**Mediterranean Marine Science**

Vol 8, No 1 (2007)


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doi: 10.12681/mms.162

*Mediterranean Marine Science*
Volume 8/1, 2007, 41-66

# A critical review of records of alien marine species from the Maltese Islands and surrounding waters (Central Mediterranean)

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**Abstract**

*An updated list of alien marine species recorded from the Maltese Islands and surrounding waters, compiled from scientific and 'grey' literature and from authenticated unpublished reports to the authors, is presented. The listed species are classified in one of four categories as regards establishment status: established, casual, invasive and questionable. Doubtful records are listed as '?'. A total of 48 species, including nine dubious ones, are included in the list. Of the accepted records, 64% are established, of which 15.4% are invasive, 18% are casual and 18% are questionable. The most represented groups are molluscs (14 species), fish (13 species) and macrophytes (10 species). Six species are classified as invasive in Maltese waters: Lophocladia lallemandii, Womersleyella setacea, Caulerpa racemosa var. cylindracea, Percnon gibbesi, Fistularia commersonii and Sphoeroides pachygaster; impacts of some of these species on local ecosystems are discussed. Since the early 1900s, there has been an increasing trend in the number of alien marine species reported from the Maltese Islands. Transportation via shipping and in connection with aquaculture, as well as the range expansion of Lessepsian immigrants, appear to be the most common vectors for entry, accounting for 20%, 11% and 32% respectively of the alien species included in this review. The general warming trend of Mediterranean waters and increasing marine traffic may be facilitating the spread of warm-water Atlantic and Indo-Pacific species to the central Mediterranean, including the Maltese Islands.*

**Keywords:** Alien species; Invasive species; Malta; Biodiversity; Aquaculture; Lessepsian immigrants.

## Introduction

Invasion of native biotas by non-indigenous species is a threat to the integrity of biotic communities, the economy and even human health that is recognized worldwide (VITOUSEK *et al.,* 1996). The environmental impact of invasive marine species may be so severe that the introduction of aliens has been identified as one of the four greatest threats to the world's oceans (IMO, 2000-2007). Alien species may affect recipient ecosystems through predation, direct and indi-

rect competition, contamination of the native gene pool by exotic genes (for example, through hybridization), habitat modification, and through the introduction of new parasites and pathogens. Human communities may also be impacted in several ways. For example, in the Mediterranean, the massive swarms of the voracious Indo-Pacific jellyfish, *Rhopilema nomadica* Galil that have appeared along the Levantine coast since the mid-1980s, have adversely affected tourism, fisheries and coastal installations when large groups of the jellyfish draw close to the coast (GALIL & ZENETOS, 2002). On the contrary, Erythrean fish *(Upeneus moluccensis* (Bleeker), *U. pori Ben-Tuvia & Golani, Dussumieria acuta Valenciennes in Cuvier & Valenciennes)* and penaeid prawns (*Marsupenaeus japonicus* (Bate), *Metapenaeus monoceros* (Fabricius), *M. stebbingi* Nobili), constitute most of the catches along the Egyptian and Israeli coasts (GALIL & ZENETOS, 2002).

Invasion by non-indigenous species may be a natural phenomenon whereby an organism is dispersed into a region where it did not exist before by means of natural mechanisms. Such invasions have been termed 'range expansions' by MORI & VACCHI (2002). The problem with human-facilitated introductions is that, more often than not, these occur at rates higher than the natural rate of range expansion (MACK *et al.,* 2000), often overcoming many natural barriers to dispersal, such as distance or currents (SCHEMBRI & LAFRANCO, 1996; RUIZ *et al.,* 1997). Consequently, existing equilibria between the native biota and their physical and biological environments may be disrupted. The high number of non-indigenous species in the Mediterranean Sea has been attributed to such human activities as seafaring, commerce, and tourism; to the occurrence of numerous habitats susceptible to invasion, in particular those subject to anthropogenic disturbance such as lagoons, estuaries, and marinas; to aquaculture ventures; and to the opening of the Suez Canal which has led to the introduction of hundreds of Lessepsian immigrants (CHU *et al.,* 1997; COUTTS *et al.,* 2003; OCCHIPINTI-AMBROGI & SAVINI, 2003; GALIL, 2006; MINCHIN, 2007). Although temperature change scenarios in Europe vary regionally, there is a clear trend towards overall warming (SCHROTER *et al.,* 2005). Consequently, present day sea warming favours the occurrence and establishment of warm-water species, whether alien or native, in the Mediterranean Sea (BIANCHI, 2007; OCCHIPINTI-AMBROGI, 2007). The number of macroscopic marine species inhabiting the Mediterranean is today estimated at about 12,000 (BOUDOURESQUE, 2004), of which around 745 species are alien to the region (ZENETOS *et al.,* 2005). Immigration through the Suez Canal and transportation by ships are the two vectors contributing largely to introductions into the Mediterranean (STREFTARIS *et al.,* 2005).

The fate of immigrants is decidedly mixed. Those which survive the multitude of physical stressors during the immigration or transportation processes, and succeed in reaching a suitable new environment, may survive to reproduce and become established, and some become invasive. The degree of success of the introduced species depends on a multitude of physical and biological factors, such as

the availability of vacant, under- or un-utilized niches, escape from biotic constraints (competitors, predators, parasites and diseases), low resident-community species richness, disturbance before or upon immigration to the recipient environment, as well as the physico-chemical requirements of the invader and its community interactions (RUIZ *et al.,* 1997; MACK *et al.,* 2000; TORCHIN *et al.,* 2001).

Because of their location on or close to the biogeographic boundary between the western and eastern Mediterranean bioregions (BIANCHI, 2007), the Maltese Islands are an important station for monitoring the entry and spread of alien marine species in this sea. With increasing marine traffic, both commercial and tourist (cruise liners, yachting), the Maltese Islands face the ever increasing threat of alien species arriving in ballast water or on ship hulls. Due to their position, the Maltese Islands may act as a stepping stone for already established alien species to expand their range from west to east or vice versa. Moreover, the Maltese Islands are at the meeting point of Atlantic-derived aliens with those originating from the Red Sea and Indo-Pacific, providing an interesting opportunity to study the interactions of alien species of different biogeographic affinities.

