorophyta	*Caulerpa cylindracea* Sonder	1993	inv	UNA	2013	1993	1997	1996	2003
Macroalgae/Chlorophyta	*Caulerpa racemosa* var. *lamourouxii* f. *requienii* (Montagne) Weber van Bose	1956	est	UNA		2009		1991	1956
Macroalgae/Chlorophyta	*Caulerpa taxifolia* var. *distichophylla* (Sonder) Verlaque, Huisman & Procaccini	2010	est	UNA				2013	2010
Annelida	*Caulleriella viridis* (Langerhans, 1881)	2006	ques	TS				2006	
Bryozoa	*Celleporaria brunnea* (Hincks, 1884)	2015	unk	TS-hulls				2015	
Bryozoa	*Celleporaria vermiformis* (Waters, 1909)	2015	est	TS-hulls				2015	2016
Crustacea/Copepoda	*Centropages furcatus* (Dana, 1852)	1988	est	UNA			2011		1988
Macroalgae/Rhodophyta	*Ceramium bisporum* Ballantine	1980	cas	TS-hulls			1980		
Macroalgae/Rhodophyta	*Ceramium strobiliforme* Lawson & John	2001	ques	TS-hulls		2001			
Mollusca/Gastropoda	*Cerithidium perparvulum* (Watson, 1886)	2010	cas	UNA					2010
Mollusca/Gastropoda	*Cerithiopsis pulvis* (A. Issel, 1869)	2010	est	TS				2015	2010
Mollusca/Gastropoda	*Cerithiopsis tenthrenois* (Melvill, 1896)	1994	cas	UNA				1994	
Mollusca/Gastropoda	*Cerithium scabridum* Philippi, 1848	2007	est	UNA				2011	2007
Fish	*Chaetodipterus faber* (Broussonet, 1782)	2019	est	REL				2019	
Annelida	*Chaetozone corona* Berkeley & Berkeley, 1941	1982	est	TS		1982	1991	1989	
Mollusca/Bivalvia	*Chama asperella* Lamarck, 1819	2007	est	TS			2007	2007	
Mollusca/Bivalvia	*Chama pacifica* Broderip, 1834	2005	est	UNA, TS				2009	2005
Fish	*Champsodon nudivittis* (Ogilby, 1895)	2012	est	UNA				2012	
Crustacea/Decapoda	*Charybdis (Charybdis) hellerii* (A. Milne-Edwards, 1867)	2004	est	UNA				2010	2004

continued

Appendix I continued

Group	Species	all	ES	path	Adriatic	Ionian	N. Aegean	S. Aegean	Levantine
Crustacea/Decapoda	*Charybdis (Goniohellenus) longicollis* Leene, 1938	1996	est	UNA				1999	1996
Fish	*Cheilodipterus novemstriatus* (Rüppell, 1838)	2020	est	UNA					2020
Macroalgae/Rhodophyta	*Chondria collinsiana* Howe	1980	ques	TS-hulls			1980		
Cnidaria/Scyphozoa	*Chrysaora* cf. *achlyos* Martin, Gershwin, Burnett, Cargo & Bloom, 1997	2018	cas	TS				2018	
Ascidiacea	*Ciona robusta* Hoshino & Tokioka, 1967 (as *Ciona intestinalis* (Linnaeus, 1767))	1901	est	TS-hulls			1958	1901	2016
Foraminifera	*Clavulina* cf. *multicamerata* Chapman, 1907	2012	cas	TS				2012	
Mollusca/Bivalvia	*Clementia papyracea* (Gmelin, 1791)	1985	cas	UNA					1985
Cnidaria/Hydrozoa	*Clytia linearis* (Thornely, 1900)	1977	est	UNA		1977		1981	
Macroalgae/Chlorophyta	*Codium fragile* (Suringar) Hariot	1985	inv	TS-Angl/fis		1985	1992	1998	
Crustacea/Decapoda	*Coleusia signata* (Paulson, 1875)	2005	est	UNA				2005	2005
Macroalgae/Ochrophyta	*Colpomenia peregrina* Sauvageau	1986	est	TS-hulls		2001	1986	1994	
Mollusca/Gastropoda	*Conomurex persicus* (Swainson, 1821)	1983	inv	UNA, TS		2001	2008	1983	1983
Mollusca/Gastropoda	*Coryphellina rubrolineata* O'Donoghue, 1929	2009	est	UNA			2009	2009	2013
