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Updated review of marine alien species and other 'newcomers' recorded from the Maltese Islands (Central Mediterranean)

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Abstract

An updated review of marine alien species and other 'newcomers' recorded from the Maltese Islands is presented on account of new records and amendments to a previous review in 2007. Species were classified according to their establishment status ('Questionable', 'Casual', 'Established', 'Invasive') and origin ('Alien', 'Range expansion', 'Cryptogenic'). A total of 31 species were added to the inventory, while 6 species have been removed, bringing the total number of species to 73. Of these, 66 are considered to be aliens (or putative aliens but with uncertain origin) with the remaining 7 resulting from range expansion. Six records are considered to be questionable and hence unverified. For verified records, the dominant taxonomic groups are Mollusca (represented by 21 species) and Actinopterygii (15 species), followed by Crustacea (8 species) and Rhodophyta (7 species). Eight of these species (aliens: *Caulerpa cylindracea*, *Lophocladia lallemandi*, *Womersleyella setacea*, *Brachidontes pharaonis*, *Percnon gibbesi*, *Fistularia commersonii*, *Siganus luridus*; range extender: *Sphoeroides pachygaster*) are considered to be invasive. The introduction pathway for 30 species is unknown. Amongst the alien species, 'Shipping' is the most common introduction pathway, followed by 'Secondary dispersal' from elsewhere in the Mediterranean Sea. An increasing trend in the number of alien marine species reported from the Maltese Islands is evident, with a peak of 22 species recorded during the last decade (2001–2010). A discussion on the rationale for including range-expanding species in national inventories of recent arrivals, and in the analysis of trends in records from the Maltese Islands, is included. In particular, the general warming trend of Mediterranean surface waters appears to be facilitating the westward spread of thermophilic alien species from the Eastern to the Central Mediterranean, and the eastward range expansion of tropical and subtropical Eastern Atlantic species.

Keywords: Alien species, invasive species, range expansion, species introduction, biodiversity, Malta.

Introduction

The spread of alien species is widely recognized as a major threat to biodiversity at all levels, with invasive species being regarded as the second biggest cause of marine biodiversity loss, after habitat destruction (Breithaupt, 2003). Alien species can alter the structure and functioning of recipient ecosystems, which has potentially serious ecological implications and can also have negative economic impacts or even affect human health and well-being (e.g. Katsanevakis *et al*., 2014). In Europe, recognition of the threats posed by alien species has resulted in the inclusion of management of such species in a number of recent policy actions, such as the RAC/SPA action plan concerning species introductions and invasive species in the Mediterranean Sea (UNEP-MAP-RAC/SPA, 2005), the MEDPAN marine alien invasive species strategy (IUCN, 2012), the European strategy on invasive alien species (Genovesi & Shine, 2011) developed within the ambit of the Council of Europe's convention on the conservation of European wildlife and natural habitats (Bern Convention), the EU Marine Strategy Framework Directive (EC, 2008, 2010) and the EU 2020 Biodiversity Strategy (EC, 2011). More recently, the European Parliament and Council have also adopted a new regulation (No 1143/2014 of 22 October 2014) *"on the prevention and management of the introduction and spread of invasive alien species*" (EC, 2014).

Implementation of such policies requires information on the spatial distribution, introduction vectors and pathways, and on impacts of individual species. This has led to a multitude of inventories with national coverage (e.g. Katsanevakis *et al*., 2009; Çinar *et al*., 2011; Occhipinti-Ambrogi *et al*., 2011; Zenetos *et al*., 2011), and efforts at producing European-scale databases and information systems (e.g. AquaNIS [http://www.corpi.ku.lt/databases/index.php/aquanis], DAISIE [http://www.europe-aliens.org], EASIN [http://easin.jrc.ec.europa.eu]). The utility of such databases is entirely dependent on the quality of the underlying data. Thus, ensuring the accuracy and veracity of these European databases, and of the national and regional inventories on which they are ultimately based, is essential (Ojaveer *et al*., 2014).

Since the spread of alien species is an ongoing phenomenon, the accuracy of inventories relies on continuous updates and scientific validation of the information they contain. This is particularly relevant for the Mediterranean Sea, where an increasing trend in the rate of introduction of new species has been recorded over the last decades, reaching an unprecedented current rate of 1 new introduction per 10–14 days (Zenetos, 2010; Zenetos *et al*., 2012). In such a situation, national inventories checked and updated by local experts are important in order to guarantee accurate information. This is necessary to serve the needs of national environmental management agencies, given that these databases are used for higher level analyses that may provide new insights on the biology and management of incoming species. Accurate national inventories will also facilitate the scientific scrutiny of regional databases (Occhipinti-Ambrogi *et al*., 2011). For instance, country-based records have been used to ensure reliability and validity of datasets used to assess spatial and temporal patterns of introductions at a European scale (Katsanevakis *et al*., 2013).

The exceptional rate of alien introductions into the Mediterranean may be partly due to a rising trend in sea water temperature (Bianchi, 2007), which renders this sea more receptive to invasion by thermophilic alien species, for instance Indo-Pacific biota entering through the Suez Canal (Raitsos *et al*., 2010). Moreover, most of the alien species that were introduced via intentional or accidental release are of tropical or sub-tropical origin (Galil, 2008). Warming temperatures also enable thermophilic Eastern Atlantic species to extend their distribution range into the Mediterranean (e.g. Bianchi, 2007). Such species undergoing climate-induced shifts in their geographic distributions, but not direct human-assisted spread, are not considered to be alien species *per se* (EC, 2008, 2010). Nonetheless, they still represent new additions to local biotas, so their appearance and spread can contribute to biotic changes in recipient ecosystems, such as the "*tropicalization*" of the Mediterranean Sea (Bianchi, 2007). These species can also have substantial ecological or economic consequences analogous to those of alien species. For instance, the fish *Seriola fasciata* and *Sphoeroides pachygaster* are both Atlantic immigrants which were included in a list of the 100 "*Worst Invasives*" in the Mediterranean (Streftaris & Zenetos, 2006).

The Maltese Islands are an important station for monitoring the entry and spread of marine alien species and of Atlantic immigrants entering the Mediterranean through the Gibraltar Strait (Sciberras & Schembri, 2007), particularly given their location within the Sicilian Channel, which serves as the chief passageway for species to extend their range from west to east or *vice versa*. In addition, the Maltese Islands' position close to the biogeographic boundary between the western and eastern Mediterranean bioregions (Bianchi, 2007) places them at the meeting point of Atlantic-derived species and those originating from the Red Sea or the broader Indo-Pacific, providing an interesting opportunity to study the interactions of species of different biogeographic affinities (Sciberras & Schembri, 2007). This biogeographic boundary is based on the position of the February 15°C surface isotherm (Bianchi, 2007), but this 15°C "*divide*" appears to have shifted northward in recent times (Bianchi *et al*., 2012). The Maltese Islands are ideally placed to monitor at a very early stage the results of such a change.

The most recent comprehensive review of records of alien species from the Maltese Islands and surrounding waters (within the 25 NM Fisheries Management Zone established by the European Union) is that by Sciberras & Schembri (2007), which included a list of 48 species, of which 9 were considered dubious. Since then, a number of new records and changes in the status of previously recorded species have occurred, necessitating a revision of the inventory to keep this current and updated in the light of new knowledge. The aim of the present work is therefore to (a) provide an updated list of marine alien and range-expanding species recorded from the Maltese Islands and surrounding waters, and (b) analyse patterns in these records, such as in taxonomic composition and establishment success, and in the temporal distribution of records.

Methods

Part 1: Updates to the lists of alien and range-expanding species

The basis of the present work is the annotated list of marine alien species compiled by Sciberras & Schembri (2007), which has been updated by: (a) adding all new records of alien or range-expanding species published or in press by December 2014; (b) amending some of the previous records to account for nomenclature updates, changes in establishment success, or revisions to the date of first record from Maltese waters; and (c) reviewing dubious records and correcting misidentifications. Pathogens were not considered for inclusion in the updated inventory. Unless otherwise stated, species nomenclature used in the present work follows that given in the World Register of Marine Species (WoRMS [www.marinespecies.org]). Each record was critically reviewed by the authors and explanatory notes are provided where relevant. Finally, a brief review of the current status of a few species that were not included in the updated list but are nonetheless relevant to the present work is provided.

Species were classified as 'Alien' following the same definition given in Sciberras & Schembri (2007; see below). Although this definition states that the presence of alien species is "*a result of deliberate or accidental introduction by humans*", the 2007 inventory included both species whose arrival was ultimately linked to human action and records of Atlantic species that expanded their distribution range to reach the Central Mediterranean. In the present work, species that are native to the Eastern Atlantic and appear to have reached the Maltese Islands via natural range expansion

have been excluded from the list of alien species, but are instead presented as a separate list. On the other hand, species that extended their range by entering the Mediterranean via the Suez Canal, and species which are considered alien in the Eastern Atlantic and which subsequently dispersed into the Mediterranean through the Strait of Gibraltar, are considered to be alien species (following Pyšek *et al*., 2009).

The mode(s) of introduction as indicated in the scientific literature and the date of the first record of the species from Maltese waters are reported. When a species was found during a prolonged study but the exact date of its first record from the Maltese Islands is not known, then the period of the study is given instead. If no information is available on the date of first record (e.g. because the species was previously misidentified as a similar native one) this is listed as "prior to" the date of publication of its first confirmed occurrence. In the case of mode(s) of introduction, the present review differs from that by Sciberras & Schembri (2007) in focusing exclusively on the vectors responsible for species reaching Maltese waters. Thus, the term 'Lessepsian immigrant' no longer features in the updated inventory. Expert judgement based on the biology of the species and their establishment pattern in the Mediterranean was used to infer plausible mode(s) of entry when these were not reported in the original records. When the scientific literature or expert judgement indicated that two modes of introduction are plausible, both modes were listed in the inventory. In cases where more than two modes of introduction are plausible and no information is available as to which of these modes was actually involved, the mode of introduction is given as 'Unknown'.