However, records of alien marine species from the Maltese Islands are sparse and scattered; the most recent review, that by SCHEMBRI & LANFRANCO (1996), is now outdated. The aim of the present work is to present an updated list of alien marine species reported from the Maltese Islands, based on scientific and popular literature and on unpublished observations, and to evaluate these records in order to provide a baseline account of the situation to date and to assess the reliability of the available information as a prelude to future studies.

## Methods

Records of alien species from the Maltese Islands and their surrounding waters, taken to be the sea area within the 25 NM Fisheries Management Zone established by the European Union (CAMILLERI, 2003), were searched for in scientific, grey, and popular literature. Unpublished reports to the authors by other workers, fishers, sea users and others were also included if these records were supported by physical evidence such as specimens or photographs. The reliability of each record was assessed, and where possible, the establishment status of the species in the Maltese area was determined, using the terminology that follows.

***Indigenous:*** A species which occurs naturally in a particular place – in the present case, the Maltese Islands and surrounding waters as defined here; (synonymous term: native, autochthonous).

***Alien:*** Species or infraspecific taxon, inclusive of parts, gametes or propagules, that may survive and subsequently reproduce and spread outside of its historically known range (geographical area occupied naturally) and beyond its 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).

***Established:*** An alien 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).

***Casual:*** Species which find their way outside their native range but which do not seem to become established; this term is used for species which have been recorded only once or twice from the study area (as per ZENETOS, *et al.* 2005); (synonymous terms: stage II of the scheme proposed by COLAUTTI & MacISAAC, 2004).

***Questionable:*** Species for which insufficient information exists; also newly reported 'aliens' not verified by experts (as per Zenetos *et al.,* 2005), cryptogenic species (species whose native geographic distribution is unknown), and supposedly alien species which are very similar to native species and which are difficult to identify.

***Invasive:*** An alien 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 (as per OCCHIPINTI-AMBROGI & GALIL, 2004) and which may also threaten economic activities dependent on these ecosystems, and/or human health.

When known, the exact date of the first record of the alien in the Maltese Islands is given, otherwise it is labelled as unknown. When the species has been found during a prolonged study but no exact date is known, then the period of the study is given.

In the list that follows, '?' signifies doubt.

**Results**

Records of alien species from the Maltese area are presented in Table 1. In this table, the natural range (when this could be ascertained), the first record from the Maltese Islands, the mode of introduction and establishment success (status) of the alien species in the Maltese Islands are given, if known. The natural range for molluscs and fish species was obtained from the CIESM Atlas of Exotic Molluscs in the Mediterranean (http://www.ciesm.org/atlas/appendix3.html) and the CIESM Atlas of Exotic Fishes in the Mediterranean (http://www.ciesm.org/atlas/appendix1.html), respectively. Synonyms of the genus or species names under which reports have appeared in the literature are given in parentheses after the genus or species names respectively, if such synonyms exist.

Explanatory notes are provided after the table where appropriate and are cross-referenced in the table by numbers in square brackets (e.g. [1], [2] etc.). In addition, some notes on species imported for aquaculture are also given.

**Table 1**
**Alien species reported from the Maltese Islands.**

| Species | Natural range | First Maltese record | Mode of introduction | Status | Cited by |
|---|---|---|---|---|---|
| *RHODOPHYCEAE* | | | | | |
| *Acanthophora nayadiformis* (Delile) Papenfuss | Red Sea and Indian Ocean | 1969 | Lessepsian immigrant | Established | LANFRANCO, 1989 |
| *Asparagopsis armata Harvey* [1] | Cosmopolitan | 1994 | Lessepsian immigrant? | Established | CORMACI *et al.*, 1997 |
| *Botryocladia madagascariensis* G. Feldmann [2] | Indo-Atlantic tropical | 1994 | Lessepsian immigrant? | Questionable | CORMACI *et al.*, 1997 |
| *Chondria pygmaea* Garbary & Vandermeulen [2] | Indo-Pacific | 1994 | Unknown | Questionable | CORMACI *et al.*, 1997 |
| *Lophocladia lallemandii* (Montagne) F. Schmitz [3] | Indo-Pacific | Prior to 1994 | Lessepsian immigrant? | Invasive | CORMACI *et al.*, 1997 |
| *Womersleyella setacea* (Hollenberg) R.E. Norris [3] | Circumtropical | 1994 | Lessepsian immigrant | Invasive | CORMACI *et al.*, 1997 |
| *FUCOPHYCEAE* | | | | | |
| *Colpomenia peregrina* Sauvageau | Pacific Ocean | 1997 | Unknown | Casual | E. LANFRANCO (pers. comm.) |
| *Padina* cf. *boergesenii Allender* & Kraft [2] | Pacific Ocean | 1994 | Unknown | Questionable | E. LANFRANCO (pers. comm.) |

**(continued)**

**Table 1 (continued)**

| Species | Natural range | First Maltese record | Mode of introduction | Status | Cited by |
|---|---|---|---|---|---|
| *CHLOROPHYCEAE* | | | | | |
| *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman & Boudouresque [3] | Indian Ocean | 1997 | Lessepsian immigrant | Invasive | BORG *et al.*, 1997 |
| *MAGNOLIOPHYTA* | | | | | |
| *Halophila stipulacea* (Forsskal) Ascherson | Red Sea and Indian Ocean | 1970 | Lessepsian immigrant | Established | LANFRANCO, 1970<br>LANFRANCO, 1989 |
| *BIVALVIA* | | | | | |
| *Atactodea striata* (Gmelin) (=*glabrata*) [4] | Red Sea and Indian Ocean | 1977 | Lessepsian immigrant | Casual | CACHIA *et al.*, 2004 |
| *Brachidontes pharaonis* (P. Fischer) (= *variabilis*) | Indian Ocean and Red Sea | 1970 | Unknown | Questionable | CACHIA *et al.*, 2004 |
| *Crassostrea gigas* (Thunberg) [5] | Western Pacific Ocean | mid-1970s | Deliberate introduction for aquaculture | Established | SCHEMBRI & LANFRANCO, 1996 |
| *Pinctada radiata* (Leach) | Indo-Pacific and Red Sea | 1912 | Various [6] | Established | PALLARY, 1912 |
| *GASTROPODA - PROSOBRANCHIA* | | | | | |
| *Cerithium scabridum* Philippi | Red Sea, Indian Ocean | 2005 | Transport in ballast tanks | Established | MIFSUD & SAMMUT, 2006 |
| *Crepidula fornicata* (Linnaeus) [7] | Atlantic coast of North America | 1973 | Accidental importation with oysters and mussels used for aquaculture;<br>accidental importation by shipping | Casual | CACHIA, 1981 |