Mollusca/Bivalvia	*Crassostrea/Magallana* sp./spp.	1971	est	EC/REL		1989	2008	1971	
Bryozoa	*Crepidacantha poissoni* (Audouin, 1826)	1986	unk	TS-hulls				1986	
Mollusca/Gastropoda	*Crepidula fornicata* (Linnaeus, 1758)	1985	est	TC, TS			1987	1985	
Bryozoa	*Crisularia serrata* (Lamarck, 1816)	1967	unk	TS-hulls				1967	
Macroalgae/Ochrophyta	*Cutleria multifida* (Turner) Greville	1932	est	TS-Angl/fis		1975	1987	1932	
Crustacea/Isopoda	*Cymodoce fuscina* Schotte & Kensley, 2005	2015	cas	TS				2015	
Mollusca/Bivalvia	*Dendostrea* cf. *folium* (Linnaeus, 1758)	2005	inv	TS			2015	2010	2005
Annelida	*Desdemona ornata* Banse, 1957	1986	cas	TS				1986	
Echinodermata	*Diadema setosum* (Leske, 1778)	2010	est	UNA		2019	2017	2016	2010
Macroalgae/Ochrophyta	*Dictyota cyanoloma* Tronholm, De Clerck, A.Gómez-Garreta & Rull Lluch	2013	cas	TS-hulls		2013			
Mollusca/Gastropoda	*Diodora funiculata* (Reeve, 1850)	2013	est	TS				2013	
Ascidiacea	*Diplosoma listerianum* (Milne Edwards, 1841)	1996	est	TS-hulls				1996	2016
Annelida	*Dispio magnus* (Day, 1955)	1982	cas	TS		1982			
Annelida	*Dodecaceria capensis* Day, 1961	1976	est	TS		1980	1976	1989	
Annelida	*Dorvillea similis* (Crossland, 1924)	2014	cas	UNA					2014
Crustacea/Decapoda	*Dyspanopeus sayi* (Smith, 1969)	2015	cas	TS				2015	

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Group	Species	all	ES	path	Adriatic	Ionian	N. Aegean	S. Aegean	Levantine
Fish	*Equulites klunzingeri* (Steindachner, 1898)	1946-64	cas	UNA				1964	
Mollusca/Gastropoda	*Ergalatax junionae* Houart, 2008	2007	est	UNA			2013	2007	2011
Crustacea/Stomatopoda	*Erugosquilla massavensis* (Kossmann, 1880)	1963	est	UNA		2017		1963	1996
Fish	*Etrumeus golani* Di Battista, Randall & Bowen, 2012	2003	est	UNA				2003	2015
Mollusca/Gastropoda	*Eunaticina papilla* (Gmelin, 1791)	2020	unk	TS				2020	
Mollusca/Gastropoda	*Euthymella colzumensis* (Jousseaume, 1898)	2017	est	TS				2017	
Annelida	*Ficopomatus enigmaticus* (Fauvel, 1923)	1959	est	TS-hulls		1981	1959	2003	
Fish	*Fistularia commersonii* (Rüppell, 1835)	2001	inv	UNA		2007	2003	2001	2002
Mollusca/Bivalvia	*Fulvia fragilis* (Forsskål in Niebuhr, 1775)	1997	inv	TS		2015	2003	1997	
Annelida	*Glycinde bonhourei* Gravier, 1904	2007	cas	UNA			2007		
Platyhelminthes	*Glyphidohaptor plectocirra* (Paperna, 1972)	2010	est	TC					2010
Mollusca/Gastropoda	*Goniobranchus annulatus* (Eliot, 1904)	2004	est	UNA, TS				2004	2007
Crustacea/Decapoda	*Gonioinfradens giardi* (Nobili, 1905)	2010	est	UNA				2011	2010
Tracheophyta	*Halophila decipiens* Ostenfeld	2018	est	TS				2018	
Tracheophyta	*Halophila stipulacea* (Forsskål) Ascherson	1894	est	TS		1955	1924	1923	1894
Fish	*Hemiramphus far* (Forsskål, 1775)	1943	est	UNA				1943	
Ascidiacea	*Herdmania momus* (Savigny, 1816)	2010	est	UNA				2015	2010
Foraminifera	*Heterostegina depressa* d'Orbigny, 1826	<1988	est	UNA, TS				1988	