The modes of introduction were classified into seven main pathways as follows: 'Aquaculture' (including both target species and those introduced inadvertently); 'Aquarium trade' (releases or escapes); 'Shipping' (including ballast water and fouling); 'Others' (live food/bait, packaging material, floating objects, etc.); 'Secondary dispersal' (natural spread following a human-mediated introduction in a neighbouring region); 'Natural range expansion' (applicable only to Atlantic range-expanding species); and 'Unknown'. These reflect the pathways of introduction of marine aliens in European waters considered by Katsanevakis *et al*. (2013), with two major differences. First, the 'Secondary dispersal' category was not considered by Katsanevakis *et al*. (2013) since these authors focused on the pathways of the first introduction in European waters, but is relevant for alien species that were secondarily dispersed into the Maltese Islands from elsewhere in the Mediterranean. Second, Katsanevakis *et al*. (2013) include the category 'Corridors' (introductions via man-made canals, especially the Suez Canal), which is not directly relevant to the Maltese Islands – species entering the Mediterranean via such corridors would have arrived in the Maltese Islands through a different pathway (e.g. secondary dispersal or shipping).

The establishment status of each species was classified into four categories ('Questionable', 'Casual', 'Established', 'Invasive'; see definitions below). The species' establishment status was reassessed in the light of evolving ideas on the nature and status of new incoming species, and records of species whose establishment success has changed from that reported in 2007 were updated. The terminology used generally follows that given in Sciberras & Schembri (2007) and Zenetos *et al*. (2010). However, these authors defined 'Questionable' to include both species whose presence is dubious or unverified (e.g. new records that have not been verified by experts) and species whose status as aliens is uncertain (e.g. species with unresolved taxonomic status). Here, we differentiate between the two conditions by restricting the term 'Questionable' to refer solely to a species' establishment status. A second classification scheme reflecting the origin of the species ('Indigenous', 'Alien', 'Range expansion', 'Cryptogenic') is used to account for species whose status as native, alien or range-expanding species is uncertain. In addition, Sciberras & Schembri (2007) interpreted the term 'Questionable' in a broad sense, including both doubtful records and verified records of species whose establishment status was difficult to ascertain. In this updated review the term 'Questionable' is reserved for doubtful records only, using the terms 'Casual?' or 'Established?' for verified records with uncertain establishment status.

Therefore, the following terminology has been adopted in the present work:

Origin:

Indigenous: Species which have originated in a given area (the 'native range'; in the present case, the Maltese Islands and surrounding waters) without human involvement; (synonymous terms: native, autochthonous).

Species whose presence in an area is due to a recent range expansion are not considered to be native to that area (the area is outside of the species' historical native range).

Alien: Species or infraspecific taxa, inclusive of parts, gametes or propagules, that may survive and subsequently reproduce and spread outside of their historically known range (geographical area occupied naturally) and beyond their natural dispersal potential (due to minor climatic oscillations) as a result of deliberate or accidental introduction by humans; (synonymous terms: non-native, non-indigenous, allochthonous, foreign, exotic, immigrant, imported, transported, adventive, stages I to V of the scheme proposed by Colautti & MacIsaac (2004)).

Range expansion: Species that have recently arrived in a given area by natural dispersal from a neighbouring area in which they are native, without the intentional or unintentional intervention of humans.

For the purposes of this review, 'recently' means since the onset of the current 'expansion phase' of Atlan-

tic species extending their range into the Mediterranean, which in practice means after around 1960. This is consistent with the criteria used by the Mediterranean Science Commission (CIESM) for inclusion in the 'Atlas of Exotic Species in the Mediterranean', where only those species of Atlantic origin that were recorded after 1960 were considered as newcomers and included in the atlas.

Cryptogenic: Species that are not demonstrably native or introduced (*sensu* Carlton, 1996), and whose origin is therefore uncertain; includes species with unresolved taxonomic status, species whose native geographic distribution is unknown, and species for which uncertainty exists as to whether their introduction was human-mediated or not.

Establishment status:

Questionable: Species for which insufficient information exists and records of which are therefore doubtful; includes newly reported alien or range-expanding species not verified by experts and supposedly alien/range-expanding species which are very similar to native species and which are difficult to identify by non-specialists.

Casual: Species which find their way outside their native range but which do not seem to become established as they do not form self-sustaining populations; this term includes species which have been recorded only once or twice from the study area, or whose persistence in an area depends on repeated introductions; (synonymous terms: not established, stage II of the scheme proposed by Colautti & MacIsaac (2004)).

The term 'Casual?' is used for species which have only been recorded once or twice from the study area, but which are easily overlooked (e.g. because they belong to poorly studied groups, or are very similar to native species and difficult to identify by non-specialists) and may hence be more common than the presently available records suggest.

Established: An organism that is capable of reproducing and maintaining self-perpetuating populations in the wild, without deliberate human intervention, outside its native range; (synonymous terms: naturalized, stages III to V of the scheme proposed by Colautti & MacIsaac (2004)).

The term 'Established?' is used for species that appear to have been established within the study area at some point in time, but for which no recent data to ascertain whether they are still established or not is available. This is often the case with species that are easily overlooked or not easy to identify in the field.

Invasive: An established species whose population has undergone an exponential growth phase and may threaten the diversity or abundance of native species and the ecological stability of the impacted ecosystem and which may also threaten economic activities dependent on these ecosystems, and/or human health.

Part 2: Analysis of patterns

The updated inventory of alien and range-expanding species recorded from Maltese waters was used to analyse patterns in: (a) the taxonomic composition of these species; (b) their establishment status; (c) the pathways of introduction; and (d) the trend in rates of first records. These analyses were based on records of both alien and range-expanding species, but the two groups were analysed separately.

For the purpose of these analyses, the higher taxonomy of each species has been amended to conform to current usage as given in the World Register of Marine Species (WoRMS [www.marinespecies.org]). Establishment status was based on the four main categories identified above, that is, species given as 'Casual?' or 'Established?' were included within the categories 'Casual' and 'Established' respectively. Regarding introduction pathways, in some cases two different modes are plausible for a given species. Such species were therefore included under both categories, especially since pathways are not necessarily mutually exclusive and species introductions may have been facilitated by more than one vector.

All calculations were based on species' records up to December 2014. Doubtful records (i.e. species whose establishment status is 'Questionable') were only included in the analysis of establishment status and excluded from all other analyses.

Results

Part 1: Updates to the lists of alien and range-expanding species

(a) Records of alien species

Records of alien species from the Maltese area, updated until December 2014, are listed in Table 1.

(b) Species excluded from the list of alien species

Six of the species included in the inventory by Sciberras & Schembri (2007) were omitted from the updated list. Two of these records (*Asparagopsis armata* and *Siganus rivulatus*) were due to misidentifications. *Asparagopsis armata* does not occur in the Maltese Islands, the original record being actually of *A. taxiformis* (see Table 1, Note [4]). In the case of *Siganus rivulatus*, Schembri *et al*. (2012) have reviewed all substantiated records of siganids and found that all refer to *S. luridus*, indicating that *S. rivulatus* actually does not occur in Maltese waters. A third species, *Prionocidaris baculosa*, was originally included on the basis of a single individual collected in 1976 from the ballast tank of a ship that had entered the Malta dockyards (Schembri, 1978), but no other specimens of this species have been recorded from Maltese waters (Tanti & Schembri, 2006). Since this species has never been found in the wild, we are excluding it from the list of alien species.

Table 1. Marine alien species recorded from Maltese waters up to December 2014; new records are marked with an *, bold indicates changes to records previously included in the Sciberras & Schembri (2007) inventory.

Species	Natural range	First Maltese record	Mode of introduction into Maltese waters	Status	Origin	Cited by	Note
Chromista: Ocrophyta							
Colpomenia peregrina Sauvageau, 1927	Pacific Ocean	1997	Unknown	Casual	Alien	E. Lanfranco (*pers. comm.*)	
Padina cf. *boergesenii* Allender & Kraft, 1983	Pacific Ocean	1994	Unknown	Questionable	Alien	E. Lanfranco (*pers. comm.*)	
Chromista: Foraminifera							
* *Amphistegina lobifera* Larsen, 1976	Indo-Pacific and Atlantic Ocean	2006	Unknown	Established	Alien	Yokes *et al*., 2007	[1]
Plantae: Rhodophyta							
Acanthophora nayadiformis (Delile) Papenfuss, 1968	Red Sea and Indian Ocean	1969	**Unknown**	Established	Cryptogenic (may be native)	Lanfranco, 1989	[2]
* *Acrothamnion preissii* (Sonder) E.M.Wollaston, 1968	Indo-Pacific	2014	Unknown	Established	Alien	Evans *et al*. (2015)	[3]
* *Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon, 1845	Unknown (depends on lineage)	1993	Unknown (depends on lineage)	Established	Cryptogenic (depends on lineage)	Cormaci *et al*., 1997 as *A. armata*	[4]
Botryocladia madagascariensis G. Feldmann, 1945	Indo-Atlantic tropical	1994	**Unknown**	**Established?**	Alien	Cormaci *et al*., 1997	[2,5]
Chondria pygmaea Garbary & Vandermeulen, 1990	Indo-Pacific	1994	Unknown	**Established?**	Alien	Cormaci *et al*., 1997	[5]
Lophocladia lallemandii (Montagne) F. Schmitz, 1893	Indo-Pacific	Prior to 1994	**Unknown**	Invasive	Alien	Cormaci *et al*., 1997	[2]
Womersleyella setacea (Hollenberg) R.E. Norris, 1992	Circumtropical	1994	**Unknown**	Invasive	Alien	Cormaci *et al*., 1997	[2]
Plantae: Chlorophyta							
***Caulerpa cylindracea* Sonder, 1845**	Indian Ocean	1997	**Unknown**	Invasive	Alien	Borg *et al*., 1997	[2,6]
* *Caulerpa taxifolia* var *distichophylla* (Sonder) Verlaque, Huisman & Procacini, 2013	Western Australia	2014	Shipping	Established	Alien	Schembri *et al*. (2015)	[7]
Plantae: Tracheophyta							
Halophila stipulacea (Forsskål) Ascherson, 1867	Red Sea and Indian Ocean	1970	**Secondary dispersal / Shipping**	Established	Alien	Lanfranco, 1970, 1989	[2]
Animalia: Porifera							
* *Paraleucilla magna* Klautau, Monteiro & Borojevic, 2004	Brazilian Atlantic Coast	2007	Shipping?	Established	Alien	Zammit *et al*., 2009	[8]
Animalia: Cnidaria							
* *Cassiopea andromeda* (Forsskål, 1775)	Indo-Pacific and Red Sea	2009	Shipping?	Established?	Alien	Schembri *et al*., 2010a	[9]
* *Rhopilema nomadica* (Galil, 1990)	East Africa and Red Sea	2004	Secondary dispersal	Casual	Alien	Deidun *et al*., 2011a	[10]
Animalia: Sipuncula							
Aspidosiphon (Akrikos) mexicanus (Murina, 1967)	West Atlantic Ocean	Prior to 1999	Unknown	**Established**	Alien	Pancucci-Papadopoulou *et al*., 1999; **Mifsud & Saiz Salinas, 2012**	[11]
Animalia: Polychaeta							
* *Branchiomma bairdi* (McIntosh, 1885)	Caribbean Sea	2011?	Unknown	Established	Alien	Arias *et al*., 2013a	[12]
Branchiomma boholense (Grube, 1878)	Indo-West Pacific	1929	Unknown	**Questionable**	Alien	**Knight-Jones *et al*., 1991**	[12]
* *Eurythoe laevisetis* Fauvel, 1914	Atlantic Ocean	2011	Unknown	Casual?	Alien	Arias *et al*., 2013b	[13]

