Marine Biodiversity Records, page 1 of 10. © Marine Biological Association of the United Kingdom, 2015
doi:10.1017/S1755267215000123; Vol. 8; e35; 2015 Published online

Records of alien marine species of Indo-Pacific origin at Sigri Bay (Lesvos Island, north-eastern Aegean Sea)

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Ten alien species were recorded in a first-time survey of the benthic biodiversity of the upper sublittoral at Sigri Bay (Lesvos Island, north-eastern Aegean Sea). The record of the mollusc Syrnola fasciata *is the first in Hellenic territorial waters. The records of the brown alga* Stypopodium schimperi*, the bivalve* Septifer cumingii*, the gastropods* Syrnola fasciata *and* Smaragdia souverbiana *and the bony fish* Siganus luridus *constitute evidence for a further northwards extension of their geographic ranges in the Aegean Sea. The record of* Cerithium scabridum *is the first in Lesvos Island and partially fills the gap in the distribution of the species in the eastern Aegean Sea. We also recorded the green alga* Caulerpa cylindracea*, the angiosperm* Halophila stipulacea *and the bivalve* Pinctada imbricata radiata*, which are widely distributed in the eastern Mediterranean. The polychaete* Marphysa adenensis*, which was also found at Sigri Bay, has recently been reported for the first time from the Mediterranean as a cryptogenic species.*

Keywords: invasive species, non-indigenous species, Lessepsian migrants, geographic range, geographic distribution, eastern Mediterranean

Submitted 11 July 2014; accepted 29 January 2015

INTRODUCTION

Biological invasion, i.e. the process of human-mediated geographic range expansion of a species (Williamson, 1996; Lockwood *et al.*, 2013), is considered a major threat to marine biodiversity and ecosystem functioning, and a cause for serious economic and social damage (Molnar *et al.*, 2008; Costello *et al.*, 2010). The phenomenon of biological invasion is especially pronounced in the Mediterranean, where, in a total of approximately 17,000 marine species (Coll *et al.*, 2010), there are currently 986 alien species, 134 of which are invasive (Zenetos *et al.*, 2012). Accordingly, biological invasion is considered of particular importance to current EU policies relevant to biodiversity and the marine environment, and this is exemplified in documents such as the Marine Strategy Framework Directive (MSFD) (EU, 2008a), the European Commission's Communications on 'A European Strategy for Marine and Maritime Research' (EU, 2008b) and 'The EU Biodiversity Strategy to 2020' (EU, 2011). Additionally, invasive alien species have been the focus of the recent European Commission Proposal for a Regulation 'On the Prevention and Management of the Introduction and Spread of Invasive Alien Species' (EU, 2013).

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The major pathways of introduction (Hulme *et al.*, 2008) of alien species to the Mediterranean are the active dispersal of species occurring in the Red Sea via the human-made 'corridor' of the Suez Canal ('Lessepsian migration'), and their unintentional transportation by shipping activities, i.e. via hull biofouling and ballast waters (Zenetos *et al.*, 2012; Nunes et al., 2014). Lessepsian migration (Por, 1971) has been taking place in the Mediterranean incessantly since the opening of the Suez Canal in 1869 and has accelerated in recent years (Raitsos *et al.*, 2010). The eastern Mediterranean currently hosts a total of 775 alien species, mainly of Indo-Pacific origin (Zenetos *et al.*, 2012). Many of these species have entered the Aegean Sea, with the Dodecanese islands being the main entrance point (Pancucci-Papadopoulou *et al.*, 2012). The European Alien Species Information Network database (EASIN) presently contains records for 201 alien marine species in the Aegean Sea (Katsanevakis *et al.*, 2012; EASIN, 2014), while the corresponding records in the Marine Mediterranean Invasive Alien Species Database (MAMIAS) online database are 289 (MAMIAS, 2014). Most of the alien species in the Aegean Sea are benthic invertebrates, followed by fish and macroalgae, mainly of Indo-Pacific origin (Zenetos *et al.*, 2011). The presence of the thermophilic Lessepsian migrants is very important in the south Aegean Sea (Zenetos *et al.*, 2009b), which is filled with warm, highly saline water from the Levantine basin (Theocharis *et al.*, 1999). However, it is often held (e.g. Pancucci-Papadopoulou *et al.*, 2005; Zenetos *et al.*,

2005a; Katsanevakis *et al.*, 2013) that the occurrence of Lessepsian migrants is generally negligible in the north Aegean Sea, where the waters are colder (Zervakis & Georgopoulos, 2002), a few recently published exceptions notwithstanding (e.g. Karachle *et al.*, 2004; Zenetos *et al.*, 2005b; Manousis *et al.*, 2010; Yaglioglu *et al.*, 2011; Çinar and Dagli, 2012; Manousis & Galinou-Mitsoudi, 2014). On the other hand, the alien species whose pathway of introduction is shipping activities have invaded locations throughout the Aegean Sea, with major gulfs with dense marine traffic (e.g. Saronikos, Thermaikos) being hotspots for these species (Katsanevakis *et al.*, 2013).

