Time lags in reporting of biological invasions: the case of Mediterranean Sea

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Abstract

Time lags in non-indigenous species (NIS) reporting can create uncertainty in the analysis of NIS introduction rates, which can lead to inadequate prevention and management measures and their evaluation. The present study aims to highlight time lags in marine NIS reporting in the Mediterranean Sea, i.e. the time that mediates from the detection of a new NIS in the Mediterranean Sea until its publication. Our results revealed that the time lag in NIS reporting in the Mediterranean Sea has been considerably decreased during the last decades. There is a noticeable difference in the time lag of reporting NIS in association with the taxonomic group of the species. Fish have generally shorter time lags in their reporting when compared with other taxonomic groups (e.g. macrophytes, Annelida, Bryozoa). Time lags of NIS reporting need to be taken into account for more accurate assessments of introduction patterns of marine NIS and related management measures.

Keywords: NIS; marine; introduction rate; management.

Introduction

Marine non-indigenous species (NIS) represent a significant risk to the receiving environments. They may exhibit invasive behavior and induce alterations to ecosystems' structure and functions, impede the provision of ecosystem services, and even result in negative socioeconomic effects in coastal areas (Wallentinus & Nyberg 2007; Molnar *et al*., 2008; Katsanevakis *et al*., 2014). New introductions of NIS have been accelerated in the recent decades by the rapid globalization and increasing trends of human activities (shipping, aquaculture, fisheries, tourism, aquarium trade etc.) (Streftaris *et al*., 2005; Zenetos *et al*., 2012; Katsanevakis *et al*., 2013; Zenetos *et al*., 2016).

European seas host the highest number of marine NIS worldwide, with at least 1,411 non-indigenous, cryptogenic and questionable taxa reported (Tsiamis *et al*., 2018). Among Europe's seas, the Mediterranean Sea is the most affected in terms of number of introductions, mainly due to the Suez Canal and its heavy shipping traffic, which are widely documented in a long history of marine monitoring (Streftaris *et al.,* 2005; Zenetos *et al.,* 2017). Due to the threats they pose, NIS are considered in a series of policy instruments, such as the European Union (EU) Marine Strategy Framework Directive (MSFD) (EC, 2008) and the Biodiversity Strategy (EC, 2011). The MSFD requires EU Member States to consider NIS when developing their marine management strategies, which aim to reach Good Environmental Status (GES) in European seas. More specifically, NIS are treated as a distinct Descriptor (D2) of GES in the context of the MSFD (EC, 2017): "*Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem*". The Descriptor D2 includes one primary criterion (D2C1), based on which "*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 minimised and where possible reduced to zero. Member States shall establish the threshold value for the number of new introductions of non-indigenous species, through regional or subregional cooperation*".

There are also two secondary criteria of D2, dealing with the abundance and spatial distribution of NIS, particularly of the invasive ones, and their effects to indigenous species groups and broad habitat types (EC, 2017).

Time lags can be found throughout the invasion process, including in the arrival, establishment, and impacts of invaders (Crooks, 2005). A common problem

for marine NIS is that the initial introduction stages are rarely observed and the timing of first introduction is generally not known (Blackburn *et al.*, 2011), creating thus uncertainty and a time lag between the real time of first introduction of a NIS and its first observation in the wild. Moreover, there is a considerable time lag between the date of the first observation of a species in the field and its reporting into a publication (Smith *et al.*, 2018). Occasionally, the time of first introduction is backdated based on findings of specimens of known collection date in museums or private collections. Examples are the Atlantic creolefish *Paranthias furcifer* (Valenciennes, 1828), detected in Croatia in 2011 (Dulčić & Dragičević, 2012) and backdated to 2007 as reported from Lebanon (Crocetta & Bariche in Crocetta *et al.*, 2015), and the nudibranch *Goniobranchus annulatus* (Eliot, 1904), reported from Greece in 2004 (Daskos & Zenetos, 2007) and backdated to 2000 as reported from Lebanon (Bitar, 2013).