**(continued)**

**Table 1 (continued)**

| Species | Natural range | First Maltese record | Mode of introduction | Status | Cited by |
|---|---|---|---|---|---|
| *Gibbula cineraria* (Linnaeus) [8] | East Atlantic from Norway to Gibraltar | 1976 | Accidental introduction probably with oyster spat imported from Anglesey, Wales, where *G. cineraria* is very common. | Casual | SCHEMBRI, 1979 |
| *Natica gualteriana* Recluz [9] | Indian Ocean, Red Sea, Tropical Western Pacific | 1996 | Unknown | Casual | CACHIA *et al.,* 1996 |
| *GASTROPODA - OPISTHOBRANCHIA* | | | | | |
| *Bursatella leachi* de Blainville [10] | Circumtropical | 1969 | Lessepsian immigrant | Established | BEBBINGTON, 1970 |
| *Aplysia parvula* Guilding in Morch [11] | Circumtropical | 1967 | Lessepsian immigrant | Questionable | BEBBINGTON, 1970 |
| *Chelidonura fulvipunctata* Baba | Indo-Pacific | 1993 | Lessepsian immigrant | Established | PERRONE & SAMMUT, 1997 |
| *Haminoea cyanomarginata* Heller & Thompson T. | Indo-Pacific, Sudanese Red Sea | 2006 | Lessepsian immigrant or transport in ballast water | Established | MIFSUD, 2007 |
| *Aeolidiella indica Bergh* (= *takanosimensis)* [12] | Circumtropical | 1992-1998 | Unknown | Established? | SAMMUT & PERRONE, 1998 |
| *Polycerella emertoni* Verrill [12] | Tropical Atlantic | 1992-1998 | Unknown | Established? | SAMMUT & PERRONE, 1998 |

**(continued)**

**Table 1 (continued)**

| Species | Natural range | First Maltese record | Mode of introduction | Status | Cited by |
|---|---|---|---|---|---|
| *CRUSTACEA - MALACOSTRACA* | | | | | |
| *Callinectes sapidus* Rathbun | East coast of America | 1972 | Unknown | Established | SCHEMBRI & LANFRANCO, 1984 |
| *Percnon gibbesi* (H. Milne-Edwards) | Tropical and subtropical regions of the west and east Atlantic Ocean and East Pacific Ocean | 2001 | Natural range expansion by currents; ballast water; un/intentional introduction by aquarium trade | Invasive | BORG & ATTARD-MONTALTO, 2002 |
| *CRUSTACEA - MAXILLOPODA* | | | | | |
| *Dosima fascicularis* Ellis & Solander [13] | Cosmopolitan? | 2004 | Unknown | Casual | MIFSUD, 2005 |
| *Megabalanus tintinnabulum tintinnabulum* (Linnaeus) [14] | East Atlantic, south of Gibraltar | 1972 | Fouling species on ship hulls | Questionable? | RIZZO & SCHEMBRI, 1997 |
| *Spinocalanus terranovae* Damkaer [15] | Antarctic - Sub-Antarctic | 2001 | Unknown | Questionable? | LAPERNAT & RAZOULS, 2001 |
| *ECHINODERMATA* | | | | | |
| *Prionocidaris baculosa* (Lamarck) [16] | Indian Ocean | 1976 | Ballast water | Casual | SCHEMBRI, 1978 |
| *Eucidaris tribuloides* (Lamarck) [17] | Atlantic Ocean | 1998 | Ballast water | Established | TANTI & SCHEMBRI, 2006 |
| *BRYOZOA* | | | | | |
| *Celleporaria pilaefera* (Canu & Bassler) [18] | Indo-West Pacific | 1975-1976 | Ballast water; accidental importation with species used for aquaculture | Questionable | AGIUS *et al.,* 1977 |
| *Celleporaria aperta* (Hincks) [18] | Indo-Pacific | 1975-1976 | Ballast water; accidental importation with species used for aquaculture | Questionable | AGIUS *et al.,* 1977 |

**(continued)**

**Table 1 (continued)**

| Species | Natural range | First Maltese record | Mode of introduction | Status | Cited by |
|---|---|---|---|---|---|
| *POLYCHAETA* | | | | | |
| *Branchiomma boholense* (Grube) | | 1929 | Unknown | Established | GALIL, 2006 |
| *SIPUNCULA* | | | | | |
| *Aspidosiphon mexicanus* Murina [19] | West Atlantic Ocean | Unknown | Unknown | Questionable? | PANCUCCI-PAPADOPOULOU *et al.*, 1999 |
| *FISH* | | | | | |
| *Alepes djedaba* (Forsskal) | Indo-Pacific | 1961 | Lessepsian immigrant | Established | LANFRANCO, 1993 |
| *Fistularia commersonii* (Ruppell) [20] | Indo-Pacific, Eastern Central Pacific | 2005 | Lessepsian immigrant | Invasive | CINI, 2006 |
| *Pisodonophis semicinctus* (Richardson) [21] | Tropical Atlantic | 1999 | Unknown | Established? | INSACCO & ZAVA, 1999 |
| *Siganus luridus Ruppell* [22] | Indo-Pacific | 2006 | Lessepsian immigrant | Established | AZZURRO *et al.*, 2007 |
| *Siganus rivulatus Forsskal* [23] | Indo-Pacific | 2001 | Lessepsian immigrant | Questionable? | SAMMUT, 2001 |
| *Sphoeroides pachygaster* (Muller and Troschel) [24] | Circumglobal in tropical and temperate seas | 1994 | Atlantic immigrant or Lessepsian immigrant? | Invasive | CINI, 1999 |
| *Sphyraena chrysotaenia* Klunzinger [25] | Indo-Pacific | 1993 | Lessepsian immigrant | Established | LANFRANCO, 1993 |
| *Stephanolepis diaspros* Fraser-Brunner | Western Indian Ocean | 1993 | Lessepsian immigrant | Established | LANFRANCO, 1993 |