(continued)

Table 1 *(continued)*

Species	Natural range	First Maltese record	Mode of introduction into Maltese waters	Status	Origin	Cited by	Note
Animalia: Mollusca							
***Anteaeolidiella lurana* (Marcus & Marcus, 1967)**	**Atlantic Ocean**	**1992-1993**	Unknown	Established?	Alien	Sammut & Perrone, 1998	[14]
* *Aplysia dactylomela* Rang, 1828	Atlantic	2008	Unknown	Established	Cryptogenic (may be range expansion)	Schembri, 2008	[15]
Aplysia parvula Guilding in Mörch, 1863	Circumtropical	1967	**Secondary dispersal?**	**Casual?**	Cryptogenic (may be native)	Bebbington, 1970	[2,16]
Atactodea striata (Gmelin, 1791) (=*glabrata*)	Indo-Pacific and Red Sea	1977	**Unknown**	Casual	Alien	Cachia *et al*., 2004	[2]
* *Atys macandrewi* E.A. Smith, 1872	Atlantic and possibly Mediterranean	1990	Unknown	Established	Cryptogenic (may be native)	Cachia & Mifsud, 2007	[17]
=*Brachidontes pharaonis* (P. Fischer, 1870)	Indian Ocean and Red Sea	1970	Unknown	**Invasive**	Alien	Cachia *et al*., 2004	[18]
Bursatella leachii Blainville, 1817	Circumtropical	1969	**Secondary dispersal?**	Established	Alien	Bebbington, 1970	[2]
Cerithium scabridum Philippi, 1848	Red Sea, Indian Ocean	2005	Secondary dispersal / Shipping	Established	Alien	Mifsud & Sammut, 2006	
Chelidonura fulvipunctata Baba, 1938	Indo-Pacific	1993	**Unknown**	Established	Alien	Perrone & Sammut, 1997	[2]
Crassostrea gigas (Thunberg, 1793)	Western Pacific Ocean	mid-1970s	Aquaculture	Established	Alien	Schembri & Lanfranco, 1996	
Crepidula fornicata (Linnaeus, 1758)	Atlantic coast of North America	1973	Aquaculture / Shipping	Casual	Alien	Cachia, 1981	
* *Fulvia fragilis* (Forsskål in Niehbur, 1775)	Indo-Pacific and Red Sea	2008?	Secondary dispersal / Shipping	Established?	Alien	Goud & Mifsud, 2009	[19]
Gibbula cineraria (Linnaeus, 1758)	East Atlantic from Norway to Gibraltar	1976	Aquaculture	Casual	Alien	Schembri, 1979	
Haminoea cyanomarginata Heller & Thompson, 1983	Indo-Pacific, Sudanese Red Sea	2006	**Secondary dispersal** / Shipping	Established	Alien	Mifsud, 2007	[2]
* *Leucotina eva* Thiele, 1925	Indo-Pacific	2009	Shipping?	Casual?	Alien	Mifsud & Cachia, 2011	[20]
* *Melibe viridis* (Kelaart, 1858)	Tropical Indo-West Pacific (but not Red Sea)	2008	Secondary dispersal?	Established?	Alien	Borg *et al*., 2009	[21]
***Notocochlis gualteriana* (Récluz, 1844)**	Indian Ocean, Red Sea, Tropical Western Pacific	**1978**	Unknown	Casual	Alien	Cachia *et al*., 1996; **Mifsud & Cachia, 2011**	[22]
Pinctada imbricata radiata (Leach, 1814)	Indo-Pacific and Red Sea	1912	Secondary dispersal / Shipping	Established	Alien	Pallary, 1912	
Polycerella emertoni A.E. Verrill, 1880	Tropical Atlantic	**1992-1993**	Unknown	Established?	Alien	Sammut & Perrone, 1998	
* *Stomatella* sp.	Depends on species identity	2011	Unknown	Casual?	Alien	Arias *et al*., 2012, 2013a	[23]
Animalia: Crustacea							
Callinectes sapidus Rathbun,1896	East coast of America	1972	Unknown	**Casual**	Alien	Schembri & Lanfranco, 1984	[24]

(continued)

Table 1 *(continued)*

Species	Natural range	First Maltese record	Mode of introduction into Maltese waters	Status	Origin	Cited by	Note
* *Caprella scaura* Templeton, 1836	Indian ocean	2010	Unknown	Established	Alien	Fernandez-Gonzalez & Sanchez-Jerez, 2014; Ros *et al*., 2014	[25]
* *Cymadusa filosa* Savigny, 1816	Indo-Pacific	2010	Unknown	Casual?	Cryptogenic (may be native)	Fernandez-Gonzalez & Sanchez-Jerez, 2014	[25]
Dosima fascicularis (Ellis & Solander, 1786)	Cosmopolitan?	2004	Unknown	Casual	Cryptogenic (may be range expansion)	Mifsud, 2005	
Megabalanus tintinnabulum tintinnabulum (Linnaeus, 1758)	East Atlantic, south of Gibraltar	1972	Shipping	**Casual**	Alien	Rizzo & Schembri, 1997	[26]
Percnon gibbesi (H. Milne-Edwards, 1853)	Tropical and subtropical regions of the west and east Atlantic Ocean and East Pacific Ocean	2001	Secondary dispersal	Invasive	Alien	Borg & Attard-Montalto, 2002	
Spinocalanus terranovae Damkaer, 1975	Antarctic - Sub-Antarctic	2001	Unknown	**Casual?**	Cryptogenic (may be native)	Lapernat & Razouls, 2001	[16,27]
* *Stenothoe gallensis* Walker, 1904	Circumtropical	2010	Unknown	Casual?	Alien	Fernandez-Gonzalez & Sanchez-Jerez, 2014	[25]
Animalia: Echinodermata							
Eucidaris tribuloides (Lamarck, 1816)	Atlantic Ocean	1998	Shipping	Established	Alien	Tanti & Schembri, 2006	
Animalia: Bryozoa							
Celleporaria aperta (Hincks, 1882)	Indo-Pacific	1975-1976	Aquaculture / Shipping	**Established?**	Alien	Agius *et al*., 1977	[5]
Celleporaria pilaefera (Canu & Bassler, 1929)	Indo-West Pacific	1975-1976	Aquaculture / Shipping	**Established?**	Alien	Agius *et al*., 1977	[5]
Animalia: Ascidiacea							
* *Herdmania momus* (Savignyi, 1816)	Indo-Pacific	2013	Shipping	Established	Alien	Evans *et al*., 2013	[28]
* *Microcosmus squamiger* Michaelsen 1927	Pantropical	2003-2004	Shipping	Established	Alien	Izquierdo-Muñoz *et al*., 2009	[28]
Animalia: Actinopterygii							
* *Abudefduf* cf. *saxatilis* (Linnaeus, 1758)	Atlantic Ocean	2013	Unknown	Established?	Cryptogenic (may be range expansion)	UoM, 2014; Deidun & Castriota, 2014	[29]
Alepes djedaba (Forsskål, 1775)	Indo-Pacific	1961	**Secondary dispersal?**	Established	Alien	Lanfranco, 1993	[2]
* *Epinephelus malabaricus* (Bloch & Schneider, 1801)	Indo-Pacific and Red Sea	2011	Shipping?	Casual	Alien	Schembri & Tonna, 2011	[30]
***Etrumeus golanii* DiBattista, Randall & Bowen, 2012**	Indo-Pacific	?	Secondary dispersal?	Questionable	Alien	Falautano *et al*., 2006	[31]
Fistularia commersonii Rüppell, 1838	Indo-Pacific, Eastern Central Pacific	2005	**Secondary dispersal**	Invasive	Alien	Cini, 2006	[2]
* *Lutjanus fulviflamma* (Forsskål, 1775)	Indo-Pacific	2014?	Unknown	Questionable	Alien	UoM, 2014	[32]

(continued)

Table 1 *(continued)*

Species	Natural range	First Maltese record	Mode of introduction into Maltese waters	Status	Origin	Cited by	Note
* *Oplegnathus fasciatus* (Temminck & Schlegel, 1844)	North West and Eastern Central Pacific	2009	Shipping?	Casual	Alien	Schembri *et al*., 2010b	[30]
* *Scatophagus argus* (Linnaeus, 1766)	Indo- Pacific (but not Red Sea)	2007?	Aquarium trade?	Established?	Alien	Zammit & Schembri, 2011	[33]
* *Selene dorsalis* (Gill, 1863)	Tropical and subtropical East Atlantic	2007	Unknown	Casual	Cryptogenic (may be range expansion)	Vella & Deidun, 2009	[34]
Siganus luridus (Rüppell, 1829)	Indo-Pacific	**Prior to 2002**	**Secondary dispersal**	**Invasive?**	Alien	Azzurro *et al*., 2007; **Schembri *et al*., 2012**	[2,35]
Sphyraena chrysotaenia Klunzinger, 1884	Indo-Pacific	1993	**Secondary dispersal**	Established	Alien	Lanfranco, 1993	[2]
* *Stegastes variabilis* (Castelnau, 1855)	Western Atlantic	2014?	Unknown	Questionable	Alien	UoM, 2014	[32]
Stephanolepis diaspros Fraser-Brunner, 1940	Western Indian Ocean	1993	**Secondary dispersal**	Established	Alien	Lanfranco, 1993	[2]

Notes on Table 1:

[1] Yokes *et al*. (2007) reported finding several individuals of *Amphistegina lobifera* at each of four separate localities. On this basis, it appears that this species is established in Maltese waters.