Time lags in NIS reporting can create uncertainty in the analysis of NIS introduction rates, which can lead to inadequate actions, prevention and management measures and their evaluation (Crooks, 2005; Byers *et al.*, 2015). The present study aims to highlight time lags in marine NIS reporting in the Mediterranean Sea, i.e.: the time that mediates from the detection of a new NIS in the Mediterranean Sea until its publication. Considering the widespread concern on biological invasions, taking into account time lags in NIS reporting can lead to more accurate management assessments.

Materials and Methods

The analyses included marine NIS in the Mediterranean Sea retrieved from the European Alien Species Information Network (EASIN, 2019; Catalogue version 7.7) with amendments from recent literature for backdated records. In agreement with Byers *et al.* (2015), cryptogenic and questionable species were excluded from this list.

Based on an extensive literature survey covering 734 published sources, we tracked down for every marine NIS in the Mediterranean Sea the year and country of its first collection in the wild and the year of the release of the associated publication (scientific paper, book, PhD thesis, technical report, conference proceeding), either in print or online form. The time between the two dates corresponds to the time lag of the specific NIS reporting.

It is not always feasible to know the exact year of first observation of a NIS. This is common in old publications that provide check-lists with no further details. Thus, we have excluded NIS that were first reported in the Mediterranean Sea when the year of their collection is not mentioned. Moreover, we have excluded NIS for which a more recent publication revealed that the collection date

was earlier than the one mentioned in the initial publication of the NIS first record in the Mediterranean Sea (backdated records). Finally, we have focused our analysis on NIS first collected in the Mediterranean Sea after 1950 (1952 for temporal trends in accordance with the MSFD needs), excluding the older NIS introductions.

In several publications the collection date of a NIS was given in a range of years, e.g. 1986-1994, or referred to a decade (e.g. 1970s). In those cases, the collection date was set as the mid interval year. When the collection date coincided for two or three different countries of the Mediterranean Sea for the same NIS all countries were included in our analysis. In addition, trends in the time lags of NIS reporting were investigated in association with the taxonomic group of NIS and the country of first collection. On account of the low number of NIS' first records (<10 NIS) in specific Mediterranean countries that occurred since 1950, the following countries were not included in the specific analysis: Cyprus (8 NIS), Syria (6), Libya (4), Slovenia (2), Albania (1), Algeria (1), Monaco (1), Palestine Authority (1) and Bosnia and Herzegovina (0).

When it comes to the taxonomic groups, NIS were classified by the following groups: macrophytes, Mollusca, Arthropoda, Chordata/fish, Annelida, Bryozoa, Cnidaria, Porifera, Foraminifera, Ascidiacea and "Other". The latter category included the following phyla: Cercozoa, Chaetognatha, Ciliophora, Ctenophora, Microsporidia, Myzozoa, Platyhelminthes, Proteobacteria and Sipuncula.