The abundance and state characterization of non-indigenous species, especially the invasive ones, will be used as criteria for determining the environmental status relevant to the 'non-indigenous species' descriptor of Annex I to the MSFD (EU, 2010). Given the fact that new alien species are introduced every year in the Mediterranean and the Aegean Sea, and that the distribution of many of the introduced species is expanding, continuous collection of data on the geographical distribution of alien species, and the pathways of their introduction, are deemed essential prior tasks for the assessment and management of biological invasions and the environmental quality of marine waters at large (Meliane & Hewitt, 2005; Zenetos *et al.*, 2012; Katsanevakis *et al.*, 2013).

This paper aims to contribute to our knowledge of the current patterns of distribution and pathways of introduction of alien marine species in the north-eastern Aegean Sea.

MATERIALS AND METHODS

A survey of the benthic biodiversity (megafauna, macrofauna and macrophytic flora) of the upper sublittoral zone of Sigri Bay (Lesvos Island, north-eastern Aegean Sea) was conducted in 2013 (Figure 1). The marine environment in the Sigri Bay is considered to be relatively undisturbed, the most important pressure being artisanal fisheries. One of the principal aims of the survey was to check for the presence of alien marine species. The sampling of soft substrate macrofauna was carried out in June, with a Van Veen sediment grab (0.1 m^2 sampling surface), at seven sampling stations (two replicate samples per sampling station). The laboratory analysis of the macrofauna was carried out according to Eleftheriou & McIntyre (2005). A visual census (Harmelin-Vivien & Harmelin, 1975; Harmelin *et al.*, 1985) and an underwater photographic survey of the megafauna and macrophytic flora on hard substrate and in *Posidonia oceanica* (Linnaeus) Delile meadows was carried out by scuba diving in September, at eight sampling stations at a depth of ca. 15 m (three transects of 25 × 5 m^2 per habitat and per sampling station). The geographical coordinates of all sampling stations are given in Table A1 in the appendix. Accepted species names and authorities were checked using a web service provided by the World Register of Marine Species (WoRMS) online database (WoRMS Editorial Board, 2014). Species distribution-related data (range in the Mediterranean, extent of occurrence and area of occupancy in the Aegean Sea) were assessed using the mapping web service provided by the European Alien Species Information Network (EASIN) online database (Katsanevakis *et al.*, 2012; EASIN, 2014). The ranges of the species in the Mediterranean are given in terms of the marine ecoregions where the species have been recorded, according to the scheme of Spalding *et al.* (2007). The area of occupancy was assessed in relative terms, using the 10 × 10 km^2 grid option of the EASIN mapping web service. The species impact was also retrieved from the EASIN online database (EASIN, 2014). The information given in this paper regarding the beogeographical origin of the species and whether they are established or invasive in the eastern Mediterranean follows Zenetos *et al.* (2010). We considered as 'established' in the study area those species that have self-maintaining populations, as evidenced by a minimum of two (three for fishes) records from different localities in the study area (sensu Zenetos *et al.*, 2005a; Katsanevakis & Tsiamis, 2009).

RESULTS AND DISCUSSION

Ten alien marine species were recorded in the study area (Table 1): the gastropods *Cerithium scabridum*, *Smaragdia souverbiana* and *Syrnola fasciata,* the bivalves *Septifer cumingii* and *Pinctada imbricata radiata*, the polychaete worm *Marphysa adenensis*, the bony fish *Siganus luridus,* the macroalgae *Caulerpa cylindracea* and *Stypopodium schimperi* and the angiosperm *Halophila stipulacea*. The record of the mollusc *Syrnola fasciata* is the first from Hellenic territorial waters. The records of the molluscs *Septifer cumingii*, *Syrnola fasciata* and *Smaragdia souverbiana*, the bony fish *Siganus luridus* and the brown alga *Stypopodium schimperi* constitute evidence for a further northwards extension of their geographic ranges in the Aegean Sea. The record of *Cerithium scabridum* is the first in Lesvos Island and partially fills the gap in the distribution of the species in the eastern Aegean Sea. The polychaete *M. adenensis,* which was also found in Sigri Bay, has recently been reported for the first time from the Mediterranean as a cryptogenic species (Katsiaras *et al.*, 2014). All of the recorded species were rare, with the exception of *Caulerpa cylindracea*, which was observed on a variety of substrates across the study area.