**(continued)**

**Table 1 (continued)**

| Species | Natural range | First Maltese record | Mode of introduction | Status | Cited by |
|---|---|---|---|---|---|
| *Parupeneus* sp. *?* [26] | [26] | 1979 | ? | ? | CILIA, 1979 |
| *Etrumeus teres* (*De* Kay) [27] | Indo-Pacific | [27] | [27] | ? | FALAUTANO *et al.,* 2006 |
| *Seriola fasciata* (Bloch) [28] | Western and Eastern Atlantic. (Distribution in the eastern Atlantic is uncertain due to past confusion with *Seriola carpenteri*) | [28] | [28] | ? | ANDALORO *et al.,* 1999 |
| *Seriola carpenteri Mather* [29] | Tropical Atlantic | [29] | [29] | ? | PIZZICORI *et al.,* 2000 |
| *Seriola* sp. [30] | Atlantic | [30] | Atlantic immigrant | ? | SAMMUT, 2001 |

## Notes on table 1

[1] Although *Asparagopsis armata* is an established alien species in the Maltese Islands, it is relatively rare. A possible reason for this may be that whereas the conspicuous macrophytic gametophyte stage of this species is rare, the tetrasporophyte stage, which is microscopic and therefore not visible in the field, is the most common form in which this alga occurs.

[2] *Botryocladia madagascariensis, Chondria pygmaea* and *Padina cf. boergesenii* are assigned 'questionable' status since the first two have not been reported again since the original record by CORMACI *et al.* (1997), while information on the latter has still to be published, therefore the presently available records of the distribution and frequency of occurrence of these species are insufficient to assess their status. All three species are very similar to common native species and difficult to identify in the field.

[3] *Lophocladia lallemandii, Womersleyella setacea* and *Caulerpa racemosa var. cylindracea* are invasive in that they are known to modify the floristic composition of their habitat (E. Lanfranco, personal communication 2007). All three species are known from Malta, Gozo, and Comino and are abundant from the upper infralittoral to the circalittoral (BORG *et al.,* 1997; CORMACI *et al.,* 1997; personal observations).

[4] *Atactodea striata* is considered a 'casual' since to date there is only one record of a single specimen, with dead soft parts, from Marsaxlokk Bay in August 1977 (CACHIA *et al.,* 2004).

[5] *Crassostrea gigas* was introduced deliberately in the Maltese Islands for

aquaculture purposes. In the mid-1970s attempts were made to start an aquaculture industry in the Maltese Islands and the (then) Fort St. Lucian Marine Station set up experimental oyster cultures at Marsaxlokk Bay, Mistra Bay and Rinella (AGIUS *et al.,* 1977, 1978). Spat of *C. gigas* was imported from Anglesey, Wales. Although the aquaculture venture came to an end in the late 1970s (SCHEMBRI & LANFRANCO, 1996), specimens of *C. gigas* are still occasionally met with in the wild along the Maltese coast (MALLIA, 1991; personal observations), suggesting that this species has managed to establish small breeding populations.

[6] *Pinctada radiata,* has been reported as abundant in the Levantine Sea by GALIL & ZENETOS (2002), as well as from the Tyrrhenian Sea, off Sicily, Malta, Pantelleria Island and France. In Malta it has been found as single specimens attached to stones in shallow (upper infralittoral) water (Bahar ic-Caghaq, Munxar Point, Ras il-Qawra and Gnejna Bay), and attached to old fishing ropes and moorings, usually in clusters of many individuals at various stages of growth, in deeper (infralittoral to circalittoral) water (CACHIA *et al.,* 2004; personal observations). This species is also sometimes offered at the local fish market in Marsaxlokk (CACHIA *et al.,* 2004). Although there is no information on the mode of introduction of *P. radiata* in the Maltese Islands, translocation of this species in the Mediterranean has been reported to include intentional introduction for mariculture purposes in Greece (GALIL & ZENETOS, 2002), transport by ships (ZIBROWIUS, 1992), and as an epibiont on marine turtles (OLIVERIO *et al.,* 1992); the latter two mechanisms may also have operated in the Maltese Islands.

[7] Other than a 1973 record of a beached, freshly dead specimen from Marsaxlokk Bay and another in 1975 of live specimens from 10m at Marsamxett Harbour (CACHIA, 1981), there are no other published or unpublished reports of *Crepidula fornicata* from Malta. Furthermore, the last aquaculture ventures involving bivalves closed down in the mid-1970s, so no fresh individuals could have been accidentally imported with bivalve spat. This species is thus assumed to be a 'casual' alien.

[8] No further specimens of *Gibbula cineraria* have been found in the wild subsequent to those recorded in 1976 (SCHEMBRI, 1979), hence this species is considered a 'casual' alien.

[9] *Natica gualteriana* has not been recorded again since the original record in 1996, when CACHIA *et al.* (1996) found a few freshly dead specimens at Mellieha Bay.

[10] The sea hare *Bursatella leachi* is a Lessepsian immigrant that first appeared along the Israeli coasts around 1940 but is now known from as far west as Sardinia (ZENETOS *et al.,* 2004). It was first recorded from Malta in 1969 by BEBBINGTON (1970). Another specimen collected by J.A. Borg from near fish farm cages (no date) was reported by SAMMUT & PERRONE (1998). Recent records of *B. leachi* in the Maltese Islands are from June and October 2007, when several individuals were observed and photographed on a sandy bottom at 2m depth at St. George's Bay (St. Julians) (Joseph A. Borg, personal communication, 2007). This species is thus regarded as established in the Maltese Islands.

[11] *Aplysia parvula* was first recorded from the Mediterranean from the southern coast of Turkey in 1961, having been

previously misidentified as *Aplysia punctata* (BEBBINGTON, 1970). After its first record from Malta in 1967 by BEBBINGTON (1970), *A. parvula* was cited by SAMMUT & PERRONE (1998) from Birzebbuga. This species is presently regarded as circumtropical. In the NE Atlantic, its presence has been confirmed for the Canary Islands, the Azores, Madeira, Cape Verde Island, and also for the Iberian peninsula including the Mediterranean coast of Spain; however, it is likely that *Aplysia parvula* is a complex of cryptic species and therefore the Mediterranean populations may not actually be alien (José Templado, personal communication 2007). This species is therefore included as 'questionable' for the present.

[12] In their study, SAMMUT & PERRONE (1998) reported *Aeolidiella indica* spawning in January, and *Polycerella emertoni* spawning in July and August. On the basis of this information it is assumed that these two species have probably established populations in the Maltese Islands.