Results

We have analysed the time lag of reporting for 776 NIS in the Mediterranean Sea (Annex 1). The longest time lag of the investigated NIS corresponded to *Pampus argenteus* (79 years), reported from a specimen in a museum collection dated from 1896 (Soljan, 1975), followed by *Eudendrium merulum* (47 years) reported in 2000 based on a specimen collected in 1953 from Turkey and kept at the National Museum of Natural History, Leiden, The Netherlands (Marques *et al.*, 2000). Interesting is the record of *Siganus virgatus* (41 years) reported in 2016 based on a specimen collected in 1975 from Croatia and kept at the Natural History Museum in Vienna (Ahnelt, 2016). The shortest time lag (<1 year) corresponded to species reported after 2001, most of them belonging to fish, e.g. *Chlorurus rhakoura* (Insacco & Zava, 2017) and *Bathygobius cyclopterus* (Stamouli *et al.*, 2017) (Suppl. file). Our results based on the first detection year revealed a decreasing trend of the reporting time lag since 1952 (Fig. 1). Similar results are derived when the analysis is based on the publication year. A more detailed analysis for the most recent years (2001-2019), based on the publication year, also revealed a general decrease in the time lag (Fig. 2).
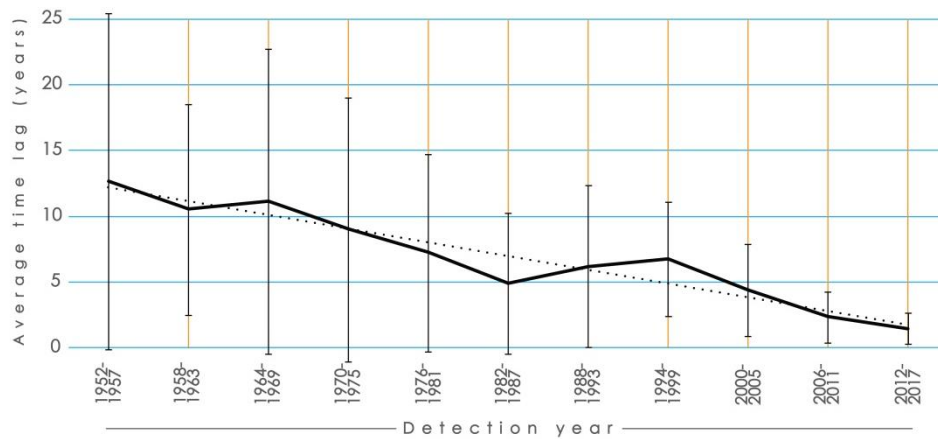
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Fig. 1: Average reporting time lags of NIS first *detected* in the Mediterranean Sea since 1952 per six-year period. Standard deviation is also given for each period.

Fig. 2: Reporting time lags per year of NIS first *reported* in the Mediterranean Sea since 2001. Standard deviation is given for each year.

The examination of the overall average time lags in reporting NIS in association with the countries of first collection revealed that the time lag was the shortest (<3 years) for Tunisia, and Malta, and the longest (>6 years) for Croatia, Egypt, Lebanon and Israel (Fig. 3). During the period 2012-2017, the time lag of reporting new Mediterranean NIS has decreased for most countries, with the minimum value (approximately 8 months) estimated for Malta. The maximum decrease was observed in Egypt where the time lag dropped to 1.8 years vs 22 years in the period 2000-2005 (avg=11 years: Figure 3). Exceptions are Lebanon and France, where a significant increase was noticed.