[2] The mode of introduction of these species was listed as 'Lessepsian immigrant' by Sciberras & Schembri (2007). These have been revised to reflect the actual (or hypothesized) pathway through which they arrived in Maltese waters.

[3] *Acrothamnion preissii* is deemed established due to the high abundance recorded in Cirkewwa (35.9875°N, 14.3270°E) while it has also been reported from a second site in Dwejra (36.0520°N, 14.1875°E); its mode of introduction is unknown since several modes may be involved (Evans *et al*., 2015).

[4] *Asparagopsis taxiformis* was not included in the 2007 inventory because the Maltese specimens had been misidentified as *A. armata* by Cormaci *et al*. (1997). However, *A. armata* is unlikely to occur in Maltese waters as it is a cold-water species; the Maltese species has been confirmed as *A. taxiformis* by Enric Ballesteros (*pers. comm.*). This was a rare species up to a few years ago but has now become more widespread and there are areas where it is becoming dominant. The 1994 record by Cormaci *et al*. (1997) is predated by a specimen collected in 1993 and identified as *Falkenbergia* sp. by Edwin Lanfranco (Borg, 1995); "*Falkenbergia*" represents the tetrasporophyte stage of *Asparagopsis*, so this has to be regarded as the first record of *Asparagopsis* from the Maltese Islands. The natural range and origin of *A. taxiformis* in Malta depend on the lineage present. Molecular studies (Andreakis *et al*., 2007) have indicated that *A. taxiformis* consists of four genetic lineages of which two occur in the Mediterranean: an Atlantic strain (Lineage 3) which may be native to the Mediterranean, and an Indo-Pacific strain (Lineage 2) which is alien in the Mediterranean. Either or both of these lineages may occur in the Maltese Islands, and it is not possible to comment on the origin of local specimens until their genetics are studied.

[5] These species were considered to be 'Questionable' by Sciberras & Schembri (2007) because of doubts as to whether they represented 'Casual' or 'Established' records. In this updated review, use of the term 'Questionable' is restricted to species whose presence in Maltese waters is unverified. Therefore, the establishment status of these species has been updated, using 'Casual?' or 'Established?' as necessary, to indicate uncertainty.

[6] At the time of writing, this species was still listed as *Caulerpa racemosa* var. *cylindracea* in the WoRMS database, but the taxonomy has been updated as per AlgaeBase (www.algaebase.org), which has been revised following Belton *et al*. (2014).

[7] Schembri *et al*. (2015) recorded *Caulerpa taxifolia* var *distichophylla* from two separate locations, with records in both 2013 and 2014 in one of them, while this species has since been observed at a third site (authors' unpublished record), indicating that it is established in Maltese waters.

[8] The substantial cover of *Paraleucilla magna* and its occurrence on several buoys suggests it has established a breeding population (Zammit *et al*., 2009). Although some authors (e.g. Zenetos *et al*., 2010) considered this species to be cryptogenic in the Mediterranean, Longo *et al*. (2012) indicate several reasons why it should be considered as an alien species that was introduced into the Mediterranean via maritime transport, which is also the most likely introduction pathway into Maltese waters (Zammit *et al*., 2009).

[9] Aggregations of up to 50 individuals of *Cassiopea andromeda* were observed on two separate occasions in 2009 (Schembri *et al*., 2010a), suggesting that this species may be established in Maltese waters. However, such aggregations have not been reported since, so it is not clear if breeding populations of *C. andromeda* presently occur; we therefore tentatively assign the status 'Established?' to this species.

[10] The 2004 sightings of *Rhopilema nomadica* were only published in 2011, hence this species was not included in the inventory by Sciberras & Schembri (2007). These sightings were of two single adult individuals only, indicating that *R. nomadica* has not established a reproducing population in local waters (Deidun *et al*., 2011a).

[11] Mifsud & Saiz-Salinas (2012) report finding specimens of *Aspidosiphon mexicanus*, including a juvenile specimen, from four different stations around the Maltese Islands, commenting that "*This species is more frequently present in circalittoral muds*." On the basis of this information, *A. mexicanus* has to be regarded as 'Established' in Maltese waters.

[12] The 1929 record of *B. boholense* from the Maltese Islands is based on four specimens collected by Mrs. B. Grey and housed at the Natural History Museum in London (see Knight-Jones *et al*., 1991). Çinar (2009) stated that Mediterranean records of *B. boholense* may actually refer to *B. bairdi*, after examining specimens from Cyprus that were originally misidentified as *B. boholense* by Çinar (2005). Similarly, Giangrande *et al*. (2012) re-examined the '*B. boholense*'

specimens collected from SE Spain by Román *et al*. (2009), showing that they were actually *B. bairdi*. Subsequently, Arias *et al*. (2013a) collected 30 individuals of *B. bairdi* from two separate locations in the Maltese Islands and suggested that previous records of *B. boholense* from the Central Mediterranean may have been misidentified specimens of *B. bairdi*. However, it appears that the 1929 specimens from Malta identified as *B. boholense* by Knight-Jones *et al*. (1991) have not been re-examined; consequently, there remain doubts as to whether these represent *B. boholense*, or the earliest record of *B. bairdi*. Given this situation, *B. boholense* is included in the present inventory with 'Questionable' status. Some of the *B. bairdi* specimens recorded in 2011 had larvae attached to their body-wall (Arias *et al*., 2013a), indicating that this species has established a breeding population. Should the identity of the '*B. boholense*' specimens collected in 1929 be confirmed as *B. bairdi*, then the date of first record of the latter species would need to be revised.

[13] Arias *et al*. (2013a, b) report collecting 11 individuals of *Eurythoe laevisetis* from two separate locations in the Maltese Islands. The record of *E. laevisetis* was originally reported as a member of the *E.* cf. *complanata* complex (*sensu* Barroso *et al*., 2010) by Arias *et al*. (2013a), and subsequently confirmed to be *E. laevisetis* by Arias *et al*. (2013b). No further information on the status of this species is available so it is considered to be a 'Casual?' record.

[14] Originally reported as *Aeolidiella indica* by Sammut & Perrone (1998), this taxon was subsequently considered to be a junior synonym of *Antaeolidiella foulisi*. Consequently, Mediterranean records originally referred to *A. takanosimensis*, and later assigned to *A. indica*, were again moved to *A. foulisi*. However, Carmona *et al*. (2014) have recently shown that *Antaeolidiella* (= *Aeolidiella*) *indica* s.l. is actually a species complex consisting of five separate species: (i) *A. indica* s.s., (ii) *A. cacaotica* (= *foulisi*), (iii) *A. saldanhensis* (= *multicolor*), (iv) *A. takanosimensis*, and (v) *A. lurana*. The only Mediterranean sample analysed by Carmona *et al*. (2014), a specimen collected from Naples, belonged to *A. lurana*. Carmona *et al*. (2014) state that this species was recorded under the name *A. indica* by Sammut & Perrone (1998), while specimens collected from Malta in 2003 (Sammut, 2011-2014) show the peculiar external morphology and colour pattern of *A. lurana*, indicating that Maltese specimens belong to this species.

[15] *Aplysia dactylomela* was originally considered a pan-global species found in tropical and subtropical regions, which invaded the Mediterranean through the Suez Canal (Crocetta & Galil, 2012). However, Alexander & Valdés (2013) have shown that *A. dactylomela* s.l. actually consists of two sister species: *A. argus* (Rüppell and Leuckart, 1828) in the tropical Indo-Pacific Ocean, and *A. dactylomela* s.s. in the Atlantic Ocean. All Mediterranean specimens belong to the latter species, hence they originated from the Atlantic (Valdés *et al*., 2013). According to Valdés *et al*. (2013), the genetic composition of Mediterranean populations is consistent with a natural dispersal of a large number of individuals through the Gibraltar Strait, but a human-mediated introduction cannot be excluded especially given the absence of records from the Western Mediterranean. In view of this, we tentatively include this species amongst our list of aliens with an 'Unknown' introduction pathway. Since the initial record by Schembri (2008), *A. dactylomela* has been recorded several times from the Maltese Islands (Crocetta & Galil, 2012; authors' unpublished records: Cirkewwa [35.9900°N, 14.3270°E] September 2008, Zurrieq [35.8180°N, 14.4500°E] July 2012, Marsascala [35.8620°N, 14.5800°E] May 2014, Ghar Lapsi [35.8250°N, 14.4250°E] June 2014), and is therefore considered to be 'Established'.

[16] These species were considered to be 'Questionable' by Sciberras & Schembri (2007) because of doubts as to whether they represented alien species or possibly native ones. In this updated review, this is reflected by attributing a 'Cryptogenic' origin to these species; their establishment status has therefore been updated.