Caulerpa cylindracea

Synonym: *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman & Boudouresque

The green alga *Caulerpa cylindracea*, endemic to south-west Australia (Verlaque *et al.*, 2003), was introduced in the Mediterranean via the Suez Canal. It is presently one of the best-known and most important invasive alien species in the Hellenic seas and the Mediterranean in general (Streftaris & Zenetos, 2006; Tsiamis *et al.*, 2010), its distribution reaching currently as far as the Canary Islands (Verlaque *et al.*, 2004). The broad distribution of *C. cylindracea* in a wide spectrum of habitats across the Mediterranean is based on its especially effective vegetative and sexual reproduction, as well as secondary dispersal mechanisms, i.e. shipping (Klein & Verlaque, 2008). In many cases, *C. cylindracea* has drastically changed the structure and functioning of the local ecosystems, causing a decline in macroalgal diversity and alteration in the composition of macrofauna, as well as a modification of the structure and properties of the substrate (Piazzi *et al.*, 2005; Klein & Verlaque, 2008).

In the area of Sigri Bay, *C. cylindracea* was found at all of the visual census stations and at the macrofauna sampling stations MF1, MF5 and MF7, in the northern part of the bay

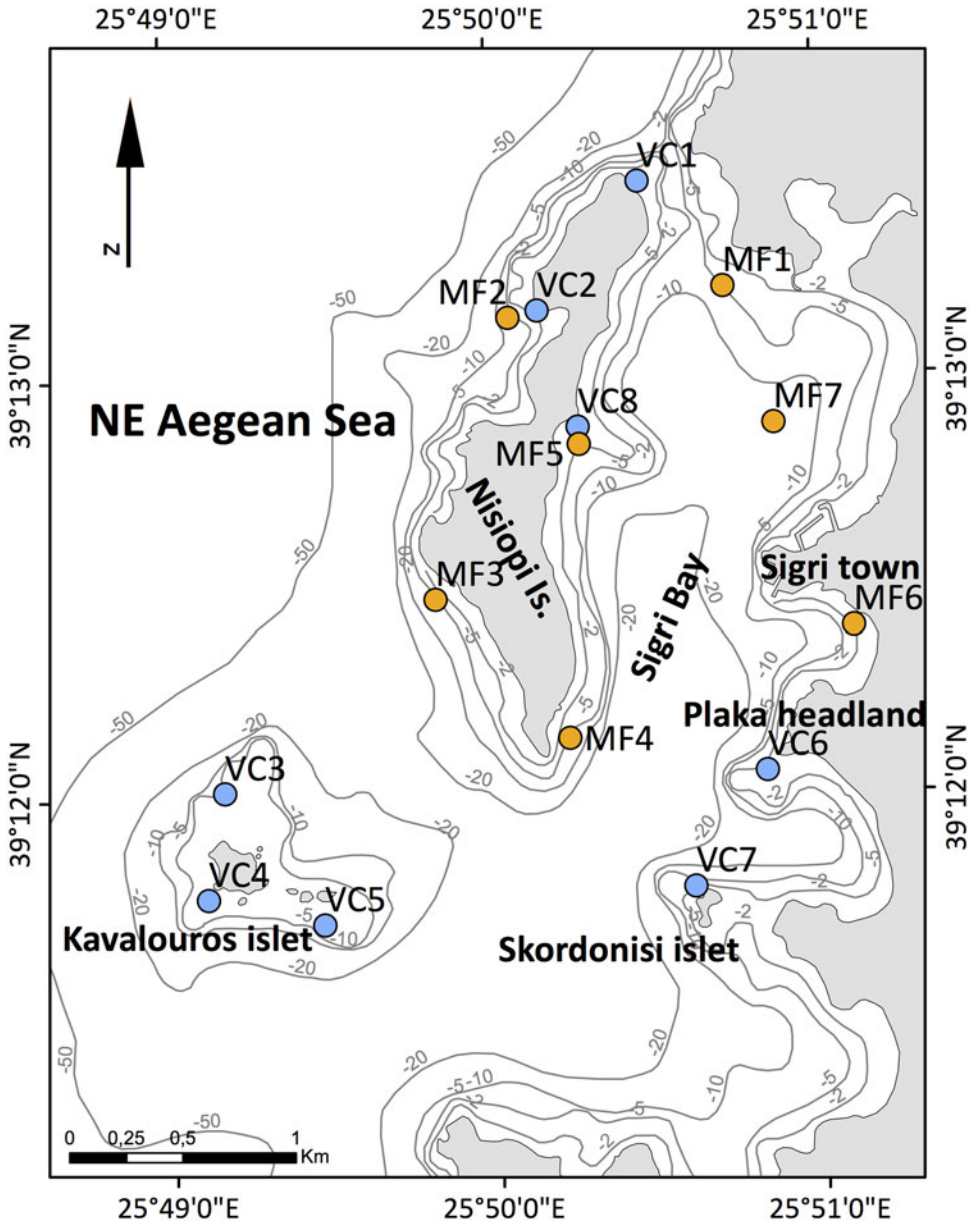

Fig. 1. Map of the study area, showing the sampling stations. The blue dots indicate the visual census sampling stations, the orange dots indicate the macrofauna sampling stations.