Finally, the examination of the overall average time lags in reporting NIS in association with the main taxonomic groups showed that the longest time lags corresponded to NIS of Annelida and Cnidara (8-10 years), while the shortest ones to fishes (4.3 years) with intermediate values (5-7 years) for the other groups (Fig. 4). In the period 2012-2017 a peak of more than 10 years time lag is noticed for Bryozoa and Ascidiacea. During the 2018-19 period the time lag has reduced to 1-3 years and leveled for most taxa; yet fishes are reported within only 9-10 months from their detection.
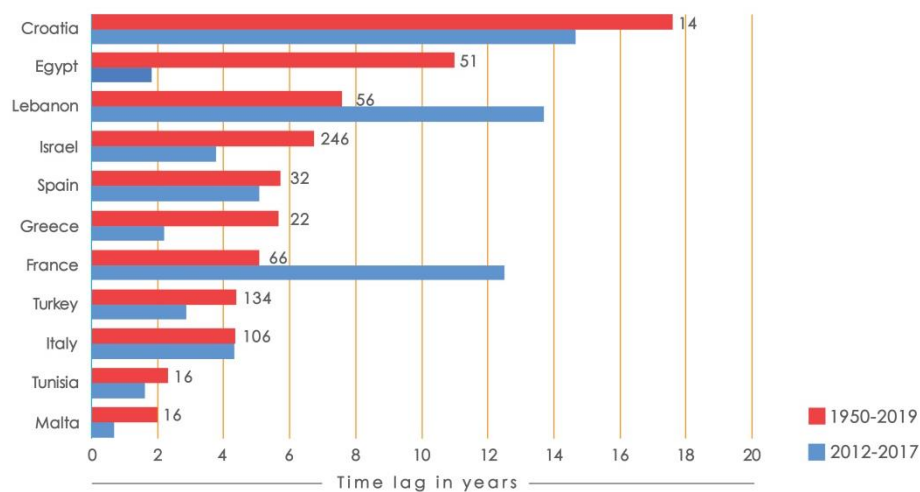
Fig. 3: Time lags in reporting of NIS in association with the country of their first collection in the Mediterranean Sea. Red bars: average time lag during 1950-2019; blue bars: average time lag during 2012-2017. Numbers in bars correspond to number of NIS reported for the first time in each country during the period 1950-2019.
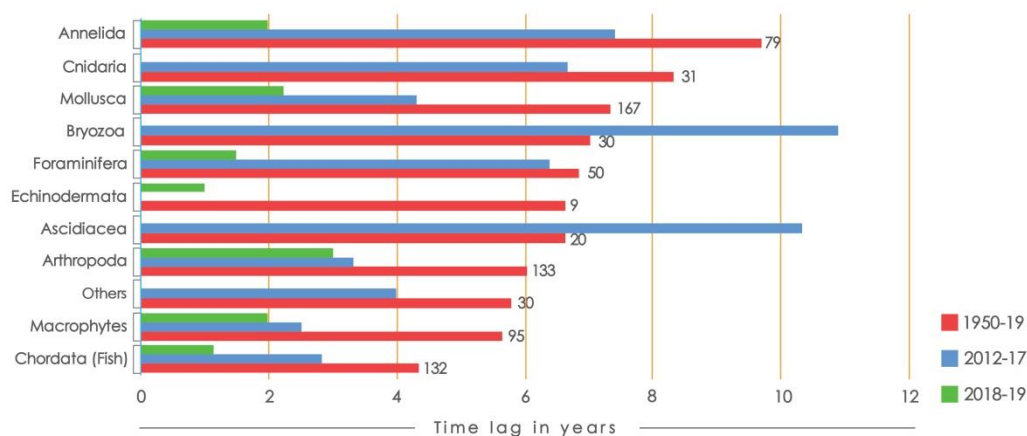

Fig. 4: Average reporting time lags of NIS reported in the Mediterranean Sea in association with their main taxonomic groups. Red bars: average time lag during 1950-2019; blue bars: average time lag during 2012-2017; green bars: average time lag during 2018-2019. Numbers in bars indicate the number of species in each group during the period 1950-2019.

Discussion

Based on our study, it is evident that the time lag in NIS reporting in the Mediterranean Sea has been considerably decreased during the last decades. This reduction can be attributed to the crucial need of reporting new NIS findings as soon as possible, in the context of early warning - early eradication which has been highlighted by the scientific community during the recent years (Ojaveer *et al.,* 2014; Lucy *et al.,* 2016). This approach has been also encouraged by several scientific journals focusing on biological invasions, such as *Aquatic Invasions*, *Neobiota, Bioinvasions Records* and the Collective Series of *Mediterranean Marine Science*, which generally accept to

publish new records of NIS findings in the Mediterranean Sea. In addition, the required time for publication processes has decreased over the last decades, availing from user-friendly online platforms of the scientific journals and the exchange of mails through the internet, skipping the snail mail used until the 1990s. In *Aquatic Invasions* for example, manuscript publication, including a comprehensive review process, takes on average less than two months (Panov *et al.*, 2011), when in the 1970s the publication process could easily take more than one year. Finally, in our view, several scientists choose to publish their new NIS findings as soon as possible in order to increase their number of publications

rapidly, which can help them in ensuring research projects and associated funding in today's scientific environment, where competition is constantly increasing.

The time lags of NIS reporting found at country level is at least partly dependent on the available taxonomic expertise of the human resources related with marine NIS. It would be expected that when local experts are lacking, a new NIS finding would possibly need additional time to be processed and analyzed with the help of foreign experts or it might be deposited until future examination. However, the above remark should be considered with caution since the number of new NIS among countries is substantially varying.