Bryozoa	*Hippopodina* sp. A as *Hippopodina feegeensis* (Busk, 1884)	1996	est	TS-hulls				1996	2014
Annelida	*Hydroides brachyacantha* Rioja, 1941	2015	cas	TS-hulls				2015	
Annelida	*Hydroides dirampha* Mörch, 1863	1981	est	TS-hulls		1981		2015	2014
Annelida	*Hydroides elegans* (Haswell, 1883)	1976	est	TS-hulls		2012	1976	1989	2016
Macroalgae/Rhodophyta	*Hypnea anastomosans* Papenfuss, Lipkin & Silva	2008	est	UNA				2008	2009
Macroalgae/Rhodophyta	*Hypnea cornuta* (Kützing) J. Agardh	1894	est	TS-Angl/fis				1894	
Macroalgae/Rhodophyta	*Hypnea spinella* (C. Agardh) Kützing	1979	est	TS-Angl/fis		2013	1982	1979	2006
Macroalgae/Rhodophyta	*Hypnea valentiae* (Turner) Montagne	2009	cas	TS-hulls					2009
Mollusca/Gastropoda	*Hypselodoris infucata* (Rüppell & Leuckart, 1831)	2007	est	UNA					2007
Mollusca/Bivalvia	*Isognomon legumen* (Gmelin, 1791)	2016	est	UNA				2016	
Crustacea/Decapoda	*Ixa monodi* Holthuis & Gottlieb, 1956	1999	est	UNA				1999	2008
Fish	*Lagocephalus guentheri* Miranda Ribeiro, 1915	1952	est	UNA		2005	1952	2007	2016
Fish	*Lagocephalus sceleratus* (Gmelin, 1788)	2005	inv	UNA	2018	2009	2007	2005	2005

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Group	Species	all	ES	path	Adriatic	Ionian	N. Aegean	S. Aegean	Levantine
Fish	*Lagocephalus suezensis* Clark & Gohar, 1953	2003	est	UNA				2003	2007
Mollusca/Gastropoda	*Lamprohaminoea ovalis* (Pease, 1868)	2001	est	UNA, TS		2001	2009	2005	2007
Macroalgae/Rhodophyta	*Laurencia caduciramulosa* Masuda & Kawaguchi	2001	est	TS-hulls		2001		2009	2009
Annelida	*Leiocapitellides analis* Hartmann-Schröder, 1960	2000	cas	UNA			2000		
Annelida	*Leonnates persicus* Wesenberg-Lund, 1949	2013	cas	UNA				2013	
Annelida	*Lepidonotus tenuisetosus* (Gravier, 1902)	2008	cas	UNA				2008	
Annelida	*Linopherus canariensis* Langerhans, 1881	2007	cas	TC				2007	
Macroalgae/Rhodophyta	*Lophocladia lallemandii* (Montagne) Schmitz	1908	est	TS-Angl/fis		1975	2012	1908	2005
Annelida	*Lumbrinerides neogesae* Miura, 1981	2002	cas	TS		2002			
Fish	*Lutjanus argentimaculatus* (Forsskål, 1775)	2019	cas	UNA				2019	
Fish	*Lutjanus sebae* (Cuvier, 1816)	2010	cas	REL				2010	
Annelida	*Lysidice collaris* Grube, 1870	1975	est	UNA		2000	1975	1983	
Crustacea/Decapoda	*Macrophthalmus indicus* Davie, 2012	2009	cas	UNA				2009	
Mollusca/Bivalvia	*Malleus regula* (Forsskål in Niebuhr, 1775)	≤1996	est	UNA				1996	2016
Cercozoa/Endomyxa	*Marteilia refringens* Cavalier-Smith, 2002	1997	est	TC			1997		
Crustacea/Decapoda	*Matuta victor* (Fabricius, 1781)	2018	cas	UNA					2018
Crustacea/Cirripedia	*Megabalanus tintinnabulum* (Linnaeus, 1758)	2010	cas	TS-hulls				2010	
Macroalgae/Rhodophyta	*Melanothamnus harveyi* (Bailey) Díaz-Tapia & Maggs	2006	est	TS-hulls			2013	2006	
Mollusca/Gastropoda	*Melibe viridis* (Kelaart, 1858)	1970	est	UNA, TS		1970	2008	1994	2011
Crustacea/Isopoda	*Mesanthura* cf. *romulea* Poore & Lew-Ton, 1986	2016	unk	TS				2016	2016