[13] A living specimen of *Dosima fascicularis* was found washed ashore at Gnejna Bay in 2004 (MIFSUD, 2005). This record is the first for the Maltese Islands, and probably also for the Mediterranean (MIFSUD, 2005). Although we include *D. fascicularis* in the list of alien species, we do so with some reserve; this species occurs attached to floating material and is common in the Atlantic, therefore we cannot exclude the possibility that it entered the Mediterranean through the Straits of Gibraltar incidentally, in what may be a natural expansion of its range.

[14] *Megabalanus tintinnabulum tintinnabulum,* whose natural area of distribution is the Atlantic coast of Africa from Gibraltar to the Cape of Good Hope (RELINI, 1980), is common on ships entering the Malta dockyards for repairs, but it has never been found in the wild in Maltese waters (SCHEMBRI & LANFRANCO, 1996; RIZZO & SCHEMBRI, 1997). Although this species is a transitional alien with the possibility of becoming established locally, no other records from the Maltese Islands exist to our knowledge. Therefore, the status of this species remains 'questionable' for the present.

[15] LAPERNAT & RAZOULS (2001) and RAZOULS *et al.* (2005-2007) record *Spinocalanus terranovae,* a meso-bathypelagic copepod, from a depth of 2000m off the southeast coast of Malta and this appears to be the only Mediterranean record of this Antarctic to Sub-Antarctic species; RAZOULS *et al.* (2005-2007) comment that 'The presence of this species in the Mediterranean is surprising, but conforms to that of the descriptor'. Nothing else is known about this species in Maltese waters therefore its status remains 'questionable'.

[16] The record by SCHEMBRI (1978) refers to an individual of *Prionocidaris baculosa* collected in 1976 from the ballast tank of a ship that had entered the Malta dockyards; no other specimens of this species have been recorded from Maltese waters (TANTI & SCHEMBRI, 2006), therefore this species is considered as casual.

[17] The record of *Eucidaris tribuloides* from the Maltese Islands is also the first of this species for the Mediterranean (TANTI & SCHEMBRI, 2006). Two populations of *E. tribuloides* are known, one in the inner part of a sheltered creek (Kalkara Creek, Grand Harbour) on mud at depths of 3-10m, and the other in Sliema

Creek (Marsamxett Harbour) on a bottom of muddy sand at a depth of 3-7m; individuals occurred on debris or some other hard substratum rather than on the muddy or sandy bottom. In both localities, one or two aggregates of 5-10 adult individuals each were noted (TANTI & SCHEMBRI, 2006).

[18] AGIUS *et al.* (1977) reported *Celleporaria pilaefera* and *C. aperta* on baskets and the cages holding these baskets from an oyster farm at Rinella (in Grand Harbour); *C. pilaefera* was rare but *C. aperta* was common. To our knowledge, there are no other records of these species from Malta in the literature. All bivalve aquaculture ventures had shut down by the late-1970s and it is not known if populations of these two species still persist, so their status remains 'questionable'.

[19] PANCUCCI-PAPADOPOULOU *et al.* (1999) make reference to unpublished records by Galena-Vantsetti Murina of this species from Malta and Lampedusa. We are not aware of any other record of *Aspidosiphon mexicanus* for Malta. Since PANCUCCI-PAPADOPOULOU *et al.* (1999) give no indication of the number of individuals recorded from Malta or whether the occurrence of this species was transient or not, we are regarding its status in the Maltese Islands as 'questionable' for the present.

[20] *Fistularia commersonii* was first recorded in the Mediterranean along the coast of Israel in 2000; subsequently it spread westward along the coast of Antalya (Turkey), Rhodes and Crete, and has recently also reached the central Mediterranean (GOLANI *et al.,* 2004). The first record of *F. commersonii* from the Maltese Islands was in 2005, when a specimen caught from Xwejni Bay, Gozo was identified by one of us (PJS) and reported in a newspaper article by CINI (2006). Since then, this species has been sighted more than once around the Maltese Islands, on two particular occasions in shoals of about 20 individuals (Mark Dimech, personal communication 2007; Sarah Gauci Carlton, personal communication 2007).

[21] According to INSACCO & ZAVA (1999) and ELI (2006), *Pisodonophis semicinctus* occurs in the 'Malta Channel', where the latter author states it has become established. The geographical limits of the 'Malta Channel' can be interpreted in different ways, leading to doubt as to whether this species has been actually sighted in Maltese waters or not. However, if the 'Malta Channel' is taken to include the sea area between Sicily and Tunisia, including also the Pelagian Islands and Pantelleria, then the chances of *P. semicinctus* also occurring in Maltese waters as defined here are high. For this reason we include this species in the list of aliens occurring in Maltese waters and regard its status as 'established' with some reserve.

[22] Six individuals of *Siganus luridus* were collected from Malta in October 2006; three of these were mature females (23.8 – 24.6 cm TL) carrying eggs and two were mature males (23.0 – 24.0cm TL) (AZZURRO *et al.,* 2007).

[23] LANFRANCO (1993) includes *Siganus rivulatus* in his catalogue of Maltese fish and while hinting that this species might occur in Malta, he does not provide a definite record. SAMMUT (2001) includes this species in his work on fish of the central Mediterranean with the following comment 'This new species lives at the edges of reefs with broken seabeds and feeds mainly on algae. It is rare but may become more common...' and '...amateur

fishermen occasionally find it entangled in their trammel nets...' The date of introduction of this species in Malta therefore appears to be between 1993 and 2001. On the other hand, neither author includes *Siganus luridus* so there is the possibility that the records of *Siganus rivulatus* may refer to *Siganus luridus* and for this reason, for the present we regard this record as doubtfully 'questionable'.

[24] In the Mediterranean, *Sphoeroides pachygaster* was first reported from the Balearic Islands in the western basin in 1979, and subsequently from the eastern basin from Ashdod, Israel, in 1991 (PSOMADAKIS *et al.,* 2006). *Sphoeroides pachygaster* is now widespread and common throughout the Mediterranean, including the Straits of Sicily (BIANCHINI & RAGONESE, 2007). Although general opinion considers *S. pachygaster* a recent immigrant of Atlantic origin, there is also the possibility that this circum-globally distributed puffer fish is a Lessepsian immigrant of ancient origin (RELINI & ORSI RELINI, 1995). Neither LANFRANCO (1993) nor SAMMUT (2001) record this species in their catalogues of Maltese fishes; however, in an illustrated newspaper article on this species (given as *Sphoeroides cutaneus,* which is a junior synonym), CINI (1999) states that fishermen he interviewed said that they first noted the species in Maltese waters around 1994. *S. pachygaster* is now relatively common in the Maltese Islands and is caught regularly in trawls (Mark Dimech, personal communication 2007).