There is also a noticeable difference in the time lag of reporting NIS in association with the taxonomic group of the species. Fish (Chordata) are generally easier to identify in the field, while other groups (e.g. macrophytes, Annelida, Bryozoa) might require extensive laboratory and possibly molecular work to identify them in species level. Moreover, some groups can be much inconspicuous (Foraminifera, Bryozoa, micro-mollusca, Platyhelminthes) and may lack of sufficient number of related taxonomic experts. As a result, newcomers of these groups may be collected but not identified and reported as non-indigenous (Crooks, 2005).

For the marine NIS, collection time does not imply true introduction time. Species may have been present a long time before they are observed for the first time. This is proven true for 43 NIS whose presence was backdated in later publications or from museum collections (Gratsia & Zenetos, in preparation). It is expected that this number will increase once several overlooked specimens kept in drawers or museum collections are re-examined and /or new techniques are applied. One such case was that of the bivalve *Anadara tranversa* (Say, 1822). Albano *et al.* (2017) used two independent methods: 210Pb radiometric sediment dating and radiocarbon calibrated amino acid racemization dating (AAR) of bivalve shells preserved in sediment cores to show that the first occurrence of *Anadara transversa* in the northern Adriatic Sea dates back in the 1970s, that is 25 years earlier than its first collection year (2000: Morello & Solustri, 2001).

The aforementioned time lags as correction factors should be used with caution in the case of parasites. In many cases, species' registered introduction record is assumed much earlier than the observed one. A good example is that of the parasite *Perkinsus chesapeaki* (McLaughlin, Tall, Shaheen, El Sayed & Faisal, 2000). The first collection date in the Mediterranean mentioned in the literature is 2005 (Arzul *et al.,* 2012), but potential introduction date is probably 1992. According to Arzul *et al.* (2012), *P. chesapeaki* appeared south of France, along the Mediterranean Sea (Leucate), although its introduction might have occurred through *Mya arenaria* (Linnaeus, 1758) or *Mercenaria mercenaria* (Linnaeus, 1758) from North America a long time ago (Arzul *et al.,* 2012).

Our study can support a more accurate analysis in NIS introduction trends by estimating the first introduction dates (date of first collection) when this information is missing from the related publications. The first finding date can be set based on the taxonomic group, the country and the period it was reported, e.g. the green algal *Codium taylori* P.C.Silva was reported from Israel in 1955 (Rayss, 1955). Its potential introduction date can be set approximately based on the time lag estimated for Israel in the period 1953-57 (3 years) (Table 1) and /or the time lag for the specific taxonomic group (macrophytes=8 years) (Table 2). Consequently, it can be assumed that the species was first collected at least 3-8 years before its publication (1947-1952). Another example is the polychaete *Lumbrinerides neogesae* Miura, 1981, reported from Italy (Gravina & Cantone, 1991); its correction factor for the country (8.6 years) should be considered in combination with the average time lag for the taxonomic group of Annelida (9.7 years). Time lags as high as 79 years (Croatia case) attributed to unreported museum collections should not be considered.

Based on the MSFD D2 requirements (EC, 2017), it is a prerequisite to determine the number of new introductions of marine NIS per EU Member State following a 6-years assessment period, starting from the year of the initial assessment of the MSFD (2012). Consequently, up to the end of 2018/early 2019, Member States need to report the number of new marine NIS in their countries for the period 2012-2017. However, several NIS already collected during that period might not be reported since they are pending analyses or publication processes. Thus, it is crucial to consider the related time lags of reporting NIS, which could support a more accurate assessment of new NIS by the Member States, and thus a more precise implementation of the MSFD D2. Moreover, the number of new NIS introductions per national marine area, marine region or subregion support the process towards the establishment of the threshold values for D2C1 (i.e. the number of new introductions of NIS which reveals GES at regional or subregional level). In this context, accounting of time lags in NIS reporting can be used to calibrate the information related with the time trends of the NIS introductions. In overall, there is a wide international consensus that preventive management is of the absolute priority in effectively combating marine NIS (Ojaveer *et al.*, 2018). European legislation, such as the Biodiversity Strategy (EC, 2011), highlights the target of preventing new introductions into EU countries. The evaluation of trends in new NIS introductions can reveal valuable information to support NIS management, in particular to reduce the risk of new introductions through the management of their pathways. However, trends in new introductions can be severely biased from the time lag of reporting new NIS (Costello & Solow, 2003). Considering the widespread concern on marine introductions, it is essential to recognize the importance of taking into account time lags that skew introduction patterns of marine NIS.