Crustacea/Decapoda	*Metapenaeopsis aegyptia* Galil & Golani, 1990	1996	est	UNA				1999	1996
Crustacea/Decapoda	*Metapenaeopsis mogiensis consobrina* (Nobili, 1904)	1995	est	UNA					1995
Bryozoa	*Microporella coronata* (Audouin, 1826)	1967	ques	TS-hulls			1967	1996	
Ctenophora	*Mnemiopsis leidyi* (Agassiz, 1865)	1990	est	UNA			1991	1990	
Mollusca/Gastropoda	*Mnestia girardi* (Audouin, 1826)	1994	est	UNA				1996	1994
Mollusca/Bivalvia	*Mya arenaria* Linnaeus, 1758	1984	est	TC				1984	
Crustacea/Decapoda	*Myra subgranulata* Galil & Golani, 1990	2004	est	UNA					2004
Annelida	*Neanthes agulhana* (Day, 1963)	2007	cas	TS				2007	
Fish	*Nemipterus randalli* Russell, 1986	2018	cas	UNA					2018
Mollusca/Gastropoda	*Nerita sanguinolenta* Menke, 1829	1969	est	UNA				1969	
Annelida	*Notomastus aberans* Day, 1957	1964	est	UNA		2000	2000	1964	
Crustacea/Copepoda	*Oithona davisae* Ferrari F.D. & Orsi, 1984	2018	cas	UNA, TS			2018		

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Group	Species	all	ES	path	Adriatic	Ionian	N. Aegean	S. Aegean	Levantine
Echinodermata	*Ophiactis savignyi* (Müller & Troschel, 1842)	1993	cas	UNA				1993	
Mollusca/Gastropoda	*Oscilla galilae* Bogi, Karhan & Yokeş, 2012	2016	cas	UNA				2016	
Fish	*Oxyurichthys petersi* (Klunzinger, 1871)	2010	cas	UNA					2010
Macroalgae/Ochrophyta	*Padina boryana* Thivy	≤1981	ques	UNA				1981	
Crustacea/Copepoda	*Paracartia grani* (G. O. Sars, 1904)	1988	est	TS-ball			1995	1988	
Crustacea/Isopoda	*Paracerceis sculpta* (Holmes, 1904)	2009	est	TS			2009	2015	2016
Crustacea/Isopoda	*Paradella dianae* (Menzies, 1962)	1997	cas	TS			1997	2015	
Annelida	*Paradyte* cf. *crinoidicola* (Potts, 1910)	1964	cas	UNA				1964	
Porifera	*Paraleucilla magna* Klautau, Monteiro & Borojevic, 2004	2014	est	TC			2014	2015	2016
Crustacea/Isopoda	*Paranthura japonica* Richardson, 1909	2012	est	TS				2012	2016
Fish	*Parexocoetus mento* (Valenciennes, 1846)	1946-64	est	UNA				1964	
Fish	*Parupeneus forsskali* (Fourmanoir & Guézé, 1976)	2017	est	UNA				2018	2017
Crustacea/Copepoda	*Parvocalanus crassirostris* (Dahl, 1894)	2009	est	UNA			2009		
Fish	*Pempheris rhomboidea* Kossmann & Rauber, 1877	1983	est	UNA			2017	1983	1985
Crustacea/Decapoda	*Penaeus aztecus* Ives, 1891	2012	inv	UNA	2018	2013	2012	2014	2015
Crustacea/Decapoda	*Penaeus hathor* (Burkenroad, 1959)	2012	est	UNA				2014	2012
Crustacea/Decapoda	*Penaeus pulchricaudatus* Stebbing, 1914	1995	est	UNA				1995	1995
Mollusca/Bivalvia	*Petricolaria pholadiformis* Lamarck, 1818	1985	est	TS			1994	1985	
Fish	*Petroscirtes ancylodon* Rüppell, 1838	2004	est	UNA				2004	2009
Ascidiacea	*Phallusia nigra* Savigny, 1816	2008	est	UNA		2015	2008		2009
Cnidaria/Scyphozoa	*Phylloriza punctata* von Lendenfeld, 1884	2005	unk	UN		2005			
Mollusca/Bivalvia	*Pinctada imbricata radiata* (Leach, 1814)	1961	inv	REL		1995	1962	1961	1970