[17] The records of *Atys angustatus* from Israel in 1974 and from Turkey in 1986 by van Aarsten & Goud (2006) are considered to refer to *A. macandrewi* by Cachia & Mifsud (2007) and by Delongueville & Scaillet (2010), making them the earliest record of *Atys macandrewi* from the Mediterranean, followed by that from Malta in 1990 by Cachia & Mifsud (2007). This species seems to be widespread in the Mediterranean, having also been recorded from Sicily and Cyprus (Cachia & Mifsud, 2007; Delongueville & Scaillet, 2010). *Atys macandrewi* is considered to be an amphi-Atlantic species, suggesting it has been introduced into the Mediterranean via the Strait of Gibraltar, but there is a possibility that it was present in the Mediterranean but has been overlooked; we therefore consider it to have a 'Cryptogenic' origin. With regards to establishment status, live individuals have been collected from several locations (e.g. off Rdum id-Delli [35.9530°N, 14.3280°E] October 2006, off Gnejna Bay [35.9280°N, 14.3230°E] November 2006, and off Fomm ir-Rih Bay [35.9120°N, 14.3250°E] September 2008; C. Mifsud, *pers. comm.*) indicating that well-established and breeding populations are present.

[18] The status of *Brachidontes pharaonis* is considered to be 'Invasive' following the discovery of a bed of this mussel by Mifsud & Cilia (2009) (see also density estimates given in Bonnici *et al*., 2012) and given its widespread distribution as reported by Cilia & Deidun (2012).

[19] Although the first Maltese record of *Fulvia fragilis* was in 2008, the observation of large specimens led Goud & Mifsud (2009) to suggest this species may have been present in Maltese waters for a while before. Goud & Mifsud (2009) also suggested that the mode of introduction was via shipping, but *F. fragilis* can also spread via secondary dispersal (Zenetos *et al*., 2004); therefore both pathways are included in the present inventory.

[20] *Leucotina eva* was originally recorded on the basis of two fresh empty shells beached at Birzebbugia Bay. No further records have been published to date, but a few more shells of this species have been found at the same locality (C. Mifsud, *pers. comm*.), so we provisionally consider it to be a 'Casual?' species.

[21] Several individuals of *Melibe viridis*, including young specimens, were observed by Borg *et al*. (2009), while two separate sightings of this species were also made from Comino (36.0080°N, 14.3250°E) and Cirkewwa (35.9880°N, 14.3270°E) in 2011 (S. Farrugia-Randon, *pers. comm.*), which indicates that this species was locally established. However, we are not aware of any further records of this species since 2011, and are therefore assigning it the status 'Established?'.

[22] The dates of first records of *Notocochlis gualteriana* and *Polycerella emertoni* have been updated as per details given in Mifsud & Cachia (2011) and Sammut (2011-2014) respectively.

[23] The only known previous record of *Stomatella* sp. from the Mediterranean is that of *S. varia* by Schniebs (2000), but this was considered as a synonym of *S. impertusa* by Zenetos *et al*. (2004) and has been referred to using the latter name in subsequent publications. On the other hand, *S. impertusa* and *S. varia* are currently both accepted as taxonomically valid species (Bouchet, 2014; Gofas, 2014). Although Arias *et al*. (2012) reported *S. impertusa* from the Maltese Islands, the species identity of these specimens is still unresolved and was subsequently listed as *Stomatella* sp. (see Arias *et al*., 2013a). However, since no species belonging to the genus *Stomatella* are native to the Mediterranean, we are provisionally including it in our inventory of alien species as '*Stomatella* sp.'. Arias *et al*. (2013a) reported finding several specimens of this species but it has not been recorded again so we are treating this as a 'Casual?' record.

[24] *Callinectes sapidus* was considered to have established a population in Maltese waters, but we are not aware of any recent records of this species, suggesting its numbers have declined and it is probably no longer established; its status has therefore been updated to 'Casual'.

[25] Fernandez-Gonzalez & Sanchez-Jerez (2014) recorded *Caprella scaura, Cymadusa filosa*, and *Stenothoe gallensis* as part of the fouling community associated with fish farm moorings in 2010. *Caprella scaura* is considered to be established since several individuals, including brooding females, were recorded by Fernandez-Gonzalez & Sanchez-Jerez (2014) while in 2012 Ros *et al*. (2014) discovered another population of this species in a coastal marina. On the other

hand, Fernandez-Gonzalez & Sanchez-Jerez (2014) did not provide any details on the abundance or reproductive state of *C. filosa* or *S. gallensis*, and neither species has been recorded again, so we are provisionally considering these to be 'Casual?' records.

[26] As noted by Sciberras & Schembri (2007), *Megabalanus tintinnabulum tintinnabulum* is a transitional alien that is common on ships entering Maltese dockyards for repairs, but has never been found in the wild. Its status was considered to be 'Questionable' by Sciberras & Schembri (2007) because it was not established, and did not fit into the definition of 'Casual' species (those recorded only once or twice from the study area) used by these authors. Here, we follow Pyšek *et al*. (2009) in considering the status of species which are recorded more than twice in an area due to multiple introductions, but which fail to establish themselves, to be equivalent to that of species recorded only once via a single introduction. Hence *M. tintinnabulum tintinnabulum* is assigned the status 'Casual' in line with the revised definition of this term.

[27] The record of *Spinocalanus terranovae* from a depth of 2000m off the southeast coast of Malta by Lapernat & Razouls (2001) remains the only one from Maltese waters to date. However, mesopelagic copepods and bathyal species in general are both very poorly studied locally, so this species may turn out to be more common and is hence assigned the status 'Casual?'. Razouls *et al*. (2005-2014) comment that "*the presence of this species in the Mediterranean is surprising*" because it is considered to be an Antarctic to Sub-Antarctic species, but we consider its origin to be 'Cryptogenic' because its habitats are so poorly studied that it may well turn out to be a native species that was simply never recorded before. This species has also been reported from Turkish waters by Zenetos *et al*. (2010) and Katsanevakis *et al*. (2012), based on the record of *Ctenocalanus citer* by Uysal *et al*. (2002), which is listed as a synonym of *S. terranovae* by Katsanevakis *et al*. (2012). On the other hand, WoRMS (2014a, b) and Razouls *et al*. (2005-2014) consider both *S. terranovae* and *C. citer* to be taxonomically valid species.

[28] Both *Herdmania momus* and *Microcosmus* squamiger were recorded as fouling organisms, in sufficient numbers to consider their status as 'Established' (Izquierdo-Muñoz *et al*., 2009; Evans *et al*., 2013). The original date of collection of *M. squamiger* is not reported by Izquierdo-Muñoz *et al*. (2009); however, this record is based on samples collected as part of the CIESM 'PORTAL' project that was implemented in Malta during 2003–2004 (Muscat *et al*., 2007).

[29] A species of *Abudefduf* was recorded from Malta in 2014 (UoM, 2014), but no specific identification other than that it could be either *A. saxatilis* or *A. vaigiensis* was provided. Deidun & Castriota (2014) subsequently recorded a species of *Abudefduf* on the basis of photographs of a school of 6–7 individuals taken in October 2013. These authors provide a detailed analysis of the photographs suggesting that the species was most likely *A. saxatilis* originating from the Atlantic, but they report this as "*A.* cfr *saxatilis*" given that the occurrence of the Indo-Pacific *A. vaigiensis* in Maltese waters was considered possible and that distinguishing the two congeners typically requires specimen collection. On the other hand, phylogenetic analysis of Levantine *Abudefduf* sp. has shown that these belong to *A. saxatilis* (Tsadok *et al*., 2015), so it is unlikely that Maltese specimens can be *A. vaigiensis*. The two separate records and observation of a school of individuals suggests that *A.* cf. *saxatilis* may be established in Maltese waters.

[30] *Epinephelus malabaricus* was recorded as a single individual from the Grand Harbour (Schembri & Tonna, 2011), while *Oplegnathus fasciatus* was observed on two separate occasions within a month of each other, one in the Grand Harbour and another in the adjacent Marsamxett Harbour (Schembri *et al*., 2010b). Neither species has been recorded again, and these species are therefore considered to have a 'Casual' status.

[31] At the time of writing, *Etrumeus golanii* had not yet been listed in the WoRMS database, but we have updated the identity of the species (formerly reported as *E. teres*) as per the FishBase (Froese & Pauly, 2014) entry, which has been revised following DiBattista *et al*. (2012). The establishment status for this species is considered 'Questionable' since it has not yet been recorded from Maltese waters *per se*; however, *E. golanii* was recorded off Lampedusa in 2005 (Falautano *et al*., 2006) and, given the proximity of the Maltese Islands, there is a high probability that this pelagic species also occurs in Maltese waters.

[32] *Lutjanus fulviflamma* and *Stegastes variabilis* were reported from the Maltese Islands in 2014 (UoM, 2014), which also represent the first records on these species from the Mediterranean. However, no details on the date or locality of capture are provided, but only a single photograph of each species without further information. Therefore, at present, there is insufficient information to assess the status of these species, while it is not possible to confirm the identity of either solely on the photographs in UoM (2014). For these reasons, we are treating these two records as 'Questionable' until details on the specimens and on the basis for identification of the species are published.

[33] Although Zammit & Schembri (2011) comment that "*all indications point to this species having established a breeding population since at least 2007*", it has not been recorded since, leading to doubts as to whether *Scatophagus argus* is still established in Maltese waters.

[34] Vella & Deidun (2009) reported the occurrence of *Selene dorsalis* in Maltese waters based on a single specimen caught in 2007; this also represented the first Mediterranean record of this species. According to Vella & Deidun (2009), *S. dorsalis* may have arrived in Maltese waters via natural range expansion through unaided dispersal of adult individuals, especially given the apparent shift in the northern limit of its native range. However, these authors comment that transport of larvae or juveniles through ship ballast water may also have occurred. On the other hand, Zenetos *et al.* (2012) suggest that the occurrence of this species in the Central Mediterranean is attributable to the aquarium trade. Therefore, we do not have sufficient information to determine whether *S. dorsalis* should be considered an 'Alien' or a 'Range-expanding species', and are instead listing it as having a 'Cryptogenic' origin. This species has never been recorded again and is therefore regarded as a 'Casual' record.

[35] According to Schembri *et al*. (2012), the first authenticated record of *Siganus luridus* was made in August 2002, but this species was probably present before this date since Castriota & Andaloro (2005) state that a Maltese diver communicated to them that this species had been observed by SCUBA divers in Maltese waters since the 1990s. Schembri *et al*. (2012) reported 13 authenticated records comprising at least 33 individuals and a further 25 unauthenticated records comprising 48 individuals of *S. luridus* made in Maltese waters, indicating that *S. luridus* is not only well-established but may have started to become invasive.