Table 1. Correction factor in the year of first introduction (first collection) according to country and year of a NIS record in the Mediterranean Sea.

	1950 1957	1958 1963	1964 1969	1970 1975	1976 1981	1982 1987	1988 1993	1994 1999	2000 2005	2006 2011	2012 2017	2018 2019
Slovenia										1	1	
Malta					2.5					3.8	0.7	1.0
Algeria							2.0				2.0	
Tunisia					1.5				4.5	1.7	1.6	
Italy			1.0	1.7	4.6	3.5	8.6	5.5	9.0	3.3	4.3	2.0
Turkey	3.0	2.0			9.8	5.0	4.0	4.6	3.4	6.3	2.8	2.7
France	5.5	1.0	10.8	3.0	5.9	4.5	1.3	1.8	5.0	4.7	12.5	
Greece			2.0	4.0		10.5		8.0	13.6	4.0	2.2	1.0
Libya						12				0.0	5.0	
Spain	4.0					3.8	7.3	4.7	3.0	16.0	5.1	2.0
Cyprus						19.0			3.0	6.7	1.0	0.0
Israel	3.0	9.4	3.0	8.7	11.0	7.5	9.6	11.5	6.6	5.1	3.8	1.7
Monaco								7.0				
Lebanon		28.0	1.4		2.9	8.0	7.4	4.0	2.0	7.3	13.7	1.0
Egypt	6.0			17.7	5.8		20.4	17.5	22.0	6.1	1.8	1.7
Croatia	6.0			**79.0**	7.0	6.0				7.0	3.7	14.7

Table 2. Correction factor in the year of first introduction (first collection) according to the taxonomic group of a NIS in the Mediterranean Sea.

	1952 1957	1958 1963	1964 1969	1970 1975	1976 1981	1982 1987	1988 1993	1994 1999	2000 2005	2006 2011	2012 2017	2018 2019	AVG
Annelida			1.6	14.7	5.3	4.5	33.0	9.9	12.4	6.2	7.4	**2.0**	9.7
Chordata	2.5	2.0	2.3	27.7	2.9	3.0	1.8	2.0	1.7	2.2	2.8	1.1	4.3
Chordata (Ascidiacea)	4.0	5.0			11.0	2.0	6.0	7.0	3.0	11.5	10.3		6.6
Mollusca		11.7	2.7	12.2	11.7	8.0	5.9	10.7	7.5	3.7	4.3	2.3	7.3
Bryozoa			1.0		9.5	3.5	8.0	3.7	7.5	12.2	10.9		7.0
Foraminifera		10.0	16.0		2.0			2.5	5.8	10.5	6.4	**1.5**	6.8
Cnidaria	1.0	28.0		9.0	7.0	4.0	13.5	2.5	7.0	4.5	6.7		8.3
Echinoderma	9.0				8.0	12.0				3.3		**1.0**	6.7
Arthropoda	2.0	8.5	3.0	16.4	4.5	9.2	8.1	3.9	6.6	4.0	3.3	**2.5**	6.0
Macrophytes	**6.6**	**18.0**	**4.3**	**2.0**	**5.8**	**3.9**	**10.1**	**2.2**	**4.9**	**5.3**	**2.8**	**2.0**	**5.6**
Others	**4.5**			**2.6**	**2.5**		**7.5**	**33.0**		**4.8**	**4.0**		**5.8**

References

Ahnelt, H., 2016. Translocations of tropical and subtropical marine fish species into the Mediterranean. A case study based on *Siganus virgatus* (Teleostei: Siganidae). *Biologia*, 71 (8), 952-959.