[25] GALIL (2006) gives 1961 as the date when *Sphyraena chrysotaenia* was first reported from Maltese waters, apparently basing this on a list of the Maltese vernacular names of Mediterranean fish published by the (then) Department of Fisheries of the Government of Malta (BARBARA, 1961). However, it is clear from his introductory comments that Barbara was giving vernacular Maltese names to species known to occur in the Mediterranean without any regard as to whether these species actually formed part of the Maltese fauna or not; this work cannot therefore be taken as a reliable source of information on the occurrence of *Sphyraena chrysotaenia* (or any other alien fish) in Maltese waters. The first reliable record of this species from Malta is due to LANFRANCO (1993).

[26] CILIA (1979) records *Pseudupeneus barberinus* (Lacepède) (= *Parupeneus barberinus*) from Gozo and LANFRANCO (1993) repeats Cilia's record. According to GOLANI *et al.* (2004) *Parupeneus barberinus* is to be excluded from the Mediterranean list of exotic fish since records of this species in the literature have been shown to be erroneous. *Parupeneus barberinus* does not occur in the Red Sea but the closely related *Parupeneus forsskali* (Fourmanoir & Guézé) does (GOLANI *et al.,* 2004), and this species has recently been recorded from the Levantine coast of Turkey (ÇINAR *et al.,* 2006). We include a species of *Parupeneus* in our list since CILIA (1979) provides a good description of the fish he records as *'Pseudupeneus barberinus'* ('... unmistakable longitudinal black line from the nostril, through the eye, to the second dorsal fin was clearly seen' and a crude drawing; however, the fish depicted shows some resemblance to *P. forsskali.* Although no further information or records exist, there is a possibility that Cilia might have actually encountered a species of *Parupeneus* (*P. forsskali* ?) in Gozo.

[27] FALAUTANO *et al.* (2006) reported the occurrence of this Lessepsian

immigrant at Lampedusa in 2005. This species has yet to be recorded from the Maltese Islands. However, owing to the proximity of the Maltese Islands to Lampedusa, there is a high probability that *Etrumeus teres* will also occur in Maltese waters.

[28] *Seriola fasciata* has not yet been recorded from the Maltese Islands as far as we are aware, however, during fishing and experimental surveys between 1994 and 1998, ANDALORO *et al.* (1999) report collecting 42 individuals from Sicilian waters and from near Lampedusa. Owing to the position of the Maltese Islands in the Straits of Sicily, there is a high probability of *S. fasciata* also occurring in waters around the Maltese Islands. We therefore include this species as '?'.

[29] As for *Seriola fasciata, Seriola carpenteri* has not yet been recorded from the Maltese Islands; however, PIZZICORI *et al.* (2000) report capturing 148 specimens of this species 42 nautical miles east of Lampedusa during a stock assessment study in 1997. Owing to 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 include this species as '?'.

[30] SAMMUT (2001) records a species of Amberjack that he gives as *Seriola samstriata* (Rio) and states that it is occasionally frequent around Malta and Gozo; he considers this a Western Atlantic species that has entered the Mediterranean through the Straits of Gibraltar, and a new record for the Mediterranean. However, this species is neither cited in ESCHMEYER (1998), nor in the FishBase database (www.fishbase.org). SAMMUT (2001) provides a good description of the fish and states that he has personally captured fry, young and adults. While this species is certainly not the native *Seriola dumerili* (Risso), we cannot assign it with certainty to any of the alien species of *Seriola* that have been recorded from the Mediterranean. The description provided by SAMMUT (2001) more or less fits that of juvenile *Seriola fasciata* and the author himself says that his species is 'closely related to a similar species *S. fasciata',* however, it does not agree with this species in all characteristics, and the rather poor drawing that SAMMUT (2001) includes has elements that are reminiscent of *Seriola rivoliana* (Valenciennes in Cuvier & Valenciennes), for example, the arched dorsal profile relative to the ventral profile, the seven divided dark vertical bars on the body, the rather elongate first dorsal and anal rays. The latter species has not been recorded from Maltese waters but there is a record of a single specimen caught 40 nautical miles west of Lampedusa (CASTRIOTA *et al.,* 2002). Because of the uncertain identity of the species recorded by SAMMUT (2001) we are including it in the catalogue as *Seriola* sp. with a '?'.

**Additional notes on species imported for Aquaculture**

Species of bivalves that occur naturally in the Maltese Islands but stock of which had been imported from elsewhere for the aquaculture industry during the mid-1970s include *Ostrea edulis* (Linnaeus), *Mytilus edulis* (Linnaeus), *Mytilus galloprovincialis* (Lamarck), and *Ruditapes* (= *Tapes*) *decussatus* (Linnaeus) (AGIUS *et al.,* 1977, 1978; CACHIA *et al.,* 2004; Carmelo Agius, personal communication

2007). Spat of *O. edulis* was imported from Anglesey, Wales; the *Mytilus* spp. were imported from Italy, and *R. decussatus* was imported from France (although it is not known if from the Atlantic or Mediterranean coast). As a consequence of these deliberate introductions, non-indigenous populations which may potentially be genetically different from those native to the Maltese Islands exist.

*Dicentrarchus labrax* (Linnaeus) and *Sparus aurata* Linnaeus are native to the Maltese Islands. However, stock of these two species was imported from elsewhere for aquaculture purposes (SCHEMBRI & LANFRANCO, 1996; Carmelo Agius, personal communication 2007). Fingerlings of *D. labrax* have been imported from Italy, the Atlantic and Mediterranean coasts of France, Cyprus, Greece and Tunisia; fingerlings of *S. aurata* have been imported from northern Spain (Carmelo Agius, personal communication 2007). Similarly, stocks of *Argyrosomus regius* (Asso) have been imported for aquaculture purposes from the Atlantic coasts of France (Carmelo Agius, personal communication 2007). Therefore, non-indigenous (Atlantic) genetic stock of all three species has been imported to the Maltese Islands.

