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Uncertainties and validation of alien species catalogues: The Mediterranean as an example

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abstract

Keywords:

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Check list

The meticulous revision by taxonomic experts of established alien species in the Mediterranean resulted in a major revision of the list proposed by Galil et al. (2016), with 73 species to be excluded (35 species categorised as non-established and 37 as not true aliens), and 72 species added to the list. Consequently, by year 2016 the total number of established alien species in the Mediterranean reached 613, which is a 28% increase over the preceding four years. If we also consider casual species (208 species), the total number of alien species in the Mediterranean is 821. This is attributed to: new findings, change in establishment status of species previously known on the basis of few and scattered records, and results of phylogenetic studies in some cosmopolitan species. However, the true number of alien species reported here is considered to be an underestimation, as it does not include phytoplanktonic organisms, Foraminifera, cryptogenic and species known on the basis of questionable records that might turn out to be true aliens. EASIN and INVASIVESNET can play a major role in the future revision/update of the present list, which currently serves for assessing indicators that are necessary for policy, and for management of alien species in the Mediterranean Sea. An increasing trend in new arrivals since 1950, which culminated in the 2001–2010 period, appeared to decline after 2010. Whether this negative trend is an indication of improvement, or is an artefact, remains to be seen. The current list provides a reliable updated database from which to continue monitoring the arrival and spread of invasive species in the Mediterranean, as well as to provide counsel to governmental agencies with respect to management and control. Current geographical, taxonomical and impact data gaps can be reduced only by instituting harmonised standards and methodologies for monitoring alien populations in all countries bordering the Mediterranean Sea.

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1. Introduction

Preparation of alien species (AS) checklists at larger scale and the development of relevant Web databases have been challenging tasks over the latest decades, with many funds and efforts being channeled in this direction from within the European Union (AquaNIS, DAISIE, EASIN, ESENIAS, NOBANIS). One major drawback in most of the aforementioned systems is the lack of long-term funding, which often results in a lack of updates which is, in turn, a prerequisite for delivering timely reliable information to environmental managers (Lucy et al., 2016). Nevertheless, the most serious problem is often the lack of expertise that ought to be engaged in such an endeavour. Species records in the existing data systems are often taken at face value without investigating their validity.

We acknowledge that no list at the national/regional scale is fully reliable unless it is the result of close collaboration of local experts. For instance, a list of AS in Greek waters that was first compiled in 2005 (Pancucci-Papadopoulou et al., 2005), and then was updated in 2009 (Zenetos et al., 2009) and again in 2010 (Zenetos et al., 2011b), is today out of date and includes some inevitable errors. For molluscs alone, out of about 100 potential alien taxa that were examined, almost half of the records turned out to be based on misidentifications or incorrect distributional data (FC, AZ unpublished data). This phenomenon is accentuated when no experts are involved, or where checklists are only based on knowledge that is provided by scientists with broad taxonomic expertise.

Apart from the aforementioned species-specific knowledge, any checklist also requires continuous updating in the light of new information on: a) new arrivals or overlooked species, e.g. *Bugula neritina* (Linnaeus, 1758); b) range expansion of already known species resulting in change of their establishment success, e.g. the brown shrimp *Penaeus aztecus* Ives, 1891, which within six years invaded almost the entire Mediterranean since the first record from Turkey (Deval et al., 2010), and whose status was switched from casual to invasive; c) changes in identification/nomenclature resulting from both traditional and molecular studies, e.g. the well-established and exploited prawn previously identified as *Penaeus japonicus* Spence Bate, 1888, and known in the Eastern Mediterranean since 1924 (Egypt: Balss, 1927), turned out to be *Penaeus pulchricaudatus* Stebbing, 1914 (Tsoi et al., 2014). Moreover, some alien fish species that are well-established in the Mediterranean and widely reported in the past literature with specific binomial names turned out to be species that are novel to science: *Etrumeus teres* (DeKay, 1842) vs *Etrumeus golanii* DiBattista et al., 2012; *Saurida undosquamis* (Richardson, 1848) vs *Saurida lessepsianus* Russell et al., 2015; *Sillago sihama* (Forsskål, 1775) vs *Sillago suzensis* Golani et al., 2014 (see DiBattista et al., 2012; Russell et al., 2015; Golani

et al., 2016); d) changes in alien or native status for cryptogenic species resulting from genetic and biogeographical studies, e.g. the alga *Caulacanthus okamurae* Yamada (see Verlaque et al., 2015), the polychaete *Chaetozona corona* Berkeley and Berkeley, 1941 (see Le Garrec et al., 2017); e) changes in the introduction pathway resulting in the alteration of native/alien/cryptogenic status, e.g. the case of *Aplysia dactylomela* Rang, 1828, initially assumed to be ship transferred or unaided via Gibraltar (Scuderi and Russo, 2005), subsequently moved to the Lessepsian immigrant category (entering via the Suez Canal: Crocetta and Galil, 2012), and was lately transferred to unknown category (Valdes et al., 2013).

Despite the aforementioned problems, several AS lists have been published in the past from the Mediterranean Sea as a whole, among which Galil (2008, 2009), Nunes et al. (2014), and Zenetos et al. (2005, 2008; 2010; 2012) are noteworthy. Galil et al. (2016) recently published an expansive article based on a critical review of historical data, highlighting how the global trend of increasing numbers of AS is magnified in the Mediterranean. Based on these data, realistic and practicable priority actions are proposed in order to reduce potential impediments that hinder the implementation of a mitigation programme of the biological invasions. This same work emphasises the need for accurate lists of AS and the urgency of reducing current geographical and taxonomical data gaps. However, the dataset that accompanies that work suffers itself from all of these problems, which can only be resolved with the assistance of active participation of taxonomic experts. The aim of the present work is to present an updated list of established AS in the Mediterranean, and to stress the need for collaboration with locals and the contribution of taxonomic experts to compile accurate lists of AS, which are a prerequisite for any mitigation action.

2. Methodology

As is well known to taxonomists and conservation biologists, taxonomic knowledge has widely increased in the last two to three decades due to the even wider use of combined approaches, and some species reported in the past literature (usually from 1700 to around 1980) have never actually lived in the area where they have been widely recorded in the past. Using as a starting point the most recent list of AS (that of Galil et al., 2016), we performed a critical update based on reviews by Mediterranean taxonomists on macroalgae, Mollusca, Polychaeta, Ascidiacea, Bryozoa and Fishes. An extensive literature survey constitutes the base of the present article. Published records of AS were sought in both indexed and non-indexed journals, as well as in the gray literature, since most of the historical journals are non-indexed and, particularly, faunal records are still being published in non-indexed journals, thus allowing only manual searching. Nomenclature of species, first record and establishment success were all checked by local experts.

The updates of the present work are as follows:

List of species. Some species that are listed are not alien and others have been excluded as they fall within one of the following criteria: i) species with unresolved taxonomic status (species complex or morphologically similar taxa) which may include native species; ii) records lacking proper scientific documentation; iii) cryptogenic species sensu [Carlton \(1996\)](#); iv) non-living records (i.e. loose valves, empty shells) unless known from the invaded area from a wide number of records/material; v) non-established species (AS, whose populations are known to be extinct or possibly not yet established, if the record is recent, i.e. within the past decade).

Taxonomic/nomenclatural issues. All species names were checked following the World Register of Marine Species ([WoRMS Editorial Board, 2016](#)). Discrepancies were reported to the WoRMS editors.

Establishment success. The terminology used varies among invasion biologists. For species reported once or twice on the basis of single individuals, we retain the term 'casual'. If there are many records, spread over time and place, it is assumed that the species are established, even though there may be no evidence of reproduction.

Year and country of the first record. For unpublished data, we searched museum collections and contacted the authors of the first report when possible. Dates of personal observations were also considered. We refer to the first recipient country according to the first collection/observation date, not according to reporting date.

Trends in introduction of new AS. We used the compiled data to ascertain the rate of new introductions, presented as a yearly rate (average per decade) since 1950. For the last six years (2011-2016) of the analysis, the number of recorded species is an underestimate. This is due to the time lag between the sampling of the species and the publication of the data, which can take several years. To better demonstrate the introduction rate, we also used the collection dates of non-established species (casual records) which have been reported after 1950.

3. Results and discussion

3.1. List of species

Our updated list of established aliens in the Mediterranean, includes species that i) are not included in the lists published by [Galil \(2008, 2009\)](#), [Zenetos et al. \(2010, 2012\)](#), [Nunes et al. \(2014\)](#), [Galil et al. \(2016\)](#); ii) were reported after these inventories, and iii) species first recorded a long time ago, which were formerly considered native and whose alien status has been recently proven in the body of literature.

Seventy four of the reported species should be excluded, 37 as not true aliens, 36 as not established. Another 72 established species are added to the list of [Galil et al. \(2016\)](#). These are: macroalgae (16 species), Mollusca (3), Polychaeta (28), Crustacea (4), Bryozoa (4), Ascidiacea (9), Cnidaria (3), Turbellaria (1); Sipuncula (1), and fishes (3). The total number of established AS in the Mediterranean is 613.

3.1.1. Species that should be excluded (misidentifications, unconfirmed, cryptogenic or non-established species)

According to the exclusion criteria of [Galil et al. \(2016\)](#), 37 species (6 macroalgae, 19 Mollusca, 7 Polychaeta, 1 Crustacea, 1 Bryozoa, 1 Cnidaria) which were reported as established should be removed from the Mediterranean aliens list of established species, either because their identification has been revised or because they are cryptogenic or questionable or based on empty shells (molluscan species). A further 36 species (9 macroalgae, 14 Mollusca, 2 Polychaeta, 3 Crustacea, 1 Ascidiacea, 1 Echinodermata, 7

Fish), should be removed from the list as the reports on them are based on casual records. We provide here a detailed explanation for each taxonomic/ecofunctional group. For each group we provide in brackets the number of the species that should be removed as not true aliens and the number of species whose reports are based on casual reports.