Fish	*Planiliza haematocheila* (Temminck & Schlegel, 1845)	1995	est	UNA			1995		
Foraminifera	*Planogypsina acervalis* (Brady, 1884)	1909	est	UN			2006	2001	
Mollusca/Gastropoda	*Plocamopherus ocellatus* Rüppell & Leuckart, 1828	2020	cas	UNA					2020
Mollusca/Gastropoda	*Polycerella emertoni* Verrill, 1881	1995	cas	TS		1995			
Annelida	*Polycirrus twisti* Potts, 1928	1983	est	UNA		2010	1991	1983	1983
Annelida	*Polydora cornuta* Bosc, 1802	2008	est	TS				2008	
Fish	*Pomacanthus imperator* (Bloch, 1787)	2016	cas	UNA				2016	
Fish	*Pomadasys stridens* (Forsskål, 1775)	2019	unk	UNA				2019	
Crustacea/Decapoda	*Portunus segnis* (Forsskål, 1775)	1991	est	UNA				2000	1991

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Group	Species	all	ES	path	Adriatic	Ionian	N. Aegean	S. Aegean	Levantine
Annelida	*Prionospio pulchra* Imajima, 1990	1991	cas	TS			1993	1991	
Annelida	*Protodorvillea biarticulata* Day, 1963	1975	est	TS		1983	1975		
Annelida	*Pseudonereis anomala* (Gravier, 1900)	2003	est	TS		2003		2003	2014
Annelida	*Pseudopolydora paucibranchiata* (Okuda, 1937)	2005	est	TS			2005	2010	
Fish	*Pteragogus trispilus* Randall, 2013	1992	est	UNA		2008		1992	1993
Fish	*Pterois miles* (Bennett, 1828)	2009	est	UNA		2018		2009	2015
Macroalgae/Ochrophyta	*Pylaiella littoralis* (Linnaeus) Kjellman	1967	ques	TS-hulls		1975	1967		
Mollusca/Gastropoda	*Pyrgulina pupaeformis* (Souverbie, 1865)	2017	est	TS				2017	
Mollusca/Gastropoda	*Pyrunculus fourierii* (Audouin, 1826)	2013	cas	UNA				2013	
Mollusca/Gastropoda	*Rapana venosa* (Valenciennes, 1846)	1986	cas	UNA			1986		
Mollusca/Gastropoda	*Rhinoclavis kochi* (Philippi, 1848)	2015	est	UNA				2015	2016
Cnidaria/Scyphozoa	*Rhopilema nomadica* Galil, 1990	2006	est	UNA		2006		2019	2017
Mollusca/Gastropoda	*Ringicula* sp.	2019	cas	TS				2019	
Macroalgae/Rhodophyta	*Sarconema scinaioides* Børgesen	1980	cas	REL				1980	
Fish	*Sargocentron rubrum* (Forsskål, 1775)	1940-45	est	UNA		2017		1940	1947
Fish	*Saurida lessepsianus* Russell, Golani & Tikochinski, 2015	<1960	est	UNA			1978	1960	
Fish	*Scarus ghobban* Forsskål in Niebuhr, 1775	2014	est	UNA				2017	2014
Fish	*Scomberomorus commerson* Lacepède, 1800	2008	est	UNA		2017	2008	2008	2008
Macroalgae/Ochrophyta	*Scytosiphon dotyi* Wynne	2013	ques	TS-hulls				2013	
Mollusca/Cephalopoda	*Sepioteuthis lessoniana* Férussac in Lesson, 1831 complex	2009	est	UNA				2009	2009
Mollusca/Bivalvia	*Septifer cumingii* (Dunker, 1855)	2010	est	UNA			2013	2010	2010
Cnidaria/Hydrozoa	*Sertularia marginata* (Kirchenpauer, 1864)	1990	est	TS				1990	
Annelida	*Sigambra parva* (Day, 1963)	1975	est	TS		1980	1975	1978	
Fish	*Siganus luridus* (Rüppell, 1829)	1964	inv	UNA	2014	1973	1978	1964	1985
Fish	*Siganus rivulatus* Forsskål, 1775	1925	inv	UNA	2014	2008	2018	1925	1928
Foraminifera	*Sigmamiliolinella australis* (Parr, 1932)	2001	est	UN		2014		2001	
Fish	*Sillago suezensis* Golani, Fricke & Tikochinski, 2014	2018	cas	UNA					2018