Stock of the freshwater/brackish Sabaki Tilapia *Oreochromis spilurus spilurus* (Gunther), native to Africa, was imported into Malta from Mombasa (Indian Ocean) for aquaculture purposes and was experimentally converted from freshwater to marine water and cultured in the sea (Carmelo Agius, personal communication 2007). Although this species is no longer cultured in the Maltese Islands, we are recording its previous occurrence since there is a remote possibility that individuals may have escaped captivity.

## Discussion

The present review lists a total of 48 alien marine species that occur or have been reported from the Maltese Islands. Of these, 39 species are accepted and the rest are doubtful records, either because information on the presence of these species in Maltese waters is insufficient, or because the species have only been transiently recorded from Maltese waters (for example, *Megabalanus tintinnabulum tintinnabulum)*. The most represented groups are molluscs (14 species), fish (13 species) and macrophytes (10 species). According to the classification scheme for 'status' used here, 25 species are considered to be 'established', of which 6 species are 'invasive' (Fig. 1).

The six species considered invasive *(Lophocladia lallemandii, Womersleyella setacea, Caulerpa racemosa var. cylindracea, Percnon gibbesi, Fistularia commersonii* and *Sphoeroides pachygaster)*

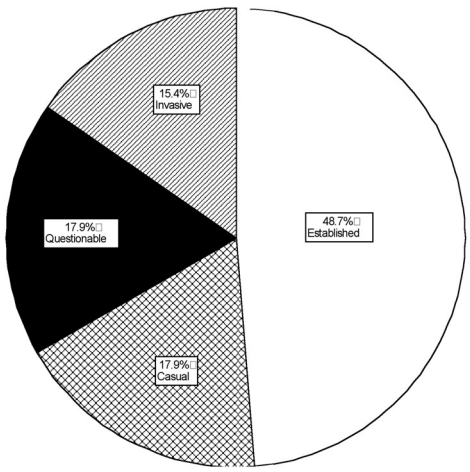


***Fig. 1:*** Establishment status in the Maltese Islands of the alien species included in the present review. Those with a doubtful occurrence or whose status is both 'questionable' and doubtful are excluded. The categories used are defined in the text.

are classified as such on the basis of their distribution and abundance, their capacity for proliferation, and their impact on native species and/or biotic communities. All six are included in the list of the top 100 'worst invasives' in the Mediterranean by STREFTARIS & ZENETOS (2006). In a study by CILIA (1999), *W. setacea* was found to occur with a percentage cover of 13.33 ± 11.11% and 35.56 ± 17.78% on two maerl beds off the north-eastern coast of Malta. The densely branched filamentous thalli of this rhodophyte grow on and between living and non-living rhodoliths and entangle the surface layers, binding them together into a crust. Whereas this stabilised surface layer of the maerl bed provides an additional substratum for settlement of foliose macroalgae on the maerl, a high cover of *W. setacea* could affect the settlement of other species negatively, particularly those living interstitially amongst the rhodoliths, by depriving propagules of settling sites. In addition, extensive algal cover can be detrimental to the rhodoliths in that it cuts down the amount of photosynthetically active radiation reaching the photosynthetic tissues of the rhodolith-forming algae, as well as preventing them from turning – a requirement for their survival. Moreover, sediment trapped in the surface crust may create an anoxic boundary-layer around the thallus of the rhodolith-forming algae, smothering them and limiting rhodolith growth. Therefore, the monopolization of the substratum by *W. setacea* can have a negative effect on the assemblages associated with maerl beds (CILIA, 1999), which are habitats of conservation concern (BIOMAERL TEAM, 2003).

*Caulerpa racemosa var. cylindracea* has occurred in the Mediterranean Sea since at least the early 1990s, and to date, it has colonized the coasts of 12 nations throughout the entire sea (STREFTARIS & ZENETOS, 2006; OULD-AHMED & MEINESZ, 2007). Since its first record from the Maltese Islands in 1997, this alga has spread to most Maltese coasts, where it has formed dense stands on infralittoral hard substrata and sparse stands on infralittoral soft substrata (BORG *et al.,* 1997). In the Maltese Islands, *C. racemosa var. cylindracea* inhabits a depth range of between 0.1m and 40m, with a percentage cover that varies between 1% and 70% for different sites around the islands (MIFSUD & LANFRANCO, 2007). The highest percentage cover values were found at sites subject to anthropogenic disturbance, suggesting that degraded localities favour expansion and enhanced growth of this species (MIFSUD & LANFRANCO, 2007).

Since the first record from Malta in 2001 (BORG & ATTARD-MONTALTO, 2002), *Percnon gibbesi* has become widespread in the Maltese Islands, where it shows a strong affinity for boulder habitats (SCIBERRAS, 2005). In such habitats, the crab occurs in densities ranging between 1.5 ± 0.5 to 11.9 ± 7.1 individuals per $m^2$ (SCIBERRAS & SCHEMBRI, 2007a). The occurrence of berried females and of juveniles shows that this species has established self-regenerating populations in the Maltese Islands. Direct observations in the field suggest that *P. gibbesi* interacts with the native grapsid *Pachygrapsus marmoratus* Fabricius. However, field observations and laboratory experiments suggest that in such encounters, *P. marmoratus* is the competitive dominant species (SCIBERRAS & SCHEMBRI, 2007b). Nonetheless, the wide distribution and high densities of *P. gibbesi* imply that this alien is utilizing

space that is potentially available for other native species. *Percnon gibbesi* is predominantly herbivorous (PUCCIO *et al.,* 2006; MS, unpublished data), and its voracious appetite might have an impact on the abundance of the algal species on which it feeds and on the structure of the communities of which they form part.

The puffer fish *Sphoeroides pachygaster* probably appeared in Maltese waters in the early 1900 s , at first a rare curiosity, it is now fished regularly, showing that it has spread and become common in the space of about 15 years; very little is know about its ecology in Maltese waters, however. The cornet fish *Fistularia commersonii* was first recorded from the Maltese Islands in 2005, but in the space of less than two years seems to have become very common and is now occurring in shoals on rocky reefs. The impact of both species on Maltese benthic ecosystems is completely unknown.