3.1.1.1. Macroalgae (6 p 9). Five species namely *Antithamnionella boergesenii* (Cormaci & G.Furnari) Athanasiadis, *Antithamnionella elegans* (Berthold) J.H.Price & D.M.John, *Antithamnionella spirographidis* (Schiffner) E.M.Wollaston, *A. ternifolia* (J.D.Hooker & Harvey) Lyle and *Caulerpa chemnitzia* (Esper) J.V.Lamouroux are classified as debatable (cryptogenic) in [Verlaque et al. \(2015\)](#) and as such should be provisionally removed from the aliens' list of the Mediterranean Sea. *Chondria collinsiana* M.A.Howe, is a probable misidentification of *Chondria curvilineata* F.S. Collins & Hervey.

Acrochaetium robustum Børgesen, *A. spathoglossi* Børgesen, *A. subseriatum* Børgesen, *Ascophyllum nodosum* (Linnaeus) Le Jolis, *Derbesia boergesenii* (Iyengar & Ramanathan) Mayhoub, *Fucus spiralis* Linnaeus, *Grateloupia patens* (Okamura) S.Kawaguchi & H.W.Wang, *Hypnea flagelliformis* Greville ex J.Agardh, and *Rhodymenia erythraea* Zanardini, which are only known from the original records (see [Verlaque et al., 2015](#)), must also be excluded from the list.

3.1.1.2. Mollusca (19 p 14). Records of *Alectryonella crenulifera* (Sowerby G.B. II, 1871) and *Alectryonella plicatula* (Gmelin, 1791) by [Mienis et al. \(2012a, b\)](#) were contemporarily confused by [Crocetta et al. \(2015a\)](#) and [Huber \(2015\)](#). Based on molecular analysis of Mediterranean specimens, [Crocetta et al. \(2015a\)](#) suggested that both species belong to *Dendostrea cf. folium* (Linnaeus, 1758) while, based on shell morphology, [Huber \(2015\)](#) suggested that they belong to *Dendostrea rosacea* (Deshayes, 1836). Mediterranean specimens originally ascribed to *Murchisonella columna* (Hedley, 1907) were recently described as *Murchisonella mediterranea* [Peras and Rolan, 2013](#), a Mediterranean endemic species (see [Peras and Rolan, 2013](#)). The record of *Cantharus tranquebaricus* (Gmelin, 1791) was based on three empty shells from the Mediterranean coasts of Israel ([Mienis, 2003](#)). However, this record was subsequently amended by the same author ([Mienis, 2006](#)), who stated that the record was presumably based on three mislabelled specimens from India, and that the species should have been excluded from AS lists. The presence of *Spondylus groschi* Lamprell and Kilburn, 1995 and *Spondylus multisetosus* Reeve, 1856 is disputed due to the confusion with their congeneric *S. spinosus* Schreibers, 1793 ([Zenetos et al., 2004](#)). Therefore, they are labelled as "questionable" species until their systematics is revised. The presence of *Centrocardita akabana* (Sturany, 1899) in the Mediterranean is dubious. Juvenile specimens of the eastern Atlantic-Mediterranean taxon *Cardites antiquatus* (Linnaeus, 1758) may be easily confused this alien taxon. Therefore, a DNA barcoding approach is required in order to support the presence of *C. akabana* in the Mediterranean. *Dendrodoris fumata* (Rüppell and Leuckart, 1830) was recorded from Israel ([Barash and Danin, 1986](#)), Turkey ([Çevik et al., 2012](#)) and Italy ([Trainito and Doneddu, 2014](#)). However, published identifications were never confirmed by molecular and/or anatomical data, and therefore remain all highly doubtful. The past presence of *Zygochlamys patagonica* (King, 1832) in the Mediterranean is now considered as very doubtful, as [Mannino et al. \(2016\)](#) have excluded the records from the Alboran Sea and Italy since it is not sure if all Mediterranean records were based on discards in the field of dead specimens imported with shrimps (some presumably even with soft parts), or if specimens obtained 'from fishermen' may refer to trawlings from the Atlantic by fleets based only in the Mediterranean Sea.

In addition, although molluscan records based only on empty shells were included in [Zenetos et al. \(2004\)](#) and subsequent lists, in accordance with [Marchini et al. \(2015\)](#) they should be removed from all Mediterranean alien inventories, unless records are based on a wide number of specimens. In particular, we here refer to:

- ✓ *Antigona lamellaris* Schumacher, 1817: based on a single shell from Turkey ([Engl and Çeviker, 1999](#));
- ✓ *Canarium mutabile* (Swainson, 1821): reported from Israel ([Mienis, 2001](#)) on the basis of three empty shells;
- ✓ *Cerithium litteratum* (Born, 1778): only known by a single empty shell found in Greece in 1978 ([Garilli and Vardala-Thedorou, 2005](#));
- ✓ *Cerithium nesioticum* Pilsbry and Vanatta, 1906: only known from empty shells from Israel ([Mienis, 1977](#)) and Cyprus ([Bogi et al., 1989](#));
- ✓ *Ergalatax contracta* (Reeve, 1846): only known from empty shells ([Mienis, 2004](#));
- ✓ *Haliotis rugosa pustulata* Reeve, 1846: a few shells only in Israel and Libya (see [Zenetos et al., 2004](#));
- ✓ *Monetaria annulus* (Linnaeus, 1758): [Mienis \(2004\)](#) rejected earlier records in the Levantine basin. Records from the central-western Mediterranean are based on empty shells or unconfirmed records;
- ✓ *Notocochlis gualteriana* (Recluz, 1844): only known from two empty shells ([Mienis, 1986, 2000](#));
- ✓ *Rissoina ambigua* (Gould, 1849): a microspecies, whose records are based on few empty shells found in Turkey in 2003 ([Mienis, 2004](#));
- ✓ *Trapezium oblongum* (Linnaeus, 1758): only known by a single valve ([Mienis, 1980](#)). Its real occurrence in the Mediterranean Sea was considered doubtful by [Mienis \(1980\)](#) himself.

Finally, the following species are not established (species recorded once or twice):

- ✓ *Acanthopleura* sp.: few specimens from Tripoli (Lybia) and Zarzis (Tunisia), where the species is considered as casual (see [Zaouali et al., 2007](#); [Crocetta et al., 2014](#); [Ounifi-Ben Amor et al., 2016](#));
- ✓ *Acar plicata* (Dillwyn, 1817): only known from a single record in Israel ([Barash and Danin, 1986](#)), as the additional record from Greece should be considered as questionable (see [Corsini-Foka et al., 2015](#));
- ✓ *Atactodea striata* (Gmelin, 1791): only known from two single records - [Barash and Danin \(1977\)](#) and [Cachia et al. \(2004\)](#);
- ✓ *Conus fumigatus* Hwass in Bruguière, 1792: only recorded in 1974-1976 from a single locality in Libya ([Röckel, 1986](#)), with no follow up;
- ✓ *Chiton hululensis* (E. A. Smith, 1903): only known from two old single records, with no follow up ([Barash and Danin, 1992](#));
- ✓ *Cuthona perca* (Er. Marcus, 1958): only known from Italy on the basis of an old record of a single specimen ([Perrone, 1995](#));
- ✓ *Halgerda willeyi* Eliot, 1904: only known from Croatia on the basis of an old record of a single specimen ([Turk, 2000](#));
- ✓ *Lodderia novemcarinata* (Melvill, 1906): only known from 5 specimens from a single locality ([Öztürk et al., 2015](#));
- ✓ *Mercenaria mercenaria* (Linnaeus, 1758): the Northern quahog cannot be classified as abundant, and not even as established. Attempts were made to introduce the clam to the Etang de Thau (France), while the putative records from Italy were confuted early after [Zenetos et al. \(2004\)](#), followed by the first concrete record of few specimens (see [Turolla, 2006](#)). No populations have successfully been established anywhere in the Mediterranean;

- ✓ *Pinctada margaritifera* (Linnaeus, 1758): its potential introduction in Italy has been recently confuted (see discussions in [Crocetta et al., 2009](#)), so that it is only known on the basis of a single remaining record from Egypt ([Zenetos et al., 2004](#));
- ✓ *Plocamopherus tilesii* Bergh, 1877: only known from Turkey on the basis of a single specimen that was collected in 2009 ([Yokeş et al., 2012](#));
- ✓ *Spondylus nicobaricus* Schreibers, 1793: only known from Israel on the basis of an old record of a single specimen ([Zenetos et al., 2004](#));
- ✓ *Stomatella impertusa* (Burrow, 1815): known from a single record from Turkey (see [Zenetos et al., 2004](#)), and a possible, but still doubtful, record from Malta (see [Arias et al., 2013b](#)), where the species was not found again despite careful researches (FC, unpublished data);
- ✓ *Teredothyra dominicensis* (Bartsch, 1921): specimens from Turkey were predominantly acquired from a shipwreck off the coast of Kas. The Greek record should not be considered, as a single specimen was found on a piece of driftwood that was recovered off the coast of Fourni Island (Luisa Borges, pers. Comm.). Following [Marchini et al. \(2015\)](#), the aforementioned records do not qualify for a successful establishment.