The records of *Parupeneus* sp. and *Seriola* sp. were considered dubious by Sciberras & Schembri (2007) because of uncertainty over the identity of the species recorded by Cilia (1979) and Sammut (2001), respectively. The original records were likely misidentifications, but it is not clear of which species (see Sciberras & Schembri, 2007). Furthermore, given the increasing awareness on non-native species, it is now common for sea users (fisherman, divers, etc.) to report any observations of 'new' or unusual species. However, none of the species recorded in the past years conform to the descriptions given in Cilia (1979) or Sammut (2001). For these reasons, we are excluding these two ambiguous records from our updated inventory.

Table 2. Atlantic species which have recently extended their range into the Mediterranean, reaching Maltese waters (up to December 2014); new records are marked with an *, bold indicates changes to records previously included in the Sciberras & Schembri (2007) inventory.

Species	Natural range	First Maltese record	Mode of introduction into Maltese waters	Status	Origin	Cited by	Note
Animalia: Mollusca							
* *Cuvierina cancapae* Janssen, 2005	Southern Atlantic	2007	Natural range expansion?	Casual	Range expansion	Mifsud & Cachia, 2011	[36]
Animalia: Actinopterygii							
* *Cephalopholis taeniops* (Valenciennes, 1828)	Tropical and subtropical East Atlantic	2008	Natural range expansion	Established?	Range expansion	Vassallo, 2009; Schembri & Tonna, 2011; Deidun *et al*., 2011b	[37]
* *Ophioblennius atlanticus* (Valenciennes, 1836)	Western and Eastern Atlantic	2014	Natural range expansion?	Casual?	Range expansion	M.A. Falzon (*pers. comm*.); Chetcuti, 2014	[38]
* *Parablennius pilicornis* (Cuvier, 1829)	Atlantic and possibly Mediterranean	1998	Natural range expansion?	Established	Cryptogenic (may be native)	Falzon, 1999	[39]
Seriola carpenteri Mather, 1971	Tropical Atlantic and possibly Mediterranean	?	Natural range expansion?	Questionable	Cryptogenic (may be native)	Pizzicori *et al*., 2000	[40]
Seriola fasciata (Bloch, 1793)	Western and possibly Eastern Atlantic	**2007?**	Natural range expansion	**Established**	Range expansion	**Andaloro *et al*., 2005; Deidun *et al*., 2011b**	[41]
Sphoeroides pachygaster (Müller & Troschel, 1848)	Circumglobal in tropical and temperate seas	1994	Natural range expansion?	Invasive	Cryptogenic (may be native)	Cini, 1999	[42]

Notes on Table 2:

[36] The Maltese record of *Cuvierina cancapae* is based on a single empty shell collected from a depth of 436 m; to date, this is the only record of this species from the Mediterranean Sea. The mode of introduction for this species is not known, but transport of larvae or adults through the Strait of Gibraltar by currents is considered to be the most plausible mechanism (A. Janssen, *pers. comm.*). Therefore, *C. cancapae* has to be considered an Atlantic range-expanding species rather than an alien species. Its status is regarded as 'Casual' since it has only been recorded on one occasion.

[37] Photographs of *Cephalopholis taeniops* taken in Malta in August 2009 were published in FishBase (Froese & Pauly, 2014) in 2009, and subsequently reported on in the local media (Vassallo, 2009); these were then published again by Deidun *et al*. (2011b) as the first record of *C. taeniops* from Maltese waters, together with details of a second record made in January 2011. A third record is mentioned by Schembri & Tonna (2011); this is based on a specimen caught in July 2008, which therefore represents the earliest known record for this species in Maltese waters. Given the three separate records made between 2008 and 2011, *C. taeniops* can probably be regarded as being locally established, although some doubt remains due to the absence of further records.

[38] *Ophioblennius atlanticus* was discovered in the Maltese Islands in September 2014 by M.A. Falzon (*pers. comm.*); this also represents the first record of this species from the Mediterranean. Its occurrence in Malta was subsequently reported in the local media (Chetcuti, 2014). Although no information on its pathway of introduction is available, range expansion from the Eastern Atlantic seems the most likely mode of introduction.

[39] According to Golani *et al*. (2002), *Parablennius pilicornis* is native to the Mediterranean, with older records being listed under its junior synonym *Blennius vandervekeni*. On the other hand, Pastor & Francour (2010) reviewed all Mediterranean records of this species and clearly show that the first record was made in 1963 in Algiers where the species arrived via the Strait of Gibraltar; this would make *P. pilicornis* a range-expanding species. Due to these contrasting views, we opt to include *P. pilicornis* in our list of range-expanding species but assign it a 'Cryptogenic' origin.

[40] The situation of *Seriola carpenteri* has not changed since 2007, that is, it has still not been recorded from Maltese waters *per se*, but 148 specimens of this species were caught 42 nautical miles east of Lampedusa in 1997 (Pizzicori *et al*., 2000). According to Golani *et al*. (2002), the reproductive conditions of these specimens suggest that this species is now established in this area. Given the close proximity of the capture area to the Maltese Islands, there is a high probability of *S. carpenteri* also occurring in Maltese waters. We therefore retain this species in the inventory, but note that its presence in Maltese waters has to be regarded as 'Questionable'. We consider its origin to be 'Cryptogenic' as Zenetos *et al*. (2012) indicate it might be native to the Mediterranean.

[41] *Seriola fasciata* was originally included in the 2007 inventory with doubtful status due to records of this species from nearby Sicilian waters and off Lampedusa (Andaloro *et al*., 1999). Andaloro *et al*. (2005) reported *S. fasciata* from the Maltese Islands, citing a personal communication from Mark Gatt, but provide no details on this report, which therefore remains unauthenticated. The presence of *S. fasciata* in Maltese waters was subsequently confirmed by Deidun *et al*. (2011b), based on four records made between October 2008 and September 2010. However, we are aware of an earlier (June 2007) unpublished record, supported by a photograph of the specimen, which therefore has to be considered as the first authenticated record for this species. Given the numerous separate records of this species since 2007, it appears that it is now locally established. Although the distribution of *S. fasciata* in the East Atlantic is uncertain due to past confusion with *S. carpenteri*, it is generally considered to be an Atlantic immigrant in the Mediterranean and we follow Zenetos *et al*. (2012) in considering it to be a range-expanding species.

[42] There appears to be general consensus that *Sphoeroides pachygaster* is a recent immigrant of Atlantic origin (e.g. Zenetos *et al*., 2012), and we therefore include it in our list of range-expanding species. However, we consider its origin as 'Cryptogenic' because of the possibility that it has been present in the southern Mediterranean for several centuries (Relini & Orsi Relini, 1995).

The sixth species omitted from the present list of alien and range-expanding species is *Pisodonophis semicinctus*, which was included by Sciberras & Schembri (2007) "*with some reserve*", because it was reported as occurring in the "*Malta Channel*" (e.g. in Golani *et al*., 2002), based on the record by Insacco & Zava (1999). However, Insacco & Zava (1999) actually report the collection of a single specimen from "*3 miles south of Capo Scalambri, Punta Secca, Ragusa (Malta Channel)*", which is well outside Maltese waters. Although *P. semicinctus* has also been found in Tunisia, to date this species has never actually been sighted in Maltese waters (see Bodilis *et al*., 2012).

Besides these six species, another three species included in the 2007 inventory are no longer considered to be 'Alien', but rather 'Range-expanding species' originating from the Eastern Atlantic, which reached the Maltese Islands without human involvement. Therefore, these three species (*Seriola carpenteri*, *S. fasciata* and *Sphoeroides pachygaster*) were omitted from the list of alien species and have been transferred to the inventory of range-expanding species (see Table 2).

(c) Records of Atlantic range-expanding species

Atlantic range-expanding species recorded from the Maltese Islands and surrounding waters up to December 2014 are listed in Table 2. This list excludes new records of species considered to be native to some parts of the Mediterranean which have recently extended their range to include the Maltese Islands.

(d) Additional information on species not included in the updated inventory

Species imported for aquaculture purposes: Sciberras & Schembri (2007) provide a comprehensive review of species imported into the Maltese Islands by the aquaculture industry. Most of these species are native to the Maltese Islands, but stock imported from elsewhere could potentially be genetically different to the native Maltese populations, leading to the introduction of non-indigenous genetic stock. For further details, see Sciberras & Schembri (2007).

Species not considered for inclusion in the present inventory: The omission of species which may be considered to be alien in Maltese waters based on recent publications or online databases requires explanation. Four species are relevant in this regard: *Cymbium olla*, *Erosaria turdus*, *Littorina saxatilis* and *Epinephelus fasciatus*.

Cymbium olla (Linnaeus, 1758) was included in an update to the checklist of marine Mollusca of the Maltese Islands by Mifsud & Cachia (2011), based on "*a single shell found in fish boxes from fishmongers*". However, the specimen was an eroded empty shell which was probably imported together with fish (C. Mifsud, *pers. comm.*). Given these circumstances, it appears that live *C. olla* were never introduced in Maltese waters.

Records of living specimens of *Littorina saxatilis* (Olivi, 1792) and *Erosaria turdus* (Lamarck, 1810) dating back a few decades were also recently published by Mifsud & Cachia (2011). The *L. saxatilis* individuals were found together with imported oyster spat in 1977, whereas *E. turdus* has been recorded on more than one occasion but always in ships' ballast tanks. Although these records refer to live specimens, neither species has ever been recorded in the wild (C. Mifsud, *pers. comm.*) so there is no evidence that they were actually introduced in Maltese waters.