(Figure 1). We consider it as established in the study area. The alga was observed to grow on hard and soft substrates and along the edges of the mattes of *Posidonia oceanica* (Figure 2A, B). It is known that *C. cylindracea* has the ability to grow at the edges of *P. oceanica* meadows and this growth is likely to have a negative impact on *P. oceanica* leaves in the proximity of the alga, while growth inside the seagrass meadow has been found to be dependent on the seagrass shoot density (Ceccherelli *et al.*, 2000; Katsanevakis *et al.*, 2010). This species has been recorded at Lesvos Island also by Tsiamis *et al.* (2010).

Stypopodium schimperi

Stypopodium schimperi is a brown alga which was introduced in the Mediterranean via the Suez Canal and is considered as one of the tropical species that is becoming dominant in the eastern Mediterranean (Bianchi, 2007). It has been recorded in both the south and the north Aegean Sea (Tsiamis *et al.*, 2010, 2013) and it grows on rocky bottoms, in shallow waters up to several meters deep (Verlaque & Boudouresque, 1991). It is considered among the worst invasive species in the Mediterranean because of its impact on biodiversity and ecosystem functioning (Streftaris & Zenetos, 2006). Although its invasive behaviour is well known along the Levantine coasts, such behaviour had not been observed in Greece until extremely high abundances and dominance of this species were observed in Rhodes Island in 2009 (Tsiamis *et al.*, 2010). Its effectiveness as an invasive species may be attributed to its perennial life cycle, its possession of defence metabolites and its avoidance by grazers (Boudouresque & Verlaque, 2002).

In the area of Sigri Bay, *S. schimperi* patches were observed on rocky substrate at the visual census station VC4, at the

Table 1. List of the alien species recorded in the study area and their invasion ecology-related attributes. Data are compiled from the scientific literature and on-line databases (cf. Materials and Methods), except *, which is new information in this paper.

Species	Phylum	Sampling stations	Origin	Range in the Mediterranean	Impact	Established in the eastern Mediterranean	Invasive in the eastern Mediterranean	Area of occupancy in the Aegean Sea (Hellenic territorial waters)	Extent of occurrence in the Aegean Sea (Hellenic territorial waters)
Stypopodium schimperi (Kützing) M.Verlaque & Boudouresque	Ochrophyta	VC4	IWP	31–33	High	+	+	High	Sea of Crete to Lesvos Island*
Caulerpa cylindracea Sonder	Chlorophyta	VC1–VC7, MF1, MF5, MF7	IP	30–36	High	+	+	High	Sea of Crete to Chalkidiki peninsula
Halophila stipulacea (Forsskål) Ascherson	Tracheophyta	MF5–MF7	RS	30–35	High	+	+	High	Sea of Crete to Thessaloniki Bay
Cerithium scabridum Philippi, 1848	Mollusca	MF1	IO, RS	31–34	Low or unknown	+	+	High	Lesvos Island*, Rhodes Island
Septifer cumingii Récluz, 1849	Mollusca	MF7	RS	31	Low or unknown	+	+	Low	Crete, Cyclades, Saronikos Gulf, Lesvos Island*
Smaragdia souverbiana (Montrouzier in Souverbie & Montrouzier, 1863)	Mollusca	MF5, MF7	IP, RS	31–32	Low or unknown	+	−	Low	Rhodes Island, Saronikos Bay, Lesvos Island*
Syrnola fasciata Jickeli, 1882	Mollusca	MF1, MF7	IP	32	Low or unknown	+	−	Low	Sigri Bay (Lesvos Island)*
Pinctada imbricata radiata (Leach, 1814)	Mollusca	VC7	IP, RS	30–35	High	+	+	High	Sea of Crete to Lesvos Island
Marphysa adenensis Gravier, 1900	Annelida	MF7	IP?	31, 34	Low or unknown	?	?	Low	Lesvos Island
Siganus luridus (Rüppell, 1829)	Chordata	VC4, VC6	IO, RS	31–35	High	+	+	High	Sea of Crete to Lesvos Island*