3.1.1.3. Polychaeta (7 p 2). The following species must be omitted:

- ✓ *Eunice indica* Kinberg, 1865: most probably it could be *E. vittata* (see discussion in [Ben-Eliahu, 1976](#));
- ✓ *Hydroides dianthus* (Verrill, 1873): according to a recent molecular study ([Sun et al., 2017](#)), the global invader *H. dianthus* seems to be originated from the Mediterranean Sea. However, it was emphasised that specimens of *Hydroides* cf. *dianthus* in the Black Sea could have been introduced to the region from the West Coast of the USA;
- ✓ *Linopherus incarunculata* (Peters, 1854): this species has not been reported from the Mediterranean Sea. The only species reported was *L. acarunculatus* ([Monro, 1937](#)) that was later proved to be a misidentification of *L. canariensis* Langerhans, 1881 (see [Çinar, 2009](#));
- ✓ *Marphysa disjuncta* Hartman, 1961: the species was re-identified as *Marphysa cinari* [Kurt-Sahin 2014](#), a Mediterranean endemic species ([Kurt Sahin, 2014](#));
- ✓ *Neanthes willeyi* (Day, 1934): [Fauvel \(1955\)](#) reported that *N. willeyi* was found in Port Said (as *Nereis capensis*), quoting his 1927 paper ([Fauvel, 1927](#)). Indeed [Fauvel \(1927\)](#) found this species at one station in the Suez Canal just 5 km away from Port Said. [Ben-Eliahu \(1991\)](#) considered this species as AS in the Mediterranean, based on the expression made by [Fauvel \(1955\)](#). As there is no true record of this species in the Mediterranean, this species should be excluded from the list;
- ✓ *Onuphis eremita oculata* Hartman, 1951: the record was re-identified as *Onuphis eremita* Audouin and Milne Edwards, 1833. [Arias and Paxton \(2014\)](#) stated 'Since the original description of *O. eremita* indicates the presence of eyespots, as well as that they are present in the neotype in most of the studied specimen, it is very likely that the subspecies reported by [Çinar \(2009\)](#) is actually *O. eremita* and hence is a Mediterranean native species';
- ✓ *Laonome elegans* Gravier, 1906: it is a questionable species (see [Ben-Eliahu, 1972](#), p. 232)

In addition, the following species are not established (species recorded once or twice):

- ✓ *Perinereis nuntia* (Lamarck, 1818): the species was regarded as casual (Zenetos et al., 2010) as it was only reported from Port Said (Egypt) in 1924 by Fauvel (1927). There is no subsequent record of this species in the Mediterranean;
- ✓ *Branchiommaboholense* (Grube, 1878): besides the record by Knight-Jones et al. (1991), all other reports are questionable. The reports from the western Mediterranean were proved to be *B. bairdi* (McIntosh, 1885) (see Çinar, 2009; Giangrande et al., 2012), as well as the reports from Cyprus (see Çinar, 2005).

3.1.1.4. Crustacea (1 þ 3). The following species must be omitted:

- ✓ *Nothobomolochus fradei* Marquès, 1965: reported as parasite on *Herklotsichthys punctatus* (Rüppell, 1837), which was caught in Egyptian waters off the Alexandrian coast in 2008 (El-Rashidy and Boxshall, 2009, 2010). It cannot be confirmed as an alien because of its natural distribution [which includes both the Arabian Gulf and the Eastern Atlantic coast (Gulf of Guinea)]. This widespread distribution indicates that it could be native in the Mediterranean, where it was also found on the native fish *Sardina pilchardus* (Walbaum, 1792) (G. Boxshall, pers. comm.);
- ✓ *Bemlos leptocheirus* (Walker, 1909): only known from a single record from Port Said (Schellenberg, 1928);
- ✓ *Eriocheir sinensis* H. Milne Edwards, 1853: based on four records, of single specimens in lagoons, 46 years apart, one in France (1959: Petit, 1960) and three in Italy (2005, 2013, 2014: see Bettoso and Comisso, 2015);
- ✓ *Grapsus granulosus* H. Milne Edwards, 1853: it is not established in Tunisia or other Mediterranean localities (Ounifi-Ben Amor et al., 2016).

3.1.1.5. Ascidiacea (0 þ 1). *Perophora multiclathrata* (Sluiter, 1904): reported in Corsica (Monniot, 1983; Monniot and Monniot, 1987). It is different from *Perophora viridis* Verrill, 1871. Common synonyms are *Perophora bermudensis* Berrill, 1932 and *Perophora formosana* (Oka, 1931) (Monniot and Monniot, 1987; Kott, 1985). If we accept these synonymies, then *P. multiclathrata* occurs in the Indo-Pacific, and on both sides of the tropical Atlantic. The Mediterranean reports, however, concern only two findings in the same locality (F. Monniot, pers. comm.), thus the species cannot be considered as presently established.

3.1.1.6. Bryozoa (1 þ 0). *Schizoretepora hassi* Harmelin, Bitar & Zibrowius, 2007: Harmelin et al. (2016) considered this species as cryptogenic.

3.1.1.7. Echinodermata (0 þ 1). *Ophiocoma scolopendrina* (Lamarck, 1816): record based on a single specimen (Zaouali et al., 2007).

3.1.1.8. Cnidaria/Anthozoa (1 þ 0). The colonial scleractinian *Oculina patagonica* de Angelis, 1908, was described from fossil material in South America. It is assumed to have been introduced in anthropogenic times into the Mediterranean, but as “nothing is known on the actual range of the species” (Zibrowius, 1974). However, genetic, historic, demographic, and fossil evidence suggests that *O. patagonica* has not been anthropogenically introduced into the Mediterranean from the western North Atlantic. Mediterranean and Atlantic populations are genetically distinct and appear to have begun diverging about 5 Mya (Leydet and Hellberg, 2015). Results support the hypothesis that *Oculina* has had a long history in the eastern Atlantic, but remained undetected until it recently began expanding to invasive numbers in the Mediterranean, likely in response to environmental changes (Leydet and Hellberg, 2015).

3.1.1.9. Fish (0 þ 7). Seven species must be omitted as not established:

- ✓ *Sciaenops ocellatus* (Linnaeus, 1766): aquaculture escapee. Only two specimens have been collected to date. This species does not reproduce in the wild in the Mediterranean (Golani et al., 2015);
- ✓ *Chanoschanos* (Forsskål, 1775): only one record from Turkey (Şvzarol and Gökkoğlu, 2012);
- ✓ *Coryogalops ocheticus* (Norman, 1927): only one record from Egypt (Golani et al., 2016);
- ✓ *Elates ransonnettii* (Steindachner, 1876): only 2 single records, five years apart, one from Italy in 2005 (Mastrototaro et al., 2007) and one from Croatia in 2010 (Dulčić et al., 2010);
- ✓ *Pampus argenteus* (Euphrasen, 1788): a museum record in Croatia in 1896, followed by a record in Tunisia in 2007 (Sami et al., 2014) with no follow up, cannot account for establishment of the species;
- ✓ *Tridentiger trigonocephalus* (Gill, 1859): only one specimen has been collected. However, the people that collected the specimen claimed that they saw several specimens in the same location that looked similar to this species (DG, unpublished). With the lack of concrete evidence, the species is classified as non-established;
- ✓ *Abudefduf vaigiensis* (Quoy and Gaimard, 1825): the species that occurs in the Levant is *Abudefduf saxatilis* (see: Tsadok et al., 2015), therefore, it obviously did not arrive via the Suez Canal and it is not rare. However, recently Vella et al. (2016) claim that in their genetic study they found that both *A. vaigiensis* and *A. saxatilis* co-exist in Malta.

3.1.2. Additional species

Annex 1 includes 72 established aliens in the Mediterranean that are missing in Galil et al. (2016). Among the taxa, most of the macroalgae are included in the recent CIESM atlas (Verlaque et al., 2015), while 4 species, namely *Monosporus indicus* Børgesen, *Dityotocyanoloma Tronholm*, De Clerck, Gomez Garreta & Rull Lluç, *Cutleria multifida* (Turner) Greville and *Halimeda incassata* (J. Ellis) J. V. Lamouroux were reported in 2016 (Hoffman and Wynne, 2016; Aragay et al., 2016; Kawai et al., 2016; Alos et al., 2016). Previously considered as debatable (Verlaque et al., 2015), the introduction of the Red Sea species *Palisada marisrubri* (K.W. Nam & Saito) K.W. Nam in the Mediterranean has been confirmed by reports from Greece (Tsiamis et al., 2015) and Tunisia (Boudouresque et al., 2016).

The molluscan aliens are adequately covered. Exceptions are: i) *Indothais scellum* (Gmelin, 1791), a species first recorded in 2000 as very common in the Beyrouth Harbour, Lebanon (Zibrowius and Bitar, 2003). The species is also spreading in other Mediterranean countries, such as Israel, where it was found in at least in two localities (Mienis, 2006); ii) *Fossarus eutorniscus* Melvill, 1918, a taxon that was first reported in the Mediterranean Sea as *Parviturbo dibellai* Buzzurro and Cecalupo, 2006 on the basis of a wide number of shells from Israel and Turkey (Buzzurro and Cecalupo, 2006), and subsequently assigned to the Lessepsian species *F. eutorniscus* (Rubio et al., 2015). In addition, Galil et al. (2016) excluded “species with unresolved taxonomic status (species complex or morphologically similar taxa)”. This approach presumably led to the exclusion of *Dendostrea cf. folium* from the species list, although this taxon is clearly an AS in the Mediterranean Sea and only its specific attribution is problematic due to the absence of molecular studies that aim to solve the Indo-Pacific *Dendostrea* complex of species (Crocetta et al., 2015a).

The majority of polychaetes are included in the reviews by Zenetos et al. (2010, 2012) and Çinar (2013). The most recently

introduced species is *Diopatra marocensis* Paxton, Fadlaoui & Lechapt, 1995, which was reported from different localities along the Levant and Aegean coasts of Turkey (Çinar et al., 2014a) and might have been introduced to the area via the ballast water of ships. Furthermore, worth mentioning are:

- ✓ *Prionospio pulchra* Imajima 1990: first reported from the Greek coast of the Aegean Sea by Pancucci-Papadopoulou et al. (2005) and subsequently reported from Levantine, Sea of Marmara and Black Sea coasts by Dagli and Çinar (2011). However, the specimens that were collected on the Italian coast of the Tyrrhenian Sea in 1982 and identified as *P. cirrifera* Wiren, 1883 by Giangrande and Gambi (1982) were re-identified as *P. pulchra* (Dagli and Çinar, 2011);
- ✓ *Timarete punctata* (Grube, 1859), which was possibly confused with *T. semicineta* (Ehlers, 1905) identified from the Lebanon coast in 1965 (Laubier, 1966), occurred abundantly in harbour environments on the southern coast of Turkey (Çinar, 2007);
- ✓ *Chaetozone corona* Berkeley and Berkeley, 1941: the species was initially reported as cryptogenic in the Mediterranean Sea (Çinar and Ergen, 2007), but it was later reported from the eastern Atlantic coast as an AS that was introduced by shipping from the East Coast of the USA (Le Garrec et al., 2017). Therefore, the species can be also considered as an established alien species in the Mediterranean Sea;
- ✓ *Loimia medusa* (Savigny, 1818) was mentioned as questionable in Zenetos et al. (2010). However, there is growing evidence that this species occurs in the eastern Mediterranean and can be regarded as an established AS (Dorgham and Hamdy, 2015; MEÇ pers. observ.). The first record of this species was given by Rullier (1963) in the Sea of Marmara. In the Mediterranean basin, *L. medusa* was included in species lists from Greece (collection date: 1976) (Bogdanos and Satsmadjis, 1983) and Italy (collection date: 1987) (Albertelli et al., 1995);
- ✓ *Eurythoe complanata* (Pallas, 1766): whose first report from the Mediterranean Sea (Israeli coast) was given by Monro (1937). The species was subsequently reported from different parts of the Mediterranean Sea, including Gibraltar (see Arias et al., 2013a). As Çinar (2008) postulated, unless the taxonomic status of the *Eurythoe* species, *E. syriaca* Kinberg, 1857 and *E. hedenborgi* Kinberg, 1857, which were originally described from the eastern Mediterranean by Kinberg (1857) and subsequently considered as a junior synonyms of *E. complanata* or indeterminable by different authors, are solved, it is hard to determine the status and first arrival time of *E. complanata* in the Mediterranean Sea. However, as types of *E. syriaca* and *E. hedenborgi* are presumably lost and their original descriptions were too short and without figures, we should assume, for the time being, that the taxonomic status of these species are nomen dubium. Therefore, we can conclude that *E. complanata* occurs in the region and is an established alien species;
- ✓ *Eurythoe laevisetis* Fauvel, 1914 was first reported from the Chafarinas Island (Alboran Sea) and Malta in the Mediterranean Sea, and was considered as an established alien species (Arias et al., 2013a). However, as this species was originally described from the eastern Atlantic (Gulf of Guinea) and known also from the Canary Island (Arias et al., 2013a), this species might have entered into the Mediterranean by the process of range expansion rather than by human assistance. However, there is a gap in the distribution of the species within the Mediterranean, which is absent in the westernmost part. Therefore, this species should be kept in the list as an established alien species until more data about its distributional pattern in the western Mediterranean are accumulated that would enable us to realise the pathway through which it has become established in Maltese waters; natural dispersal via Gibraltar or shipping?

Crustacea are also successfully covered. In addition to the two Cumacean species *Eocuma rosae* Corbera and Galil, 2007 and *Eocuma sarsii* (Kossmann), 1880 that are reported as established in Corbera and Galil (2016), the copepod *Parvocalanus crassirostris* (Dahl F., 1894), an old record from Egypt (Gurney, 1927), which was recently found in the Adriatic (Vidjak et al., 2016) is missing. The amphipod *Linguimaera caesaris* Krapp-Schickel, 2003 has been mistakenly deleted from earlier lists and reported as *Hamimaera hamigera* (Haswell, 1879) (Zenetos et al., 2011a).

With regards to alien ascidians the list is enriched with the addition of nine species:

- ✓ *Aplidium accarense* (Millar, 1953): recently found in Spain and Italy, and is likely introduced by vessels (Lopez-Legentil et al., 2015);
- ✓ *Asciadiella aspersa* (Müller, 1776): described from Norway. *A. aspersa* is a widespread species that is introduced into many parts of the world. It can be safely assigned an introduced status in the Mediterranean (Nishikawa et al., 2014; Lopez-Legentil et al., 2015). Its vector is most likely vessels, as the species occurs in harbours. The oldest Mediterranean report is that of Delle Chiaje (1828) (as *Phallusia mamillaris*, according to Traustedt, 1883) from the Gulf of Naples;
- ✓ *Botrylloides nigrum* (Herdman, 1886): reported by Perès 1958 from the coast of Israel (see also Sheets et al., 2016 for a recent report in Israel);
- ✓ *Ciona robusta* Hoshino and Tokioka, 1967: the cosmopolitan taxon *Ciona intestinalis* has been recently shown to comprise several cryptic species, of which the most widespread are the so-called *Ciona intestinalis* type A and type B (Zhan et al., 2010). Recent studies (Brunetti et al., 2015; Pennati et al., 2015) have shown that *Ciona intestinalis* type A is in fact *C. robusta*. Genetic data (Bouchemousse et al., 2016) support the introduced status of *C. robusta* in Europe, based on low genetic diversity as compared with the presumed native area in the NW Pacific. Nowadays, *C. robusta* can be safely assigned an introduced status in the Mediterranean, being reported there since the 19th Century (Savigny, 1816; as *Phallusia intestinalis*), most often under the name *C. intestinalis*;
- ✓ *Clavelina oblonga* Herdman, 1880: this is a true introduced species that has been mistakenly described as a new species *Clavelina phlegraea* Salfi, 1929 in the Mediterranean and is found in Italy, Corsica, and Spain (Ordóñez et al., 2016);
- ✓ *Diplosoma listerianum* (Milne Edwards, 1841): often cited as cryptogenic, it can be considered as introduced in the Mediterranean. It is a species complex, but the Mediterranean clade is native to the Atlantic shores (Perez-Portela et al., 2013). Della Valle (1877) first reported this species (as *Pseudodidemnum listerianum* Milne-Edwards, 1841) from the Gulf of Naples;
- ✓ *Microcosmus anchylodeirus* Traustedt, 1883: collected in Corsica over a period of at least 12 years (Monniot, 2016). The donor region and the introduction pathway of this western-Atlantic species are unknown;
- ✓ *Polyclinum constellatum* Savigny, 1816: Halim and Abdel Messeih (2016) report this species from the area of Port Said;
- ✓ *Styela clava* Herdman, 1881: although the first record in Egypt (Ghobashy and Abdel Messeih, 1991) is unsubstantiated (insufficient description), the species was reported from France (Davis and Davis, 2008; first seen in 2004), and now is spreading into the Mediterranean (Çinar, 2016).

Four Bryozoa species should be added. The vast majority of them

were reported in Lebanon, after the inventories of [Zenetos et al. \(2005, 2012\)](#). To be more precise, [Harmelin \(2014\)](#) and [Harmelin et al. \(2016\)](#), based on collections made some years earlier, reported 27 AS from Lebanon. Among them, two are cryptogenic and others such as *Thalamoporella rozieri* (Audouin, 1826), and *Celleporaria vermiformis* (Waters, 1909) cannot be included in the present inventory because they were recorded from a single site. In contrast, other species seem to be widely distributed in the Levantine Sea as they have also been recorded along the coasts of Israel by [Sokolover et al. \(2016\)](#).

- ✓ *Celleporina bitari* [Harmelin, 2014](#): this species has been recorded in samples that were collected in 2002 and 2003 in Lebanon. Also known from the Red Sea, *C. bitari* has been considered by [Harmelin \(2014\)](#) as introduced into the Mediterranean via Suez either through shipping or colonising successive relays along the Canal;
- ✓ *Celleporaria cf. sherryae* Winston, 2005: this species has been reported from Lebanon by [Harmelin \(2014\)](#) and is considered as an alien bryozoan in the Mediterranean by [Harmelin et al. \(2016\)](#) who postulate its introduction through Gibraltar via long-distance vessels;
- ✓ *Microporella genisii* (Audouin, 1826): this species has been reported from the coasts of Lebanon, predominantly in natural habitats on various substrata and in a wide depth range (5e40 m);
- ✓ *Mucropetraliella thenardii* (Audouin, 1826): this species has been reported from the coast of Lebanon ([Harmelin, 2014](#); [Harmelin et al., 2016](#)) and from some localities along the coasts of Israel by [Sokolover et al. \(2016\)](#).

With regards Cnidaria, molecular analyses of the widely distributed jellyfish *Aurelia*, have revealed the presence of *Aurelia coerulea* von Lendenfeld, 1884 and *Aurelia solida* Browne, 1905, as established AS in the Mediterranean Sea ([Scorrano et al., 2016](#)). The firework anemone *Pachycerianthus multiplicatus* Carlgren, 1912 was reported from Iskenderun Bay based on material collected in 2009 and might have been introduced to the area by ballast waters of vessels ([Çinar et al., 2014b](#)).

The flatworm *Maritigrella fuscopunctata* (Prudhoe, 1978) was reported from Malta in 2015 but it was known from Israel and Lebanon since 2014 (Portelli et al. in [Crocetta et al., 2015a,b](#)).

The sipunculan *Aspidosiphon elegans* (Chamisso and Eysenhardt, 1821) that was reported by [Wesenberg-Lund, 1957](#), appears to be established in the Levantine Sea (Turkey: [Açik, 2011](#)).

Finally in this revised list, three fish species are added:

- ✓ *Equulites elongatus* (Günther, 1874): known from Israel since 2011, and is now established in the area (Golani, unpublished data);
- ✓ *Cryptocentrus caeruleopunctatus* (Rüppell, 1830): reported in Israel by [Rothman and Goren, 2015](#);
- ✓ *Stolephorus indicus* (van Hasselt, 1823): reported in Israel by [Fricke et al. \(2015\)](#).

The information gaps, the lack of previous records, as well as difficulties in taxonomic identification and general confusion in species global biogeography and species level biodiversity makes it difficult for some groups to decide on categorising them as alien or cryptogenic. This is a common problem in alien marine species which will be only solved with molecular studies. Here are some examples of established species that are presently not included in our list as there is not enough information on taxonomic status, introduction vector, cryptic diversity, etc. These examples are best labelled as cryptogenic species until more information is available.

The ascidian *Clavelina lepadiformis* (Müller, 1776). [Turon et al. \(2003\)](#) show that the form living inside ports in the Mediterranean is likely introduced from the Atlantic. But, at present, although the forms living inside and outside of ports are considered as two clades of a single species, no formal taxonomic distinction has been made. The earliest record that specifically mentioned *C. lepadiformis* inside ports in the Mediterranean is [Della Valle \(1877\)](#) in Naples, and the introduction vector is likely via vessels.