Albano, P.G., Gallmetzer, I., Haselmair, A., Tomašových, A., Stachowitsch, M. *et al*., 2017. Historical ecology of a biological invasion: the interplay of eutrophication and pollution determines time lags in establishment and detection. *Biological Invasions*, 1-14.

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Arzul, I., Chollet, B., Michel, J., Robert, M., Garcia, C. *et al.,* 2012. One *Perkinsus* species may hide another: characterization of Perkinsus species present in clam production areas of France. *Parasitology*, 139 (13), 1757-1771.

Bitar, G., 2013. Les mollusques exotiques de la côte libanaise. In: *3éme Congres Franco-Maghrebin de Zoologie et d'Ichtyologie - Marrakech 2012. Marrakech, Morocco, p 8.

Blackburn, T.M., Pisek, P., Bacher, S., Carlton, J.T., Duncan, R.P. *et al.,* 2011. A proposed unified framework for biological invasions. *Trends in ecology & evolution*, 26 (7), 333-339.

Byers, J.E., Smith, R.S., Pringle, J.M., Clark, G.F., Gribben, P.E. *et al.,* 2015. Invasion expansion: time since introduction best predicts global ranges of marine invaders. *Scientific reports,* 5, 12436.

Costello, C.J., Solow, A.R., 2003. On the pattern of discovery of introduced species. *Proceedings of the National Academy of Sciences,* 100 (6), 3321-3323.

Crocetta, F., Agius, D., Balistreri, P., Bariche, M., Bayhan, Y.K. *et al.,* 2015. New Mediterranean Biodiversity Records (October 2015). *Mediterranean Marine Science*, 16 (3), 682-702.

Crooks, J.A., 2005. Lag times and exotic species: the ecology and management of biological invasions in slow-motion. *Ecoscience* 12, 316-329.

Daskos, A., Zenetos, A., 2007. Additions to the knowledge of alien Opisthobranchia of Greece. *Aquatic invasions*, 2, 258-260.

Dulčić, J., Dragičević, B., 2012. *Paranthias furcifer* (Perciformes: Serranidae), a new alien fish in the Mediterranean Sea. *Journal of Fish Biology*, 82 (1), 332-337.

EASIN, 2019. European Commission - Joint Research Centre - European Alien Species Information Network (EASIN). https://easin.jrc.ec.europa.eu/ [16 June 2019].

European Commission (EC), 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008, establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). *Official Journal of the European Union* L164: 19-40.

European Commission (EC), 2011. Our life insurance, our natural capital: an EU biodiversity strategy to 2020. Communication from the Commission to the European Parliament, the council, the economic and social commitee and the commitee of the regions. http://www.eur-lex.europa.eu/legalcontent /EN/ TXT/?uri=CELEX:52011DC0 244.

European Commission (EC), 2017. Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardized methods for monitoring and assessment, and repealing Decision 2010/477/EU, *Official Journal of the European Union L 125*: 43-74.

Gravina, M.F., Cantone, G., 1991. *Lumrinerides neogesae* Miura, 1980, un Lumbrineridae (Annelida, Polychaeta) nuovo per il Mediterraneo. *Animalia*, 18, 149-155.

Insacco, G., Zava, B., 2017. *Chlorurus rhakoura* Randall & Anderson, 1997 (Perciformes, Scaridae), an Indo-Pacific fish new for the Mediterranean Sea. *Mediterranean Marine Science*, 18 (2), 285-291.

Katsanevakis, S., Zenetos, A., Belchior, C., Cardoso, A.C., 2013. Invading European Seas: assessing pathways of introduction of marine aliens. *Ocean & Coastal Management*, 76, 64-74.

Katsanevakis, S., Wallentinus, I., Zenetos, A., Leppäkoski, E., Çinar, M.E, *et al*., 2014. Impacts of invasive alien marine species on ecosystem services and biodiversity: a pan-European review. *Aquatic Invasions*, 9 (4), 391-423.