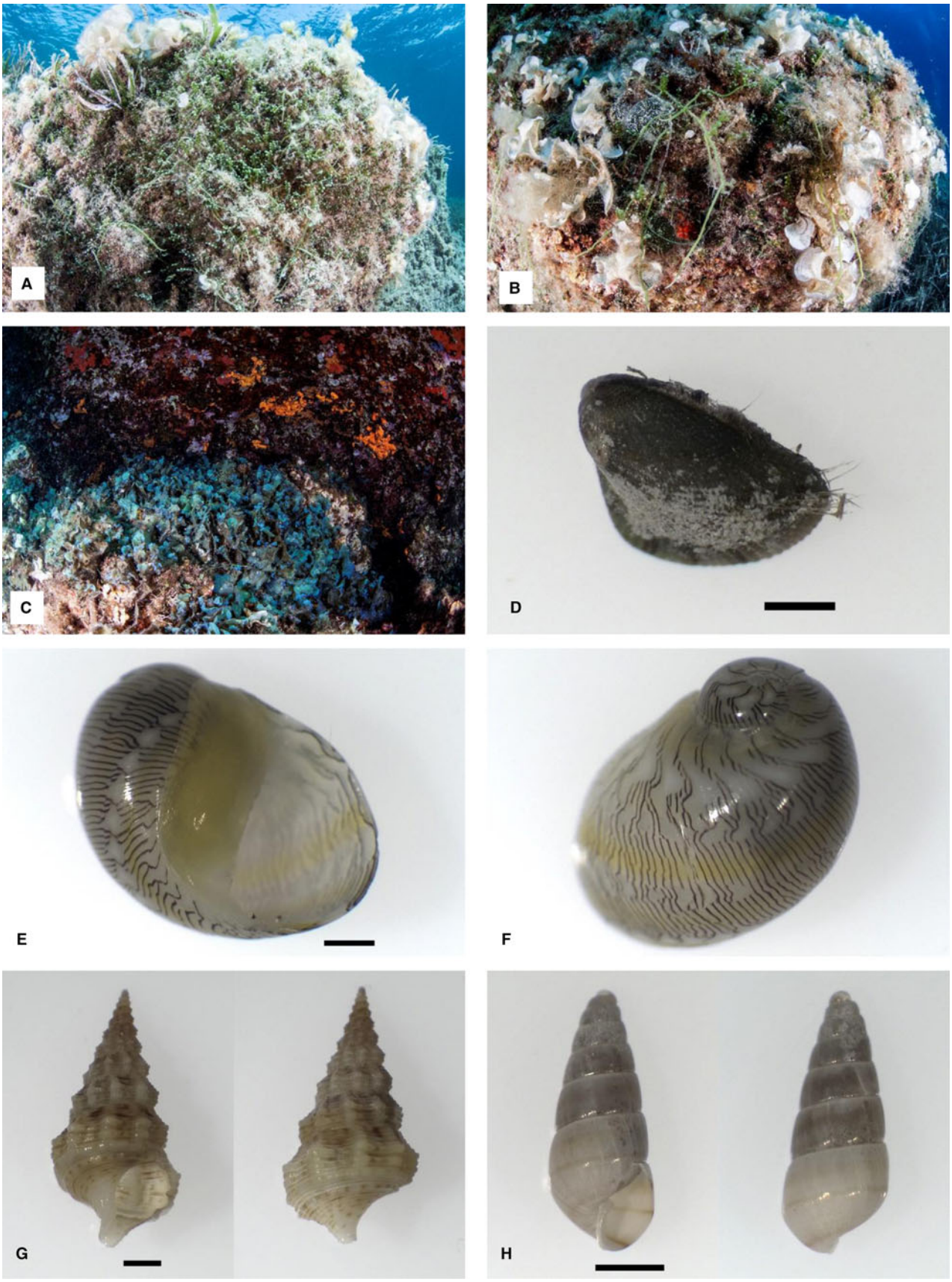

Fig. 2. Photographs of the alien species recorded in the study area: (A) *Caulerpa cylindracea* growing on the edge of a *Posidonia oceanica* matte; (B) *Caulerpa cylindracea* growing among photophilic algae (e.g. *Padina pavonica* (Linnaeus) Thivy); (C) a *Stypopodium schimperi* stand; (D) *Septifer cumingii*; (E, F) *Smaragdia souverbiana*; (G) *Cerithium scabridum*; (H) *Syrnola fasciata*. Scale bar: 1 mm.

south of Kavalouros islet (Figures 1 & 2C). We do not have enough data to assess its establishment status in the study area. To our knowledge, this is presently the northernmost published record of this species in the Aegean Sea, the immediately preceding one having been at Chios Island (Katsanevakis & Tsiamis, 2009).