Epinephelus fasciatus (Forsskål, 1775) is listed as an alien species occurring in Maltese waters in the EASIN database (Katsanevakis *et al*., 2012). This is based on records of occurrences listed in the Global Biodiversity Information Facility (GBIF [www.gbif.org]) (S. Katsanevakis, *pers. comm.*). GBIF actually lists two occurrences of *E. fasciatus* from Malta, based on specimens housed in the Natural History Museum London (NHML). The first specimen is identified in the NHML catalogue as *Epinephelus alexandrinus* (species code BMNH 1964.7.14.1), and was donated to the museum by John Lythgoe. Although *E. alexandrinus* (Valenciennes, 1828) is in fact a synonym of *E. fasciatus* (Forsskål, 1775), *E. alexandrinus* (non Valenciennes, 1828) is considered to be a synonym of *Epinephelus costae* (Steindachner, 1878). Most of the recent literature (since 1895) has misapplied the name *E. alexandrinus* (Valenciennes, 1828) to refer to *E. costae* (see discussion in Heemstra & Randall, 1993). This error is also evident in two books on Mediterranean fish co-authored by John Lythgoe himself (Lythgoe & Lythgoe, 1971, 1991), clearly suggesting that the specimen he donated to the NHML was indeed *E. costae*. Furthermore, morphometric measurements of this specimen (based on a photograph of the specimen supplied by the NHML) generally fit within the ranges reported for *E. costae*, but not those for *E. fasciatus* (published values obtained from Heemstra & Randall, 1993). Therefore, the NHML specimen BMNH 1964.7.14.1 is almost certainly *E. costae*, which is native to the Maltese Islands.

The second NHML specimen included in GBIF as a Maltese record for *E. fasciatus* is listed as *Serranus fasciatus* in the NHML catalogue (specimen code BMNH 1856.12.10.486). *Serranus fasciatus* (Forsskål, 1775) is indeed a synonym of *E. fasciatus* (Forsskål, 1775), but *S. fasciatus* (Jenyns, 1840) is a synonym of *S. psittacinus* Valenciennes, 1846. The latter species occurs in the Eastern Pacific and has never been recorded from the Mediterranean. On the other hand, *E. fasciatus* is considered to be a Lessepsian immigrant in the Mediterranean, but the Maltese "*S. fasciatus*" specimen was donated to the NHML in 1856 – 13 years prior to the opening of the Suez Canal. This raises doubts over the identity of NHML specimen BMNH 1856.12.10.486, which can only be resolved through detailed examination of the actual specimen (a dried skin). Until such time, we consider the GBIF (and hence EASIN) reports of *E. fasciatus* from Malta to be unauthenticated, and therefore this species is not included in our inventory.

Part 2: Analysis of patterns

(a) Number of alien and range-expanding species

Records of 31 new species were added to the inventory, while 6 previous records have been removed. Thus the total number of species has increased from 48 (in Sciberras & Schembri, 2007) to 73 (present list). Of these, 66 species are considered to be aliens with the remaining 7 species classified as range-expanding species.

(b) Establishment success

Of the 73 species included in the updated inventory, 6 records are considered questionable and as yet unverified. When comparing alien and range-expanding species, the proportion of species included in the different categories is very similar for the two groups. In both cases, approximately half of the recent newcomers are considered to be 'Established' in Maltese waters, while a further 10-14% are 'Invasive'; 'Casual' records account for 28-29% of the species in each list (Fig. 1).

(c) Faunal composition

Alien species reported from the Maltese Islands and surrounding waters belong to a wide range of higher taxa, but most of these are represented by just one or two species (Fig. 2). Molluscs have the highest richness amongst alien species (32.8% of all alien species), followed by fish (16.4%), crustaceans (13.1%) and red algae (11.5%). On the other hand, molluscs and fish comprise all the range-expanding species found in Maltese waters, with fish having the highest richness (83.3% of all range-expanding species).

(d) Pathways of introduction

The distinction between alien and range-expanding species is mainly focused on whether their introduction occurred naturally or was mediated by humans. Thus, 'Natural range expansion' is only applicable to range-expanding species and includes all six such species with verified records from Maltese waters. The 'Secondary dispersal' pathway applies to species which arrived in Maltese waters through dispersal from an area where they are considered to be alien, and hence whose arrival in Malta was still ultimately human-mediated. This is the second most common introduction pathway for alien species in Maltese waters (24.6% of alien species), with 'Shipping' being the most common pathway (29.5%; Fig. 3). 'Aquaculture' and the 'Aquarium trade' account for a small portion (10%) of the total number of alien introductions. However, the introduction pathway for most alien species (49.2%) remains unknown.

(e) Chronology of first arrival/record

The first record of an alien species from Maltese waters is that of *Pinctada imbricata radiata* in 1912, while an alien polychaete belonging to the genus *Branchiomma* was recorded in 1929. This is included in our inventory as *B. boholense* with questionable status, since it could possibly represent the earliest record of *B. bairdi* instead (see Table 1, Note [12]). Either way, there seems to be no doubt that one of these two alien species was recorded in 1929, so we have included this record in the analysis; however, all other questionable records were excluded. An increasing trend

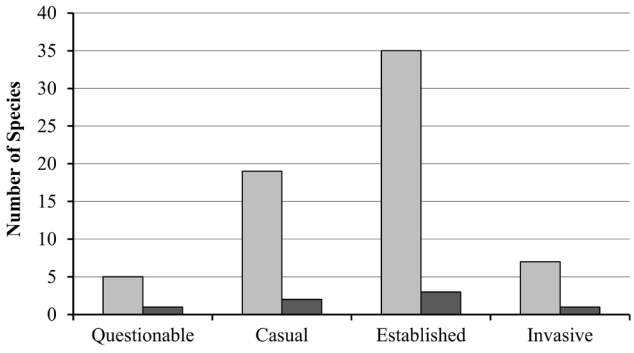

Fig. 1: Number of alien (light grey) and range-expanding (dark grey) species recorded from the Maltese Islands and surrounding waters, grouped according to their establishment success.

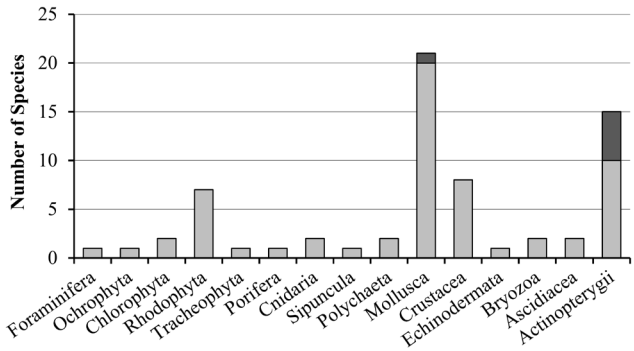

Fig. 2: Number of alien (light grey) and range-expanding (dark grey) species recorded from the Maltese Islands and surrounding waters for each of the major taxonomic groups; species with a 'Questionable' status were excluded from the analysis.

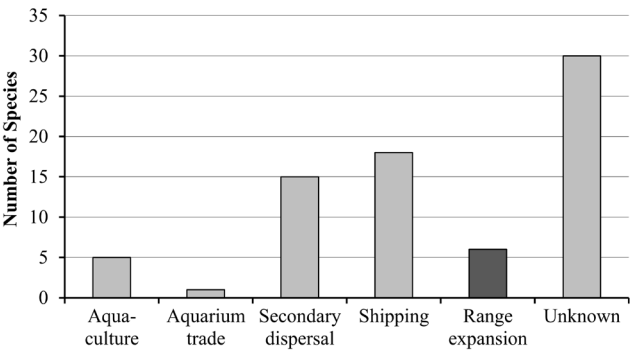

Fig. 3: Number of alien (light grey) and range-expanding (dark grey) species arriving in Maltese waters through different pathways; species with a 'Questionable' status were excluded from the analysis. Range expansion applies only to range-expanding species, while all other modes apply to alien species (see Methods for further details). The total number of species resulting from this graph is higher than that recorded from Maltese waters, because species with two plausible modes of entry were included under both modes.

in the number of alien records is evident in recent decades, starting with the 1960s, with a peak of 22 species (35.5% of all records) in 2001-2010. Records of range-expanding species are more recent, the first (*Sphoeroides pachygaster*) being made in 1994. This category also appears to be on the increase although the total number of range-expanding species recorded to date is still relatively low (Fig. 4).

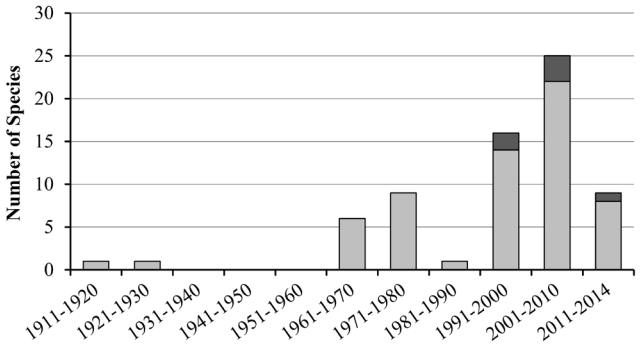

Fig. 4: Number of alien (light grey) and range-expanding (dark grey) species recorded from the Maltese Islands and surrounding waters per decade; species with a 'Questionable' status were excluded from the analysis with the exception of the 1929 record of *Branchiomma boholense* (see text).

Discussion

The spate of recent records of new introductions necessitated an update to the inventory of alien species recorded from Maltese waters by Sciberras & Schembri (2007), as evidenced by an increase of over 50% in the total number of species included in the present inventory relative to the previous one. However, our update does not only cover the species but also the terminology applied.

In particular, we have introduced a new category referring to the origin of a species, which we consider an important addition in two regards. First, it provides a convenient way of distinguishing between species whose presence is unverified ('Questionable' status as defined in the present work), and species for which there are doubts as to whether they should be considered aliens or not (i.e. 'Cryptogenic' origin). Such species were all classified as 'Questionable' by Sciberras & Schembri (2007), an approach which we now feel conflates two separate issues. Other authors (e.g. Zenetos *et al*., 2010) have used the term 'Cryptogenic' to account for species with uncertain origin, but did not clearly distinguish between establishment status and origin: 'Cryptogenic' was included with 'Questionable', 'Casual', 'Established' and 'Invasive' as terminology for establishment status. Consequently, no information on establishment status was provided for 'Cryptogenic' species. Using separate categories for establishment status and origin resolves this issue. Secondly, the 'Origin' category allows distinguishing between alien and range-expanding species, while retaining both in the inventory.