For some aliens listed in the present work, the mode of introduction is unknown or assumed, whereas in some cases introduction is thought to have been facilitated by more than one vector (for example, *Crepidula fornicata* and *Percnon gibbesi).* Immigration through the Suez Canal and transportation via shipping and in connection with aquaculture (both for stocking and due to accidental transport) account for 31.8%, 20.5% and 11.4% respectively, of those species with a known mode of introduction (Fig. 2). Vessels provide suitable transportation habitats in ballast waters, sediment in ballast tanks, sediment attached to anchors, and hull fouling (CARLTON, 1985; COUTTS *et al.,* 2003). Nine species in the list presented here were probably introduced by shipping (Fig. 2), and this is related to the island's position at the centre of the Mediterranean close to main shipping routes, as well as to the harbour, dockyard and transhipment facilities offered by the islands. Introductions due to aquaculture may be intentional or unintentional; *Crepidula fornicata* and *Gibbula cineraria* are two examples of the latter. Westward spreading of Lessepsian immigrants accounts for 32% of the species (Fig. 2); such spreading may be natural range extension of aliens now established in the Eastern Mediterranean, or it may be facilitated by human transport. Natural range extension seems to operate particularly in the case of fish,

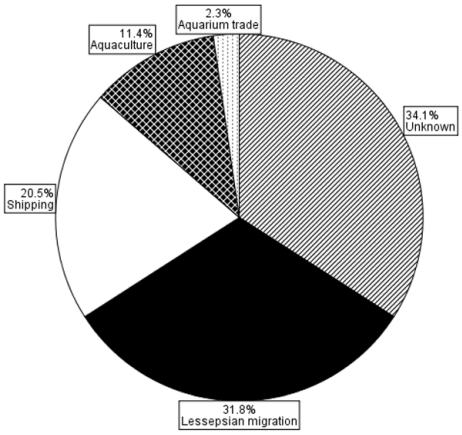


***Fig. 2*:** Mode of introduction in the Maltese Islands of alien species included in the present review. Those with a doubtful occurrence or whose establishment status is both 'questionable' and doubtful are excluded. The categories are: Lessepsian migration (introduction via the Suez Canal), Aquaculture (accidental or intentional introduction for aquaculture purposes), Shipping (transport in ballast tanks or as fouling organisms on ship hulls), Aquarium trade (intentional or accidental release of alien species from aquaria), and Unknown (species with an unknown or doubtful mode of introduction in the Maltese Islands). Species that may have been introduced by multiple modes (for example, *Percnon gibbesi* and *Crepidula fornicata)* have been included under each category.

both Lessepsian immigrants (for example, *Fistularia commersonii* and *Siganus luridus)* and those originating from the Atlantic *(Sphoeroides pachygaster)*.

Since the early 1900 s, there has been an increasing trend in the number of marine alien species reported from the Maltese Islands (Fig. 3). However, these data should be interpreted with care. For example, the high peak in the 1990s is the result of an intensive survey of benthic marine algae carried out in 1994 (CORMACI *et al.,* 1997) in which most alien species of algae were reported for the first time, and the publication of a revised edition of Lanfranco's catalogue of Maltese fish (LANFRANCO, 1993) wherein a number of alien species were recorded, also for the first time, from Maltese waters.

The high proportion of warm-water species of Indo-Pacific and subtropical Atlantic origin that now occur in Maltese waters, including many that have only recently been reported and which may therefore be new arrivals, may be a consequence of the general warming trend of Mediterranean waters in recent years (BIANCHI, 2007; GALIL, 2007; OCCHIPINTI-AMBROGI, 2007); if this is the case, then further arrivals are to be expected, which makes monitoring of the alien marine biota of the Maltese Islands of critical importance both as an indicator of change in the Mediterranean marine environment, and for the ecological effects that such alien species may have on local species, communities and ecosystems.

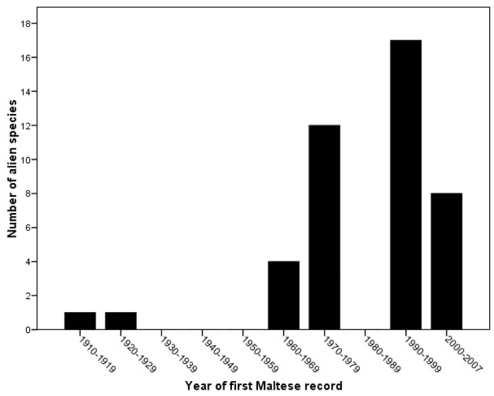


***Fig. 3:*** The number of alien species recorded from the Maltese Islands and surrounding waters per decade. Species with a doubtful occurrence or whose establishment status is both 'questionable' and doubtful are excluded.

**Acknowledgements**

We thank the various persons who contributed valuable personal observations of alien species in the Maltese Islands, in particular Dr. Joseph A. Borg, Mark Dimech, Sarah Gauci Carlton, Edwin Lanfranco and Dr. José Templado. Special thanks are due to Prof. Carmelo Agius and Mr Edwin Lanfranco (Department of Biology, University of Malta) for information on species in aquaculture in Malta and on marine algae, respectively. We are grateful to Dr. Argyro Zenetos (Hellenic Centre for Marine Research, Greece) for inviting this review, for providing data for Malta from her database of Mediterranean alien species and for much other help. We are also grateful to two anonymous referees for suggesting improvements to this paper. This work was supported in part by research grants from the University of Malta, for which we are thankful.

**Addendum**

While the present review was in press, YOKES *et al.* (2007) published their records of the foraminiferan *Amphistegina lobifera* Larsen from the Maltese

Islands. Live specimens were collected from four stations in Malta, Gozo and Comino in June 2006, suggesting that this species is well established. This foraminiferan is widely distributed in the Indo-Pacific and Atlantic; in the Mediterranean, where it is an alien, this species has been recorded from Israel, Lebanon, Greece, Turkey and the Sea of Marmara in the Eastern Mediterranean basin, and from Libya and Tunisia in Central Mediterranean (YOKES *et al.,* 2007). How *Amphistegina lobifera* arrived in the Maltese Islands is not known. With the present record, the number of marine aliens known from the Maltese Islands is 49 species, of which nine are dubious records. Of the accepted records, 65% are established; of the established species, 15% are considered invasive; 17.5% are casual, and 17.5% are questionable.

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*Accepted in 2007*