Halophila stipulacea

The marine angiosperm *Halophila stipulacea* is a Lessepsian migrant that is established and invasive in the eastern Mediterranean (Zenetos *et al.*, 2010) and in the Hellenic seas, although it is absent from the far north Aegean Sea, probably because of the lower seawater temperature therein (Tsiamis *et al.*, 2010). It is found on sandy bottoms at various depths, usually along with the native seagrass *Cymodocea nodosa* (Ucria) Ascherson and, occasionally, it can be abundant (Tsiamis *et al.*, 2013). It is considered to be harmful to biodiversity (Streftaris & Zenetos, 2006) because there are indications of invasive behaviour on sandy bottoms due to its high abundance. However, no displacement of native species due to *H. stipulacea* has been reported in the Mediterranean Sea yet (Tsiamis *et al.*, 2013).

In the area of Sigri Bay, *H. stipulacea* was found on soft substrate, at the macrofauna sampling stations MF5, MF6 and MF7, in the northern part of the bay (Figure 1). We consider it as established in the study area. The northernmost published records in the Aegean Sea have been at the Pagasitikos Gulf and Sporades Islands (Tsiamis *et al.*, 2010). To our knowledge, this is presently the northernmost published record of this species in the eastern Aegean Sea, the immediately preceding ones having been at Dikili, on the Turkish coast of the Aegean Sea (Akçli & Cirik, 2007) and at Chios Island (Katsanevakis & Tsiamis, 2009).

Septifer cumingii

Synonym: *Septifer forskali* Dunker, 1855

The bivalve *Septifer cumingii* was introduced in the Mediterranean via the Suez Canal and is currently established and invasive in the eastern Mediterranean (Zenetos *et al.*, 2012). A suspension feeder, epifaunal and actively mobile, it attaches with byssus on hard substrata in shallow waters (Zenetos *et al.*, 2003). A rare species, it was found on the Levantine coast of Turkey (Bakir *et al.*, 2012) and only recently in the southern Aegean (Zenetos *et al.*, 2011) and Saronikos Bay (Zenetos *et al.*, 2013).

In the area of Sigri Bay, *S. cumingii* was found in soft substrate samples at the macrofauna sampling station MF7 (one specimen), in the northern part of the bay (Figures 1 & 2D). We do not have enough data to assess its establishment status in the study area. To our knowledge, this is presently the northernmost published record of this species in the Aegean Sea, the immediately preceding ones having been at the island of Astypalaia in the Dodecanese (Zenetos *et al.*, 2011) and Saronikos Bay (Zenetos *et al.*, 2013).

Smaragdia souverbiana

Smaragdia souverbiana is a gastropod species that is widely distributed in the Indo-West Pacific (Dekker, 2000). Its first published record in the Mediterranean was from the Levantine coast of Turkey (Buzzurro & Greppi, 1994), although a single shell of *Smaragdia souverbiana* was found in the intestine of the Erythrean alien fish *Callionymus filamentosus* Valenciennes, 1837, which had been caught in Haifa Bay in 1987 (Rothman & Mienis, 2011). *Smaragdia souverbiana* is a seagrass-associated gastropod species (Dekker, 2000; Rossini *et al.*, 2014) that was found to directly consume tissues of the seagrass species *Halophila ovalis* (R. Brown) J.D. Hooker, *Zostera capricorni* Ascherson and *Cymodocea serrulata* (R. Brown) Ascherson & Magnus in eastern Australia (Rossini *et al.*, 2014). Another neritid species that is also directly feeding on seagrasses is *Smaragdia viridis* (Linnaeus, 1758), the only native marine species of the family Neritidae from European coasts (Rueda & Salas, 2007). *Smaragdia viridis* was found to feed on *Zostera marina* Linnaeus and *Cymodocea nodosa* (Ucria) Ascherson in the western Mediterranean (Rueda & Salas, 2007). *Smaragdia viridis* is the only known native species of marine gastropods that has been shown to belong to the trophic group of seagrass-consuming animals in the Mediterranean (Rueda & Salas, 2007). However, it remains to be demonstrated whether the alien in the Mediterranean *Smaragdia souverbiana* is also directly feeding on seagrasses.

In the area of Sigri Bay, *Smaragdia souverbiana* was found in soft substrate samples, at the macrofauna sampling stations MF5 (two specimens) and MF7 (one specimen), in the northern part of the bay (Figures 1 & 2E, F). We consider it as established in the study area. To our knowledge, this is presently the northernmost published record of this species in the Aegean Sea, the immediately preceding ones having been at Rhodes Island (Buzzurro & Greppi, 1994) and in the Korinthiakos Gulf (Zenetos *et al.*, 2013). We also recorded *Smaragdia viridis* in the area of Sigri Bay, in soft substrate samples, at the macrofauna sampling stations MF1 (18 specimens), MF2 (2), MF5 (2) and MF7 (6).