Such differences ultimately hinge on the definition of alien species as those whose introduction was caused by human activities, which excludes natural range expansion. Such a definition has also been incorporated in EU legislation (EC, 2008, 2010) and, consequently, databases intended as a basis for application of the relevant legislation no longer include range-expanding species. On the other hand, we contend that it should be science that ought to drive policy-making and legislation, rather than policy determining the direction that science takes. Thus, while agreeing that range-expanding species are, by definition, not aliens, we feel that from a management perspective the best approach is not to exclude such species from inventories of 'newcomers', but to include both alien and range-expanding species, clearly distinguishing between them via an 'Origin' category. Our rationale is that any newcomer will not have formed part of the native ecosystem in evolutionary time and there would not have been sufficient time for it to form co-evolutionary interactions with native species, irrespective of whether it is labelled as an 'Alien' or a 'Range-expanding' species. Thus, both types of newcomers have the propensity to disrupt native ecosystems; it is telling that some of the species considered to be amongst the "*Worst Invasives*" in the Mediterranean (e.g. *Seriola fasciata* and *Sphoeroides pachygaster;* Streftaris & Zenetos, 2006) are actually range-expanding species. While acknowledging that humans were not responsible for their introduction, for management considerations, assessment and monitoring of such species is as important as for alien invasive ones.

One consequence of the terminological updates is that the status of a number of species previously considered to be 'Questionable' has been re-evaluated, leading to a reduction in the number of questionable records when compared with those given in Sciberras & Schembri (2007). The main effect of this is that casual records now account for a greater proportion of the total number of species. Established species still comprise around half of the total records, while the number of invasive species has increased to eight. This includes one range-expanding species (*S. pachygaster*) and seven alien species (*Caulerpa cylindracea*, *Lophocladia lallemandi*, *Womersleyella setacea*, *Brachidontes pharaonis*, *Percnon gibbesi*, *Fistularia commersonii*, *Siganus luridus*). Of these, *B. pharaonis* and *S. luridus* were not considered to be invasive in 2007. All eight species are included in the list of the top 100 "*Worst Invasives*" in the Mediterranean by Streftaris & Zenetos (2006).

Discussions on the status of the six species considered invasive in 2007 are provided in Sciberras & Schembri (2007). In most cases the situation is unchanged, but *C. cylindracea* is an exception. This species was first recorded from the Maltese Islands in 1997, and it subsequently spread to most coasts, forming dense stands on infralittoral hard substrata and sparse stands on infralittoral soft substrata (Borg *et al*., 1997). It persisted in high abundance until the mid-2000s, but its spatial distribution and abundance decreased rapidly after 2006, to the extent that by 2009 it had become quite rare, albeit

still established (Barbara & Borg, 2014). Similar rapid declines have been observed in south-eastern France and Turkey (Klein & Verlaque, 2008). Such disappearances may be due to unfavourable conditions, such as extreme temperatures, or to sediment abrasion or high hydrodynamism, or due to massive reproductive or other natural decline (Klein & Verlaque, 2008). The cause of collapse of the Maltese population is unknown. Barbara & Borg (2014) speculated that it might be due to decreased nutrient levels in coastal waters. However, *C. cylindracea* has made a comeback in recent months, and has started becoming once again widespread and abundant.

The occurrence of *B. pharaonis* in the Maltese Islands was first noted in October 1970, and this mussel is now present at various localities around the islands (Cachia *et al*., 2004; Cilia & Deidun, 2012). It generally occurs as solitary individuals found sporadically on rocky shores, but densities of 100–1000 individuals/m^2 have been observed in some localities (Cilia & Deidun, 2012), while dense clusters of this species have given rise to a mussel bed in Birzebbugia Bay, Marsaxlokk Harbour (Mifsud & Cilia, 2009) with a peak density >15000 individuals/m^2 and including recent recruits (Bonnici *et al*., 2012). This represents a new habitat for the Maltese Islands, since no mussel beds existed previously. The presence of this bed has altered the rocky shore community structure, with a greater small-scale heterogeneity and lower species richness recorded from the mussel bed site, compared to the adjacent rocky shore where mussels are present but where there is no bed formation (Bonnici *et al*., 2012). Thus, establishment of extensive beds by this invasive mussel could change the structure of native rocky shore assemblages around the Maltese Islands. Although a mussel bed has only been reported from Birzebbugia Bay, the densities recorded by Cilia & Deidun (2012) from elsewhere around the Maltese Islands indicate that the population of this species is increasing.

Siganus luridus may have been present in Maltese waters since the 1990s (Castriota & Andaloro, 2005), but the first verified record of this species was made in August 2002 (Schembri *et al*., 2012). Since then *S. luridus* has been sighted regularly, either as single specimens or in schools of up to seven individuals. Although the increasing frequency of occurrence of this species suggests it may have started to become invasive, its impact on native species and/or local biotic communities is not known.

These eight invasive species comprise three macrophytes (two rhodophytes and a chlorophyte), a mollusc, a crustacean and three fish. Molluscs, fish, macrophytes (particularly rhodophytes) and crustaceans are also the most common alien taxa found in Maltese waters, when also considering casual and established species. These, together with polychaetes, are considered to be the dominant alien groups in the Mediterranean. However, in the faunal composition of alien taxa for the Central Mediterranean region, macrophytes are the dominant group with 23% of all alien species, while alien polychaetes, molluscs, crustaceans and fish comprise around 15-17% of alien taxa each (Zenetos *et al*., 2012). This contrasts with the situation in the Maltese Islands, where molluscs are clearly the dominant group, followed by fish, crustaceans and macrophytes, while only two alien polychaete species (excluding questionable records) have been recorded. These differences may partly be due to the lack of local taxonomic expertise on certain groups. Detailed data on range-expanding species are not available, but fish are the dominant group amongst range-expanding species recorded along the Italian coasts (Occhipinti-Ambrogi *et al*., 2011), similar to the situation observed in Maltese waters.

Introduction pathways are often not known but have been inferred from the establishment pattern of a species in the Mediterranean and from the biology of the species in question. Several modes may be plausible in some cases, and in the absence of any additional information, we consider the mode of introduction of such species to be 'Unknown'. This situation applies to nearly 50% of the alien species reported from the Maltese Islands and surrounding waters, which can significantly influence the analysis of modes of introduction. Nonetheless, 'Shipping' is the most common vector for those species with a known (or hypothesized) introduction pathway into Maltese waters; this agrees with data for the Central Mediterranean given in Zenetos *et al*. (2012). These authors list "*canals*" or "*corridors*", referring mainly to alien species entering the Mediterranean via the Suez Canal, as the second most common pathway. This is also in line with our data for the Maltese aliens, assuming that these species reached the Maltese Islands via secondary dispersal within the Mediterranean. Other vectors account for only a small portion of introductions into Maltese waters, while the introduction pathway for range-expanding species is, by definition, 'Natural range expansion'.

The number of species recorded has been steadily increasing in recent decades. Sciberras & Schembri (2007) cautioned that chronological patterns must be interpreted with care since the high number of records from the 1990s was partly due to the intensive survey of benthic marine algae carried out by Cormaci *et al*. (1997) and the publication of a revised edition of Lanfranco's catalogue of Maltese fish (Lanfranco, 1993), which in both cases included the first records of a number of alien species from Maltese waters, while the gap for 1981–1990 was due to a lack of research activity on marine biodiversity during that decade. On the other hand, the number of new records during the 2000s exceeded that made in the preceding decade. This could partly be due to increasing local awareness of alien species, making sightings of new or unusual species in Maltese waters more likely to be reported, although a similar increasing trend since the 1970s has also been recorded for the entire Mediterranean region (Zenetos *et al*., 2012). The overall rate of introductions into the Mediterranean may have slowed down

recently (Zenetos *et al*., 2012), but such a pattern is not yet apparent in the case of the Maltese Islands. Records of range-expanding species from Maltese waters also indicate an increase between the 1990s and 2000s, but it is difficult to draw conclusions on temporal trends given that there are only six verified records in this category.

The number of recent arrivals reported in the present work excludes new records of species considered to be native to the Mediterranean but previously unknown from the Maltese Islands. In some cases, it is likely that these species are actually native but were not previously recorded due to inadequate sampling of their habitats (e.g. *Gobius couchi*, *Millerigobius macrocephalus* and *Zebrus zebrus*; see Kovačić *et al*., 2013) but in other cases it appears that a recent range expansion from elsewhere in the Mediterranean is more plausible (e.g. *Pachygrapsus maurus* and *P. transversus*; see Crocetta *et al*., 2011; *Lobotes surinamensis*; see Deidun *et al*., 2010). As with any inventory, a line has to be drawn somewhere determining what will be included and what will not. In the case of range-expanding species, we chose to draw this line at the Strait of Gibraltar, including those species which have only recently extended their range into the Mediterranean, because these are the ones which are relevant at a regional scale. It should be noted, however, that internal range-extenders may be responding to the same changing environmental conditions as alien species extending their range via secondary dispersal. In particular, warming sea temperatures may enable thermophilic Lessepsian immigrants originally restricted to the Eastern Mediterranean to extend their range northwestwards and reach Maltese waters, but this may also apply to some native species, and appears to be the case for the recently reported *L. surinamensis* (Deidun *et al*., 2010).

Besides enabling thermophilic species to spread from the Eastern to the Central Mediterranean, rising Mediterranean sea surface temperatures may also facilitate range-expansion of tropical and subtropical Eastern Atlantic species into this sea through the Strait of Gibraltar. The high proportion of species having warm-water affinities (particularly those of Indo-Pacific and subtropical Atlantic origin) included in the present inventory may thus be a consequence of the general warming trend of Mediterranean waters in recent years (Lejeusne *et al*., 2010; Bianchi *et al*., 2012). As noted by Sciberras & Schembri (2007) this could well mean that further arrivals of alien and range-expanding species are to be expected, making monitoring of such species in the Maltese Islands of critical importance as an indicator of change in the Mediterranean marine environment and particularly of biogeographic exchanges within the sea. However, such monitoring must not only focus on new records or changing status of alien and range-expanding species, but also on their biological interactions with native species, in order to better understand the ecological effects that the newcomers may have on the local populations, communities and ecosystems.

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