Mollusca/Gastropoda	*Sinezona plicata* (Hedley, 1899)	2019	unk	TS				2019	
Mollusca/Gastropoda	*Smaragdia souverbiana* (Montrouzier, 1863)	≤1993	est	UNA		2012	2013	1993	
Mammalia	*Sousa plumbea* (G. Cuvier, 1829)	2017	cas	UNA				2017	
Crustacea/Isopoda	*Sphaeroma walkeri* Stebbing 1905	2017	unk	TS				2017	
Fish	*Sphyraena chrysotaenia* Klunzinger, 1884	1995	est	UNA		2011		1995	1995

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Group	Species	all	ES	path	Adriatic	Ionian	N. Aegean	S. Aegean	Levantine
Fish	*Sphyraena flavicauda* Rüppell, 1838	2003	est	UNA				2003	2003
Annelida	*Spirobranchus tetraceros* (Schmarda, 1861)	1970	est	TS-hulls			2014	2003	1970
Annelida	*Spirorbis marioni* Caullery & Mesnil, 1897	1997	est	TS-hulls			1997	1997	
Mollusca/Bivalvia	*Spondylus* cf. *spinosus* Schreibers, 1793	2008–13	cas	TS-hulls			2008		
Fish	*Stephanolepis diaspros* Fraser-Brunner, 1940	1943	est	UNA		2016	2008	1943	2007
Mollusca/Gastropoda	*Sticteulima* sp. [cf. *lentiginosa* (A. Adams, 1861)]	2015	cas	TS				2015	
Ascidiacea	*Styela plicata* (Lesueur, 1823)	1968	est	TS-hulls			1968	2015	
Macroalgae/Ochrophyta	*Stypopodium schimperi* (Buchinger ex Kützing) Verlaque & Boudouresque	1994	inv	UNA		2008	2009	1996	1994
Ascidiacea	*Symplegma brakenhielmi* (Michaelsen, 1904)	2015	est	TS-hulls				2015	2016
Echinodermata	*Synaptula reciprocans* (Forsskål, 1775)	1995	inv	UNA				2005	1995
Fish	*Synchiropus sechellensis* Regan, 1908	2014	est	UNA		2018		2016	2014
Mollusca/Gastropoda	*Syphonota geographica* (A. Adams & Reeve, 1850)	2002	est	UNA		2002		2014	
Mollusca/Gastropoda	*Syrnola fasciata* Jickeli, 1882	2012	est	TS			2013	2012	
Fish	*Terapon theraps* Cuvier, 1829	2008	cas	UN			2008		
Crustacea/Decapoda	*Thalamita poissonii* (Audouin, 1826)	1983	est	UNA		1986		1983	2009
Annelida	*Timarete punctata* (Grube, 1859)	2006	cas	TS				2006	
Fish	*Torquigener flavimaculosus* Hardy & Randall, 1983	2006	est	UNA		2016		2006	2008
Crustacea/Decapoda	*Trachysalambria palaestinensis* (Steinitz, 1932)	1995	est	UNA					1995
Bryozoa	*Tricellaria inopinata* d'Hondt & Occhipinti Ambrogi, 1985	2015	unk	TS-hulls				2015	
Foraminifera	*Triloculina* cf. *fichteliana* d'Orbigny, 1839	2006	est	UNA, TS		2006	2012	2006	
Fish	*Tylerius spinosissimus* (Regan, 1908)	2004	est	UNA				2004	
Fish	*Tylosurus crocodilus* Péron & Lesueur, 1821	2003	cas	UNA			2003		
Fish	*Upeneus moluccensis* (Bleeker, 1855)	1947	est	UNA		1976	2016	1947	1947
Fish	*Upeneus pori* Ben-Tuvia & Golani, 1989	2003	est	UNA		2014		2003	2007
Fish	*Vanderhorstia mertensi* Klausewitz, 1974	2019	cas	UNA				2019	
Mollusca/Gastropoda	*Viriola* sp. [cf. *bayani*] Jousseaume, 1884	2016	est	TS				2016	2017
Macroalgae/Rhodophyta	*Womersleyella setacea* (Hollenberg) Norris	1988	inv	TS-Angl/fis		2001	1992	1988	2006
Crustacea/Decapoda	*Xanthias lamarckii* (H. Milne Edwards, 1834)	2013	cas	UNA				2013	
					7	**78**	**92**	**196**	**113**