Cerithium scabridum

The gastropod *Cerithium scabridum* is a Lessepsian migrant that is considered established and invasive in the eastern Mediterranean (Zenetos *et al.*, 2010). It is found in shallow waters, on a variety of substrates that include sandy mud, with *Cymodocea nodosa* or *Zostera noltei* Hornemann (Zenetos *et al.*, 2004). Its considerable success as an invasive species may be attributed to its ability for long-distance dispersal via a long-lived pelagic larval stage, high fecundity and a wide ecological niche (Lavie & Nevo, 1986).

In the area of Sigri Bay, *Cerithium scabridum* was found in soft substrate samples at the macrofauna sampling station MF1 (three specimens), in the northern part of the bay (Figures 1 & 2G). We do not have enough data to assess its establishment status in the study area. Its known distribution in the Aegean Sea consists of Imvros (Albayrak, 2001) and Rhodes (Zenetos *et al.*, 2009a) islands. This new record in Lesvos Island, at an intermediate latitude along the eastern Aegean, further closes the gap in its distribution in the eastern Mediterranean Sea.

Syrnola fasciata

Syrnola fasciata is a marine gastropod species of the family Pyramidellidae. It is of Indo-Pacific origin, it was introduced in the Mediterranean via the Suez Canal and is currently established in the eastern Mediterranean (Zenetos *et al.*,

2010). *Syrnola fasciata* was recorded for the first time in the Mediterranean off the Israeli coast in 1958 (Van Aartsen *et al.*, 1989), and since then its distribution has spread along the Turkish coasts up to the south Aegean Sea (Öztürk & Can, 2006). Pyramidellids are ectoparasites, mainly of polychaetes and molluscs (Robertson & Mau-Lastovicka, 1979).

In the area of Sigri Bay, *S. fasciata* was found in soft substrate samples, at the macrofauna sampling stations MF1 (two specimens) and MF7 (three specimens), in the northern part of the bay (Figures 1 & 2H). We consider it as established in the study area. To our knowledge, this is presently the only published record of this species in Hellenic territorial waters, although it was found off the Turkish coast of the south Aegean Sea (Öztürk & Can, 2006).

Pinctada imbricata radiata

Synonym: *Pinctada radiata* (Leach, 1814)

The pearl oyster *Pinctada imbricata radiata* was introduced in the Mediterranean via the Suez Canal and is currently established and invasive in the eastern Mediterranean (Zenetos *et al.*, 2010). It was found in Rhodes Island (Zenetos *et al.*, 2005b), in the Cyclades and in Crete (Zenetos *et al.*, 2008). It also has established populations in sites where it was originally imported for aquaculture, such as Lesvos Island (Serbetis, 1963; Zenetos *et al.*, 2005b). An epifaunal suspension feeder, it lives attached by its byssus to hard substrata (Zenetos *et al.*, 2003). Its tolerance to chemical contamination has enhanced its expansion in enclosed polluted ecosystems (Zenetos *et al.*, 2008) and this species is used as a heavy metal bioindicator (e.g. Al-Madfa *et al.*, 1998).

In the area of Sigri Bay, *P. imbricata radiata* was found on hard substrates at the visual census station VC7, near Skordonisi islet (Figure 1). Although it is known to be established in Lesvos Island (Zenetos *et al.*, 2005b), we do not have enough data to assess its establishment status in the study area.

Marphysa adenensis

The polychaete *Marphysa adenensis* that we found in Sigri Bay has recently been reported for the first time from the Mediterranean as a cryptogenic species (Katsiaras *et al.*, 2014). It has been known to occur mainly in Indian Ocean locations, e.g. in Madagaskar (Day, 1962) and in the Gulf of Aden (Gravier, 1900).

In the area of Sigri Bay, *M. adenensis* was found in soft substrate samples, at the macrofauna sampling station MF7 (one specimen), in the northern part of the bay. We do not have enough data to assess its establishment status in the study area.

Siganus luridus

Siganus luridus is a Lessepsian migrant herbivorous fish species. Along with *Siganus rivulatus* Forsskål & Niebuhr, 1775, they effectively compete for food and habitat resources with the two native herbivorous fish of the Mediterranean, *Sarpa salpa* (Linnaeus, 1758) and *Sparisoma cretense* (Linnaeus, 1758), and in many cases became the dominant herbivorous fish along the coasts of the eastern Mediterranean (Bariche *et al.*, 2004; Golani, 2010). It is believed that the *Siganus* species pose a potential threat to the benthic biodiversity of the Mediterranean (Galil, 2007; Dimitriadis *et al.*, 2013), especially to the hard-bottom habitats that are dominated by *Cystoseira* C. Agardh (Sala *et al.*, 2011).