Lucy, F.E., Roy, H., Simpson, A., Carlton, J.T., Hanson, J.M. *et al.*, 2016. INVASIVESNET towards an international association for open knowledge on invasive alien species. *Management of Biological Invasions*, 7 (2), 131-139.

Marques, A.C., Cantero, A.P., Vervoort, W., 2000. Mediterranean species of *Eudendrium* Ehrenberg, 1834 (Hydrozoa, Anthomedusae, Eudendriidae) with the description of a new species. *Journal of Zoology*, 252 (2), 197-213.

Molnar, J.L., Gamboa, R.L., Revenga, C., Spalding, M.D., 2008. Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment*, 6 (9), 485-492.

Morello, E., Solustri C., 2001. First record of *Anadara demiri* (Piani, 1981) (Bivalvia: Arcidae). *Bolletino Malacologico*, 37, 231-234.

Ojaveer, H., Galil, B.S., Carlton, J.T., Alleway, H., Goulletquer, P. *et al.,* 2018. Historical baselines in marine bioinvasions: Implications for policy and management. *PloS one*, 13 (8), e0202383.

Ojaveer, H., Galil, B.S., Minchin, D., Olenin, S., Amorim, A. *et al.*, 2014. Ten recommendations for advancing the assessment and management of non-indigenous species in marine ecosystems. *Marine Policy*, 44, 160-165.

Panov, V.E., Gollasch, S., Lucy, F., 2011. Open-access journal Aquatic Invasions: An important part of the developing European information and early warning system on invasive alien species. *Aquatic Invasions*. 6, 1, 1-5.

Rayss, T., 1955, Les algues marines des côtes Palestiniennes.I. Chlorophyceae. *Bulletin of the Sea Fisheries Research Station of Israel,* 9, 1-36.

Smith, R.M., Baker, R.H., Collins, D.W., Korycinska, A., Malumphy, C.P. *et al.*, 2018. Recent trends in non-native, invertebrate, plant pest establishments in Great Britain, accounting for time lags in reporting. *Agricultural and Forest Entomology*, 20 (4), 496-504.

Soljan, T., 1975. I pesci dell Adriatico. Verona, Mondadori, 522pp.

Stamouli, C., Akel, E.K., Azzurro, E., Bakiu, R., Bas, A.A. *et al.*, 2017. New Mediterranean biodiversity records (December 2017). *Mediterranean Marine Science*, 18 (3), 534-556.

Streftaris, N., Zenetos, A., Papathanassiou, E., 2005. Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas. In *Oceanography and marine biology* (pp. 429-464). CRC Press.

Tsiamis, K., Zenetos, A., Deriu, I., Gervasini, E., Cardoso, A.C., 2018. The native distribution range of the European marine non-indigenous species. *Aquatic Invasions*, 13 (2), 187-198.

Wallentinus, I., Nyberg, C.D., 2007. Introduced marine organisms as habitat modifiers. *Marine pollution bulletin*, 55 (7-9), 323-332.

Zenetos, A., Gofas, S., Morri, C., Rosso, A., Violanti, D. *et al*., 2012. Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. *Mediterranean Marine Science*, 13 (2), 328-352.

Zenetos, A., Apostolopoulos, G., Crocetta, F., 2016. Aquaria kept marine fish species possibly released in the Mediterranean Sea: first confirmation of intentional release in the wild. *Acta Ichthyologica et Piscatoria*, 46 (3), 255-262.

Zenetos, A., Çinar, M.E., Crocetta, F., Golani, D., Rosso, A. *et al*., 2017. Uncertainties and validation of alien species catalogues: The Mediterranean as an example. *Estuarine, Coastal and Shelf Science*, 191, 171-187.

The following supplementary information is available for the article:
Annex: "Reported NIS since 1950 (backdated excluded)" (Excel)
https://ejournals.epublishing.ekt.gr/index.php/hcmr-med-mar-sc/article/view/20716