The ascidian *Perophora viridis* Verrill, 1871 is common in the West Atlantic Ocean, where it was described. The species is present also in the Pacific Ocean. In the Mediterranean *P. viridis* was signaled in 1921 by Neppi (under the synonym *P. dellavallei*) in Naples, then by [Brunetti and Menin \(1977\)](#) in Venice, and by [Monniot and Monniot \(1987\)](#) in Corsica. It is abundant in the Iberian Mediterranean ([Turon, 1987](#); [Ramos-Espla, 1988](#)). Although it is sometimes labelled as alien, we consider *P. viridis* as cryptogenic. This species may be abundant in the Atlanto-Mediterranean area but has been confused with *Perophora listeri* Wiegman, 1835. Nowadays, although *P. listeri* and *P. viridis* are accepted as different species, it is impossible to disentangle to which species old reports are referring to. It seems difficult to consider it to be introduced if it is abundant and widely distributed in non-artificial habitats.

The golden star tunicate *Botryllus schlosseri* (Pallas, 1766) is distributed worldwide and has a marked polymorphism in chromatic patterns and colony shapes. As in other widely distributed and polymorphic species, it has been recently shown that the taxon *B. schlosseri* is a complex of five genetically differentiated species ([Lopez-Legentil et al., 2006](#); [Bock et al., 2012](#)), and all of them present in the Mediterranean. The most widespread of them is the so-called Clade A, which in turn is subject to ongoing speciation processes ([Griggio et al., 2014](#)). It is impossible, in retrospect, to assign previous reports of the species complex to any of its true genetic species. In addition, it is not clear which is the native area of the invasive Clade A ([Lejeune et al., 2011](#); [Nydham et al., 2017](#); [Reem et al., 2017](#)). It is therefore advisable to leave the status of *B. schlosseri* in the Mediterranean as cryptogenic, for the time being.

The bryozoan *Bugula neritina* (Linnaeus, 1758) has belonged to the Mediterranean fauna for a very long time. Recent molecular data ([Fehlauer-Ale et al., 2014](#)) have shown that *B. neritina* is a complex of three cryptic species, but unfortunately Mediterranean populations were not considered in that study ([Harmelin et al., 2016](#)).

The bryozoan *Scorpidinipora costulata* (Canu and Bassler, 1929). Considering the broad allopatric distribution of this morphotype across the oceans and the low capacity of dispersal of species with short-lived larvae, it is likely that this material includes several sibling species.

The bryozoan *Microporella harmeri* Hayward, 1988. It is reported from the coast of Lebanon ([Harmelin et al., 2009](#); [Harmelin et al., 2016](#)) and Israel ([Sokolover et al., 2016](#)). The species is distributed from the Atlantic to the Red Sea and the Indian Ocean, with populations from the different areas showing a series of slightly different “morphs” for several characters. Therefore, although it is listed in [Zenetos et al. \(2012\)](#) and appears to be established, it is very difficult to say with certainty whether it belongs to a complex of cryptogenic species.

Abudefduf saxatilis (Linnaeus, 1758) is an Atlantic fish that is established in the Mediterranean Sea, but the pathway of its introduction remains debatable. The first record of this species in the Mediterranean is from the Gulf of Naples ([Tardent, 1959](#)) and the second record (as *A. vaigiensis*) is from the Levantine basin ([Goren and Galil, 1998](#)). These facts indicate that the species has increased its range from West to East, after penetration via Gibraltar. Yet, the situation concerning *Abudefduf* spp. in the Mediterranean is complicated. Both *A. saxatilis* and *A. vaigiensis* have

often been found in places with shipping activities (see for example Malta and Genoa) or aquarium releases are likely (see Palamos in Spain, where further aquarium releases have been recently detected). Mediterranean findings of these species are separated by large distances and no clear geographical pattern can be highlighted. The small size of *Abudedefduf* spp. would also fit with the idea of direct human transportation (E. Azzuro, pers. Comm.). However, as natural range expansion cannot be excluded, we have not included *A. saxatilis* in our list.

Kyphosus spp.: two, perhaps three, *Kyphosus* species- *K. bigibbus* Lacepède, 1801, *K. sectatrix* (Linnaeus, 1758) and *K. vaigiensis* (Quoy and Gaimard, 1825) have been occasionally recorded in the Mediterranean. These species occur both in the Atlantic and Indo-Pacific regions, but it is likely that they entered the Mediterranean through the Strait of Gibraltar. However, it is unclear whether they have established reproductive native populations in the Mediterranean (Mannino et al., 2015).

3.2. TAXONOMIC/NOMENCLATURE issues

Nomenclatural discrepancies were noted in 26 cases (Table 1).

Following a major revision of *Bivalvia* (Huber, 2015), Mollusca is the taxonomic group with the most nomenclatural changes. For example, two *Timoclea* species are known as Mediterranean immigrants: *Timoclea djiboutiensis* (F. P. Joussemaume, 1894), so far only known from Tunisia, and *Timoclea roemeriana* (Issel, 1869) only known from the Eastern Mediterranean, but not *Timoclea marica* (Linnaeus, 1758) that does not even occur in the Red Sea (Huber, 2015).

The following species are alien species but have doubtful taxonomic entities: *Amphioctopus cf. aegina* (Gray, 1849), *Acanthopleura* sp.; *Botrytella “cf. parva”*, *C. brunnea* (Hincks, 1884) found in Turkey (as reported in Galil et al., 2016) is probably *Celleporaria* sp.

aff. *brunnea* and was found in Lebanon (Harmelin, 2014).

Based on additional morphological and a phylogenetic data, *Pelagia benovici* Piraino, Aglieri, Scorrano & Boero, 2014, a jellyfish recently described from the Northern Adriatic, has been assigned to the genus *Mawia* [renamed as *Mawia benovici* (Piraino, Aglieri, Scorrano and Boero, 2014) (Avian et al., 2016)].

3.3. Changes in establishment success

The terminology “Common, Local, Abundant, Rare” that is used to describe the establishment success may be misleading. Some species, which are reported as local, are in fact well established and widespread in the Mediterranean, or they may be local, yet abundant. Often, introduced ascidians have been reported from a few places, but in these places they can be tremendously abundant. In our list, we consider the establishment success not only in the country where they were first detected, but throughout the Mediterranean. Several examples of noted discrepancies are discussed here. Among macrophytes, *Lithophyllum yessoense* Foslie is well established and common in the Thau Lagoon and *Sargassum muticum* (Yendo) Fensholt can be classified as common/abundant (invasive) in several Mediterranean lagoons (MV, pers. observ.). *Scytosiphon dotyi* M.J.Wynne is established in Italy (Northern Adriatic); France, Spain and Turkey (Verlaque et al., 2015). *Codium fragile* subsp. *fragile* (Suringar) Hariot is established and abundant (locally invasive) in the Mediterranean (Verlaque et al., 2015).

The bivalve *Septifer cumingii* Recluz, 1849, the bryozoan *Arbopercula tenella* (Hincks, 1880), and the echinoderm *Amphiodia* (*Amphispina*) *obtecta* Mortensen, 1940 should be all listed as common.

Among polychaetes, *Pseudonereis anomala* Gravier, 1900 is an invasive AS, widely distributed in the Mediterranean Sea, from all Levant countries to Izmir and Sicily (Çinar and Ergen, 2005;

Table 1
Species whose nomenclature has been recently revised.

Taxon	Species in Galil et al., 2016	Valid name	Source/comment
Ochrophyta/ Phaeophyceae	<i>Botrytella parva</i> (Takamatsu) H.S.Kim	<i>Botrytella “cf. parva”</i>	It is likely to be <i>B. parva</i> but the identification requires a genetic confirmation
Mollusca	<i>Crassostrea gigas</i> (Thunberg, 1793)	<i>Magallana gigas</i> (Thunberg, 1793)	WoRMS
Mollusca	<i>Paphia textile</i> (Gmelin, 1791)	<i>Paratapes textilis</i> (Gmelin, 1791)	Huber, 2015
Mollusca	<i>Gafrarium pectinatum</i> (Linnaeus, 1758)	<i>Gafrarium savignyi</i> (Jonas, 1846)	Huber, 2010
Mollusca	<i>Tellina valtonis</i> Hanley, 1844	<i>Nitidotellina unifasciata</i> (G.B. Sowerby II, 1867)	Huber, 2015
Mollusca	<i>Acanthopleura gemmata</i> (Blainville, 1825)	<i>Acanthopleura</i> sp.	Crocetta et al., 2014
Mollusca	<i>Circenita callipyga</i> (Born, 1778)	<i>Circenita varia</i> (Forsskål in Niebuhr 1775)	Huber, 2015
Mollusca	<i>Mytilopsis sallei</i> (Recluz, 1849)	<i>Mytilopsis adamsi</i> J. P. E. Morrison, 1946	Huber, 2015
Mollusca	<i>Timoclea marica</i> (Linnaeus, 1758)	<i>Timoclea roemeriana</i> (Issel, 1869)	Huber, 2015
Mollusca	<i>Elysia grandifolia</i> Kelaart, 1858	<i>Elysia ornata</i> (Swainson, 1840)	Jensen, 2015
Mollusca	<i>Amphioctopus aegina</i> (Gray, 1849)	<i>Amphioctopus cf. aegina</i> (Gray, 1849)	Crocetta et al., 2014
Polychaeta	<i>Pherusa saldanha</i> Day, 1961	<i>Stylarioides grubei</i> Salazar-Vallejo, 2011	Misidentification Zenetos et al., 2012
Crustacea	<i>Macrophthalmus</i> (<i>Macrophthalmus</i>) <i>graeffei</i> A. Milne-Edwards, 1873	<i>Macrophthalmus indicus</i> Davie, 2012	Davie, 2012
Crustacea	<i>Gonioinfradens paucidentatus</i> (A. Milne-Edwards, 1861)	<i>Charybdis</i> (<i>Gonioinfradens</i>) <i>paucidentatus</i> (A. Milne-Edwards, 1861)	WoRMS
Bryozoa	<i>Celleporaria brunnea</i> (Hincks, 1884)	<i>Celleporaria</i> sp. aff. <i>brunnea</i>	Harmelin, 2014
Bryozoa	<i>Electra tenella</i> (Hincks, 1880)	<i>Arbopercula tenella</i> (Hincks, 1880)	Rosso and Di Martino, 2016
Fish	<i>Apogon queketti</i> Gilchrist, 1903	<i>Jaydia queketti</i> (Gilchrist, 1903)	Golani et al., 2016 (CIESM)
Fish	<i>Apogon smithi</i> (Kotthaus, 1970)	<i>Jaydia smithi</i> Kotthaus, 1970	Golani et al., 2016 (CIESM)
Fish	<i>Atherinomorus lacunosus</i> (Forster, 1801)	<i>Atherinomorus forskali</i> (Rüppell, 1838)	Golani et al., 2016 (CIESM)
Fish	<i>Lagocephalus spadiceus</i> (Richardson, 1845)	<i>Lagocephalus guentheri</i> Miranda Ribeiro, 1915	Misidentification: Matsuura et al., 2011
Fish	<i>Pempheris vanicolensis</i> Cuvier, 1831	<i>Pempheris rhomboidea</i> Kossmann and Rüber, 1877	Misidentification: Azzurro et al., 2015
Fish	<i>Oxyurichthys papuensis</i> (Valenciennes, 1837)	<i>Oxyurichthys petersi</i> (Klunzinger, 1871)	Golani et al., 2016 (CIESM)
Fish	<i>Bregmaceros atlanticus</i> Goode and Bean, 1886	<i>Bregmaceros nectabanus</i> Whitley 1941	Misidentification: Harold and Golani, 2016
Cnidaria/ Hydrozoa	<i>Sertularia theocarpa</i> (Jarvis, 1922)	<i>Sertularia tongensis</i> (Stechow, 1919)	WoRMS
Cnidaria/ Scyphozoa	<i>Pelagia benovici</i> Piraino, Aglieri, Scorrano & Boero, 2014	<i>Mawia benovici</i> (Avian, Ramsak, Tirelli, D’Ambra and Malej, 2016)	Avian et al., 2016
Ctenophora	<i>Beroe ovata</i> Bruguère, 1789	<i>Beroe ovata sensu</i> Mayer	WoRMS