In Sigri Bay, *Siganus luridus* was found on hard substrate and on *Posidonia oceanica* meadows at the visual census stations VC4, south of the Kavalouros islet (three individuals, 20 cm in length) and VC6, near the Plaka headland (one individual, 15 cm in length). The *Siganus luridus* individuals were observed to intermingle with *Sarpa salpa* individuals. We do not have enough data to assess its establishment status in the study area. To our knowledge, this is presently the northernmost published record of this species in the Aegean Sea, the immediately preceding ones having been at Chios Island (Katsanevakis & Tsiamis, 2009), in the gulf of Smyrna (Kara & Akyol, 2011) and at the Cyclades Islands (Giakoumi, 2014).

Half of the alien species found in Sigri Bay were molluscs. This is not surprising though, since molluscs are the most diverse group of marine alien species in the Mediterranean (Zenetos *et al.*, 2012) and also in the Aegean Sea (Zenetos *et al.*, 2011). All of the alien species recorded in the area of Sigri Bay are of Indo-Pacific origin, presumably introduced to the Mediterranean via the Suez Canal. *Stypopodium schimperi*, *Caulerpa cylindracea*, *Halophila stipulacea*, *Pinctada imbricata radiata* and *Siganus luridus* are widely distributed in the eastern Mediterranean. Whereas, there is only a small number of scattered records in the eastern Mediterranean for *Cerithium scabridum*, *Septifer cumingii*, *Smaragdia souverbiana*, *Syrnola fasciata* and *Marphysa adenensis*, and these species are considered to be 'suspected' Lessepsian migrants, or species that were possibly transported by shipping activities.

It is known that low advection contributes to the retention of both larvae and suspended, fine sediments in sheltered habitats such as embayments, and increased larval retention can contribute to an increased establishment of non-native species (Byers & Pringle, 2006). Accordingly, compared to open coasts, a much higher number and proportion of alien species are found in embayments where soft-bottom habitats predominate (Byers & Grabowski, 2014). These processes seem to control the distribution of macrobenthic alien species in the study area; almost all of the alien macrobenthic species (with the exception of *Pinctada imbricata radiata*, a species associated with hard substrates), as well as *H. stipulacea,* were recorded only in the sheltered northern part of Sigri Bay and none along the exposed western coast of Nisiopi Island.

The importance of shipping as a pathway for the introduction of alien species in the area of Sigri Bay is unknown. Today, Sigri is a minor port that is used mainly by fishing and military vessels. However, it is also sporadically used by passenger ships and yachts. As such, we speculate that shipping activities may mediate in the introduction of biofouling alien species. Indeed, *Pinctada imbricata radiata* and *Septifer cumingii*, which we found in Sigri Bay, are two biofouling species known to foul artificial surfaces (e.g. Özbek *et al.*, 2014). There is a plan for upgrading the port facilities in the near future, and the importance of shipping as a pathway of introduction for alien species in the area may also become enhanced.

Within the limited extent of the study area, we recorded ten alien marine species that are Lessepsian or 'suspected' Lessepsian migrants. This result seems to contradict the convention that the presence of Lessepsian migrants in the

north Aegean Sea is generally negligible (e.g. Pancucci-Papadopoulou *et al.*, 2005; Zenetos *et al.*, 2005b; Katsanevakis *et al.*, 2013) and indicates that the northwards expansion of the distributions of alien marine species in the Aegean Sea is presently an ongoing phenomenon.

ACKNOWLEDGEMENTS

The authors would like to thank Elena Akritopoulou, Andreas Alifragkis, Zinovia Erga, Christos Katsoupis, Zoi Thanopoulou and Hector Yiourgis for their keen participation in the fieldwork. Thanks are also due to Stuart Cochrane for the language editing of the manuscript. This research was funded by the Museum of Natural History of the Petrified Forest of Lesvos in the framework of the research project 'Survey of the benthic fauna and flora of Nisiopi Island'.

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APPENDIX

Table A1. Geographic coordinates in decimal degrees of the sampling stations.

Station	Latitude N (DD)	Longitude E (DD)
VC1	39.226931	25.842886
VC2	39.221833	25.837631
VC3	39.202821	25.821202
VC4	39.198580	25.820260
VC5	39.197512	25.826190
VC6	39.203395	25.848988
VC7	39.198810	25.845213
MF1	39.222700	25.847167
MF5	39.216483	25.839650
MF6	39.209117	25.853550
MF7	39.217233	25.849633