D'Alessandro et al., 2016). It forms dense populations (up to 2500 ind.m⁻²) in shallow-water benthic habitats along the Levantine coasts and presumably is in competition with the native nereidid species, such as *Perinereis cultrifera* (Grube, 1840) and *Platynereis dumerilii* (Audouin and Milne Edwards, 1834) (Çinar and Altun, 2007). *Branchiomma bairdi* is a common and abundant AS in the Eastern and Western Mediterranean Sea, reaching up to 50 ind.m⁻² in the harbour environment (Arias et al., 2013b) and coastal lakes (Giangrande et al., 2012).

Among ascidians, *Didemnum vexillum* Kott 2002 was first reported in the Venice Lagoon (Tagliapietra et al., 2012) and later in the Ebro Delta (Spain, Ordóñez et al., 2015). In these localities the species was highly abundant and has become a pest on bivalve cultures. It can be considered a species in expansion in the Mediterranean, a worrisome perspective given the harmful effects of this species in other areas (Lambert, 2009, and references therein). *Herdmania momus* (Savigny, 1816) should be also listed as common (Shenkar and Loya, 2008).

Among Cnidaria, *Sertularia marginata* (Kirchenpauer, 1864) seems to be widespread (Egypt, Israel, Lebanon, Syria, Turkey, Greece, and Morocco, see Gonzalez-Duarte et al., 2013).

Among fishes, *Terapon puta* Cuvier, 1829 and *Pomadasystris stridens* (Forsskål, 1775) have become prevalent on the Israeli coast in the last few years (Golani, unpublished data). Moreover, *Decapterus russelli* (Rüppell, 1830), *Pelates quadrilineatus* (Bloch, 1790), *Torquigener flavimaculosus* Hardy and Randall, 1983, *Hippocampus fuscus* Rüppell, 1838 and *Ostorhinchus fasciatus* (White, 1790) are common and widespread in the Levantine basin (see EASIN). *Pterois miles* (Bennett, 1828), not only is non-rare but has become invasive in the Levantine basin (Lebanon, Turkey, Cyprus, and Greece: Crocetta et al., 2015b; Kletou et al., 2016; Dailianis et al., 2016).

To avoid misconception in defining the degree of establishment of a species, it is suggested to use the terminology presented in Blackburn et al. (2011). This hierarchical classification allows expression of the range of establishments from a casual record through to full naturalisation.

3.4. First observation details

3.4.1. Year and country of first record

Most of the disagreements on the first recipient country coincide with disagreement on the year of first sighting. Thus, out of 53 corrections that were spotted in the first recipient country, 48 are also attributed to deviation in the introduction date. Most discrepancies are due to quoting the publication date, and not looking for the exact collection date in the papers (i.e. Moazzo, 1939) or not carefully reading the paper e.g. for Bryozoans in Harmelin et al. (2009). Some discrepancies are due to the fact that they are based on the first publication, while the first collection date was reported later. This applies for instance to the decapod *Actaea savignii* (H. Milne Edwards, 1834) first found in 2006 in Lebanon (Crocetta and Bariche in Crocetta et al., 2015b), but not in 2010 in Israel (Karhan et al., 2013); The macroalgae *Cladophora patentiramea* (Montagne) Kützing was first found in 1991 in Cyprus, *Lomentaria hakodatensis* Yendo in 1978 in France, and *Uronema marinum* Womersley in 1989 in France (Verlaque et al., 2015). Another sound case is that of the invasive macroalga *Caulerpa cylindracea* Sonder. The correct year and country of first observation is 1985 in Tunisia and not 1990 in Libya (Hamza et al., 1995; Sghaier et al., 2016). In addition to such inaccurate accounts, a plethora of missing resources was noted from national lists and databases (e.g. MAMIAS, ELNAIS). For example, many records in ELNAIS (Zenetos et al., 2015) were ignored. As an example the bivalve mollusc *Pseudochama corbierei* (Jonas, 1846) has been included in ELNAIS with its source and introduction date. However, the introduction date

was ignored. The following cases are noteworthy for crustaceans:

- ✓ *Amphibalanus reticulatus* (Utinomi, 1967): was first sighted in 2003 in Israel. The French record in 1977 was not in the wild, but relates to specimens found on the keel of a ship that sailed from the Indian Ocean to Toulon Harbour (France) through the Red Sea;
- ✓ *Plagusia squamosa* (Herbst, 1790): was first found in 1968 in Lebanon. The 1873 record of this species in France was from a ship hull.

For Ascidiacea:

- ✓ *Symplesma brakenhielmi* (Michaelsen, 1904): should be 1975 according to the museum samples at TAU, or 1999 according to Izquierdo-Munoz et al. (2009);
- ✓ *Styela plicata* (Lesueur, 1823): Heller 1877 as *Styela gyrosa*. Traustedt 1883 mentions it in the Naples Gulf with the name *Styela plicata* (but, he lists *Styela gyrosa* of Heller as a synonym).

Finally, a few date changes are attributed to direct communication with the authors. Among them. *Monotygmfulva* (A. Adams, 1853) was corrected according to pers. comm by J.J. Van Aartsen; *Septifer cumingii* Recluz, 1849, according to pers. comm. by S. Albayrak.

The list published by Galil et al. (2016) includes 124 mistakes out of 614 records (20%) in first country and/or collection date, 9 of which refer to non-established (NE) species (Table 2). Details per taxonomic group are in Table 2. Most discrepancies were noticed in Mollusca (36 established, 3 non established) and Macroalgae (27 established, 2 non established), followed by Crustacea (13 established, 1 non established); Fish (12 established, 2 non established), and Polychaeta (13), Ascidiacea (4 established, 1 non established), Bryozoa (3), other invertebrates (7). Consequently, it is inevitable to question the accuracy of data that the authors claim and the conclusions derived from those data.

3.4.2. Trends in introduction

The trend in new AS is used as a proxy of the trends of the invasive AS (IAS) in marine environments. Any increasing trend in the presence and abundance of AS in a given ecosystem, independently of their real impact, should be qualified as negative, whereas negative trends or stable situations, even if the environmental status cannot be defined as positive could be considered, at least, as acceptable. Any definition of Good Environmental Status (GES) in reference to descriptor 2 should be linked to the achievement of the GES in the biodiversity descriptors, in such a way that the environmental status in relation to AS would be defined as negative, if it is also negative for these other descriptors, and vice-versa (EEA, 2015). In our study, trend in new AS introductions was calculated on a decadal basis. We considered the decades of first introductions because the first observations have been mostly accidental. Recording a new AS requires either targeted research or the collaboration of an observer with a taxonomist. Consequently, the first sighting of an AS in a region (date and place) has often nothing to do with the true date and the place of its first introduction. Therefore, the exact date of the first observation is of low interest in setting the post-introduction dynamics, because the decade is usually sufficient.

By 1950, it is estimated that 145 AS had been introduced into the Mediterranean, 127 of which are established today. Fig. 1 demonstrates an increase in the rate of introductions after 1950 (sum of established and non-established species), which climbed to 17 species per year in the 2001e2010 period and decreased after 2010. This latter could be partly attributed to a time lapse between the

Table 2

Discrepancies in first collection/observation date and country. The revised data are in bold. The non-established species are in gray-colour shading.

Macroalgae	Acrothamnion preissii (Sonder) E.M.Wollaston	1966e69	Italy
macroalgae	Asparagopsis taxiformis [lineage 2] (Delile) Trevisan de Saint-Leon	1993	Spain
macroalgae	Bonnemaisonia hamifera Hariot	1909	Tunisia
macroalgae	Caulerpa cylindracea Sonder	1985	Tunisia
macroalgae	Chondria curvilineata F.S.Collins & Hervey	1980	Greece
macroalgae	Cladophora patentiramea (Montagne) Kützing	1991	Cyprus
macroalgae	Codium fragile subsp. fragile (Suringar) Hariot	1946	France
macroalgae	Codium taylorii P.C.Silva	1955	Israel
macroalgae	Colaconema codicola (Børgesen) H.Stegenga, J.J.Bolton & R.J.Anderson	1952	France
macroalgae	Derbesia rhizophora Yamada	1984	France
macroalgae	Derbesia boergesenii (Iyengar & Ramanathan) Mayhoub	1972	Syria
macroalgae	Fucus spiralis Linnaeus	1987	France
macroalgae	Galaxaura rugosa (J.Ellis & Solander) J.V.Lamouroux	1990	Syria
macroalgae	Hypnea anastomosans Papenfuss, Lipkin & P.C.Silva	1972	Israel
macroalgae	Hypnea cornuta (Kützing) J.Agardh	1894	Greece
macroalgae	Hypnea valentiae (Turner) Montagne	1996	France
macroalgae	Laurencia okamurae Yamada	1984	France
macroalgae	Leathesia marina (Lyngbye) Decaisne	1905	France
macroalgae	Lomentaria hakodatensis Yendo	1978	France
macroalgae	Plocamium secundatum (Kützing) Kützing	1976	Spain
macroalgae	Polysiphonia morrowii Harvey	1997	France
macroalgae	Pterosiphonia tanakae S.Uwai & M.Masuda	1993	France
macroalgae	Sarconema filiforme (Sonder) Kylin	1944	Israel
macroalgae	Sarconema scinaoides Børgesen	1945	Israel
macroalgae	Scytosiphon dotyi M.J.Wynne	1960e77	Italy
macroalgae	Spatoglossum variabile Figari & De Notaris	1944	Egypt
macroalgae	Sphaerotrichia firma (E.S.Gepp) A.D.Zinova	1970	Turkey
macroalgae	Ulva ohnoi M.Hiraoka & S.Shimada	2011	Italy
macroalgae	Uronema marinum Womersley	1989	France
Mollusca	Acteocina mucronata (Philippi, 1849)	1986	Turkey/Lebanon
Mollusca	Amathina tricarinata (Linnaeus, 1767)	2000	Turkey/Lebanon
Mollusca	Anadara kagoshimensis (Tokunaga, 1906)	1965e69	Italy
Mollusca	Arcuatula perfragilis (Dunker, 1857)	1934	Egypt
Mollusca	Bursatella leachii Blainville, 1817	1940	Israel
Mollusca	Cerithidium perparvulum (Watson, 1886)	1992	Turkey/Cyprus
Mollusca	Chama asperella Lamarck, 1819	1993	Turkey
Mollusca	Conus fumigatus Hwass in Bruguière, 1792	1974e76	Libya
Mollusca	Magallana gigas (Thunberg, 1793)	1905	Italy
Mollusca	Cycloscalaphalina (G. B. Sowerby II, 1844)	1992	Cyprus
Mollusca	Diodora ruppellii (G. B. Sowerby I, 1835)	1939	Israel
Mollusca	Favorinus ghanensis Edmunds, 1968	2003	Tunisia
Mollusca	Finella pupoides A. Adams, 1860	1958	Israel/Turkey
Mollusca	Fulvia australis (G. B. Sowerby II, 1834)	1937	Israel
Mollusca	Fulvia fragilis (Forsskal in Niebuhr, 1775)	1934	Egypt
Mollusca	Godiva quadricolor (Barnard, 1927)	1985e86	Italy
Mollusca	Goniobranchus annulatus (Eliot, 1904)	2000	Lebanon
Mollusca	Mactra olorina Philippi, 1846	1883	Egypt
Mollusca	Marginella glabella (Linnaeus, 1758)	2009	Spain
Mollusca	Modiolus auriculatus (Krauss, 1848)	1934	Israel
Mollusca	Monotygia fulva (A. Adams, 1853)	2000	Turkey
Mollusca	Mya arenaria Linnaeus, 1758	1984	Greece
Mollusca	Notocochlis gualteriana (Recluz, 1844)	1961	Israel
Mollusca	Oscilla galilae Bogi, Karhan and Yokes, 2012	1992e95	Turkey
Mollusca	Mytilopsis adamsi J. P. E. Morrison, 1946	2002	Egypt
Mollusca	Paratapes textile (J. F. Gmelin 1791)	1948	Israel
Mollusca	Petricola fabagella Lamarck, 1818	1905	Egypt
Mollusca	Petricolaria pholadiformis (Lamarck, 1818)	1985	Greece
Mollusca	Pseudochama corbieri (Jonas, 1846)	1938	Greece
Mollusca	Pseudominolia nedyma (Melville, 1897)	1959	Israel
Mollusca	Pseudorhaphitoma iodolabiata (Hornung and Mermod, 1929)	2010	Israel/Turkey
Mollusca	Sabia conica (Schumacher, 1817)	1954	Israel
Mollusca	Septifer cumingii Recluz, 1849	1999	Turkey
Mollusca	Siphonaria crenata Blainville, 1827	1934	Egypt
Mollusca	Spondylus spinosus Schreibers, 1793	1987e88	Israel
Mollusca	Syphonota geographica (A. Adams and Reeve, 1850)	1999	Italy
Mollusca	Syrnola lendix (A. Adams, 1863)	1988e89	Turkey
Mollusca	Tremoctopus gracilis (Eyedoux and Souleyet, 1852)	1937	Croatia
Mollusca	Trochus erithreus Brocchi, 1821	1968	Israel
Polychaeta	Ceratonereis mirabilis Kinberg, 1865	1969	Egypt
Polychaeta	Eusyllis kupfferi Langerhans, 1879	1998	Cyprus
Polychaeta	Glycinde bonhourei Gravier, 1904	1937	Israel
Polychaeta	Hesionura serrata (Hartmann-Schröder, 1960)	1978	Spain
Polychaeta	Leodice antennata Savigny in Lamarck, 1818	1975e81	Italy
Polychaeta	Leonnates persicus Wesenberg-Lund, 1949	1968	Egypt
Polychaeta	Linopherus canariensis Langerhans, 1881	1965	Lebanon

Table 2 (continued)

Macroalgae	Acrothamnion preissii (Sonder) E.M.Wollaston	1966e69	Italy
Polychaeta	Naineris setosa (Verrill, 1900)	2003	Italy
Polychaeta	Notomastus mossambicus (Thomassin, 1970)	1986	Spain
Polychaeta	Polycirrus twisti Potts, 1928	1983	Greece
Polychaeta	Streblosoma comatus (Grube, 1859)	1975e76	Italy
Polychaeta	Streblospio gynobranchiata Rice and Levin, 1998	2002	Turkey
Polychaeta	Terebella ehrenbergi Gravier, 1906	1952	France
Crustacea	Actaea savignii (H. Milne Edwards, 1834)	2006	Lebanon
Crustacea	Amphibalanus reticulatus (Utinomi, 1967)	2003	Israel
Crustacea	Anilocra pilchardi Bariche and Trilles, 2006	2003	Lebanon
Crustacea	Bemlos leptocheirus (Walker, 1909)	1924	Egypt
Crustacea	Calanopia elliptica (Dana, 1849)	1891	Italy
Crustacea	Calanopia media Gurney, 1927	1924	Egypt
Crustacea	Callinectes sapidus Rathbun, 1896	1947	Greece
Crustacea	Cristapseudes omercooperi (Larwood, 1954)	1947	Palestine
Crustacea	Hyastenus hilgendorffi de Man, 1887	1938	Egypt
Crustacea	Lernanthropus callionymicola El-Rashidy and Boxshall, 2012	1997	Israel
Crustacea	Mycicola ostreae Hoshina and Sugiura, 1953	1972	France
Crustacea	Mytilicola orientalis Mori, 1935	1977	France
Crustacea	Plagusia squamosa (Herbst, 1790)	1968	Lebanon
Crustacea	Pseudodiaptomus marinus Sato, 1913	2007	Italy
Ascidacea	Botrylloides violaceus Oka, 1927	1991	Italy
Ascidacea	Ecteinascidia styeloides (Traustedt, 1882)	1983	France
Ascidacea	Perophora multiclathrata (Sluiter, 1904)	1983	France
Ascidacea	Styela plicata (Lesueur, 1823)	1877	Italy
Ascidacea	Symplegma brakenhielmi (Michaelsen, 1904)	1975	Israel
Bryozoa	Parasmittina egyptiaca (Waters, 1909)	1993	Lebanon
Bryozoa	Parasmittina protecta (Thornely, 1905)	2000	Lebanon
Bryozoa	Parasmittina serruloides Harmelin et al., 2009	1995	Lebanon
Echinodermata	Amphioplus (Lymanella) laevis (Lyman, 1874)	1944	Egypt
Nematoda	Anguillicoloides crassus (Kuwahara, Niimi & Itagaki, 1974)	1980	France
Cnidaria	Campanularia morgansi Millard, 1957	2009	Israel
Cnidaria	Clytia linearis (Thorneley, 1900)	1926	Egypt
Cnidaria	Diadumene lineata (Verrill, 1869)	1925	Italy
Cnidaria	Eudendrium carneum Clarke, 1882	1950	France
Porifera	Paraleucilla magna Klautau, Monteiro & Borojevic, 2004	2000	Spain
Fish	Chanos chanos (Forsskål, 1775)	2011	Turkey
Fish	Equulites klunzingeri (Steindachner, 1898)	1924	Egypt
Fish	Hyporhamphus affinis (Günther, 1866)	1954	Turkey
Fish	Hippocampus fuscus Rüppell, 1838	1994	Israel
Fish	Lagocephalus suezensis Clark and Gohar, 1953	1975	Lebanon
Fish	Liza carinata (Valenciennes, 1836)	1924	Egypt
Fish	Liza haematocheila (Temminck and Schlegel, 1845)	1995	Greece/Turkey
Fish	Platycephalus indicus (Linnaeus, 1758)	1902	Egypt
Fish	Sargocentron rubrum (Forsskål, 1775)	1945	Israel
Fish	Saurida lessepsianus Russell et al., 2015	1951	Turkey
Fish	Sciaenops ocellatus (Linnaeus, 1766)	1999	Israel
Fish	Siganus luridus (Rüppell, 1829)	1931	Syria
Fish	Sillago suezensis Golani et al., 2014	1975	Lebanon

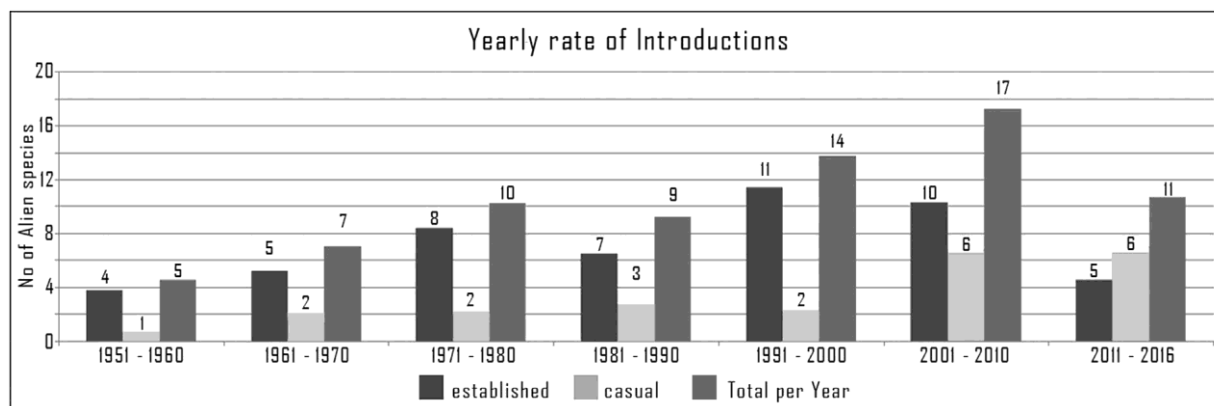


Fig. 1. Number of new AS per year at 10-yr intervals.

observation of the latest finding and publication. At subregional level, in 2015 it was estimated that the rate of new introductions of

AS during the period 2001e2010 was highest in the Aegean-Levantine Sea (~17 species per year), followed by the Ionian Sea

and the Central Mediterranean Sea (~8 species per year), and the Western Mediterranean Sea (with ~7 species per year) (EEA, 2015). The same conclusion has been reached in a series of works by Zenetos et al. (2005, 2008, 2010, 2012), each revising and updating the previous data, respectively.

When only the established species are considered, the peak of ~11 species per year accounts for the 1991-2000 period and falls to ~5 species per year after 2010. On the contrary, after 2000 the number of casual records appears to be steady (6 species per yr). It is expected that a number of the newly discovered species in the 2001-2010 period will establish viable populations, leading to an increase of the established AS. However, a negative trend is obvious after 2010. A similar trend was illustrated, but not discussed, by Galil et al. (2016).

Is this negative trend in the established species a positive sign for the biodiversity of the Mediterranean? It could be. On the other hand, the increase in the previous decades could be the result of intensive scientific effort developed following the invasion of the much mediatized "killer alga" *Caulerpa taxifolia* (Vahl) C. Agardh in the 1990s.

3.4.2.1. Uncertainties. The uncertainties behind datasets on AS reflect the challenge of adequately discovering and reporting new species and mapping their distribution, but also of compiling data at a national/regional level.

Lists of invasive AS (IAS) are essential for preventing, controlling, and reporting on the state of biological invasions. However, these lists suffer from a range of errors, with serious consequences for their use in science, policy, and management (McGeoch et al., 2012). No checklist can be accurate by the time it is published. New data come to light and there are continuous changes on species nomenclature, likely date and pathway of introduction, origin, establishment success, and distribution of species. Consequently, every list could be called a 'provisional list'.

The list for Mediterranean AS is still an underestimate, for a number of reasons:

a) The present list does not include unicellular organisms. The diversity of marine microalgae is scarcely known in wide areas of the Mediterranean Sea. This makes it difficult to determine whether a suspected microalgal invader was already present as part

of the rare, hidden and un-sampled phytoplankton. Therefore, phytoplankton has not been included in the analysis of the indicator;

b) Miscategorising AS species as native is not rare. The Suez Canal is relatively recent, but entries by vessels through Gibraltar have been occurring long before marine biologists started inventorying AS. Many pseudoindigenous species (Carlton, 2009) occur in the Mediterranean, precisely because many old taxonomic works originated in the Mediterranean, and what was there at the time of these initial inventories was assumed to be native, even if many species were described from ports and areas that were typical of introductions;

c) There are many records of new sightings that refer to species which are presently reported as cryptogenic. Phylogenetic studies have revealed that some of them are true aliens. Examples are reported in the section for 'Additional species'. Further studies will shed some light on the rest;

d) The alien status is still pending for many species that are presently categorised as 'questionable' (see Zenetos et al., 2010).

Inventories of the regional Online information systems (e.g. EASIN, MAMIAS) are difficult to keep up-to-date. Comparison of the present work with previous work (Zenetos et al., 2012) revealed an increase of approximately 28% in established AS during the previous 5 years (>600 species vs. approximately 500 established species that were reported in Zenetos et al. (2012)).

With regards to the latest published list (Zenetos et al., 2010, 2012; Galil et al., 2016), the difference in the number of established AS per taxonomic groups is demonstrated in Fig. 2. The phyla with the highest increase since 2012 are the Bryozoa (108% increase), followed by Ascidiacea (100%) and Polychaeta (41%). In the groups treated in the CIESM atlases (Galil et al., 2002; Golani et al., 2016; Verlaque et al., 2015; Zenetos et al., 2004) there seems to be a steady increase of approximately 20%. Considering updates of the Galil et al. (2016) per taxonomic group, in decreasing order, they are major in Ascidiacea (58% of taxa), Polychaeta (57%), Macroalgae (49%), Mollusca (45%), Bryozoa (36%), Crustacea (20%), and these are values that reflect both the taxonomic expertise of the research group and their knowledge of the local biodiversity. It should be noted here that the phylum mollusca might need a further update. Some small sized gastropods species such as *Voorwindia tiberiana*

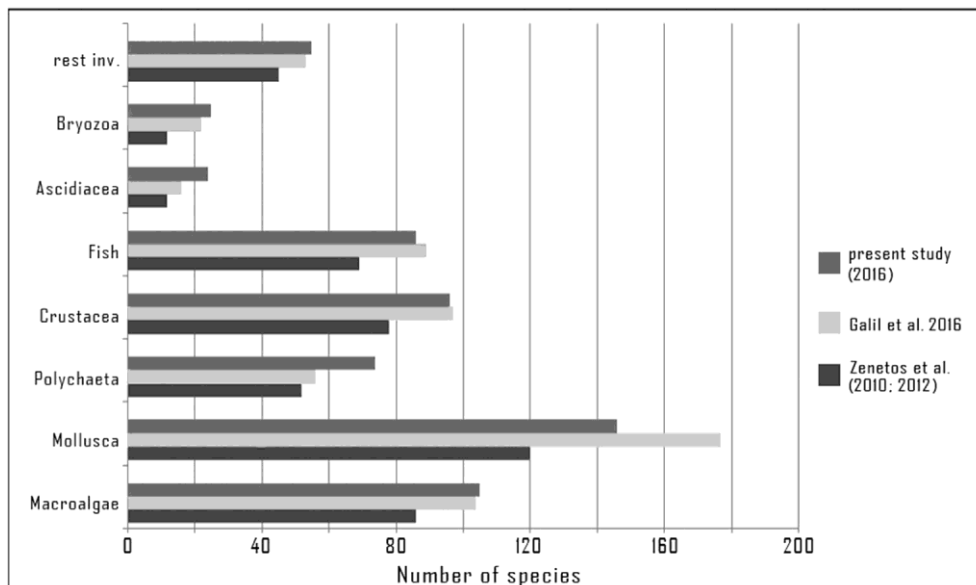


Fig. 2. Comparative number of AS in the recent body of literature.

(Issel, 1869), *Iolaea neofelixoides* (Nomura, 1936) and *Aliculastrum cylindricum* (Helbling, 1779) that noted as rare or unknown in Galil et al. (2016), are not discussed here because their true distribution remains unknown. Following Mienis (2004) they are provisionally treated as established. Other taxonomic groups such as Cnidaria also need a further update.

Inconsistencies are also observed in comparing the present list with what is archived in EASIN v.5.7, Latest Update: 15/11/2016. This is inevitable due to changes that came to light after November 2016 and not only, but we are confident that EASIN and INVASIVESNET can play a major role in the future revision/update of the present list, which can currently serve for assessing indicators that are necessary for policy, and management of AS in the Mediterranean.

We fully agree with Galil et al. (2016) that current geographical, taxonomical and impact data gaps can be reduced only by instituting harmonised standards and methodologies for monitoring NIS populations in all countries bordering the Mediterranean Sea. However, their list is another 'provisional list' in which approximately 38% of the species need revision in one of the reported fields (Nomenclature, Year of first record, First recipient country, Population status), while a significant number (>10%) of species are missing. Of the 72 added species, only 12 (4 macroalgae, 1 polychaete, 4 ascidians, 1 bryozoan, 2 cnidarians) were reported for the first time, or confirmed by genetic phylogeographic studies to be introduced, in 2016.

The present list reflects a team effort of regional experts in order to compile the most reliable source of information regarding the current status of invasive species in the Mediterranean. As professionals in this field, all authors of the present paper recognise the fact that even the current list may contain errors due to the dynamic nature of marine invasions, and the addition of new tools enabling accurate taxonomic identifications.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.ecss.2017.03.031>.

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- AquaNIS: Information System on Aquatic Non-Indigenous and Cryptogenic Species (<http://www.corpi.ku.lt/databases/index.php/aquanis>).
- CIESM: CIESM Atlas of Exotic Species in the Mediterranean (<http://www.ciesm.org/online/atlas/index.html>).
- DAISIE: Delivering Alien Invasive Species Inventories for Europe (<http://www.europe-aliens.org>).
- EASIN: European Alien Species Information Network (<https://easin.jrc.ec.europa.eu/>).
- MAMIAS: Marine Mediterranean Invasive Alien Species Database: accessible via EASIN.
- NoBANIS: The European Network on Invasive Alien Species (<https://www.nobanis.org>).