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Research Article

Updated records and range expansion of alien marine macrophytes in Greece (2009)

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Abstract

In the present study the list of alien marine macrophytes already recorded on Greek coasts has been revised in the light of recent studies and new observations. In comparison to 2008, the total number consists of 32 taxa, and the classification as established, casual and debatable species has been modified, with a total of 14, 5 and 13 species respectively. An interesting increase in established species from 9 taxa in 2008 to 14 taxa in 2009 is noted. With 23 taxa listed, Rhodobionta is the best represented group, followed by Chlorobionta (4 taxa) and Chromobionta (4 taxa), while seagrasses (Streptobionta) are represented by only one species. Several new records, one new entry and two putative additions are considered here, while two other taxa previously assumed introduced are excluded from the list of aliens.

Keywords: Alien; Invasive species; Marine macrophytes; Greece; Mediterranean.

Introduction

The introduction of alien marine species is considered to be one of the greatest threats to the marine environment at the dawn of the 21st century (SCHMITZ & SIMBERLOFF, 1997; CARLTON, 2000). Alien species, especially those showing invasive behavior, can induce biodiversity losses, alterations to an ecosystems' structure and functions, and even result in negative socioeconomic effects in coastal areas (BOUDOURESQUE & VERLAQUE, 2005; WALLENTINUS & NYBERG, 2007).

Alien species have puzzled the scientific community over recent decades, since there has been an uncontested increase in introductions worldwide, especially in Europe (CARLTON, 2002; STREFTARIS *et al.,* 2005; GALIL, 2008, 2009). This increase is

attributed mainly to intensive human activities in the marine environment (shipping, aquaculture, fisheries, tourism, etc.) since the 1960's (BOUDOURESQUE & VERLAQUE, 2005). Therefore, today there are several scientific programs focusing on alien species, such as CIESM: atlas of exotic species, www.ciesm.org/atlas, and DAISIE: Delivering Alien Invasive Species Inventories for Europe, http://www.europe-aliens.org/.

Among alien species, alien marine macrophytes represent one of the most important groups (SCHAFFELKE *et al.,* 2006), especially in Europe and Australia (WALLENTINUS, 2002; HEWITT *et al.,* 2007). In the Mediterranean Sea, more than 110 taxa of alien marine macrophytes have been hitherto recorded, most of which originate from the Indo-Pacific Ocean, and are introduced into the Mediterranean Sea through aquaculture, shipping, and via the Suez Canal (BOUDOURESQUE & VERLAQUE, 2002; CORMACI *et al.,* 2004; HEWITT *et al.,* 2007; MINEUR *et al.,* 2007; VERLAQUE *et al.,* 2007, in press; ZENETOS *et al.,* 2008). Several alien marine macrophytes, such as *Caulerpa taxifolia* (M. Vahl) C. Agardh (THIBAUT & MEINESZ, 2004) and *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman *et* Boudouresque (KLEIN & VERLAQUE, 2008), exhibit invasive behavior and have a severe impact not only on the native algal and/or macrophytic communities but also on human activities (SCHAFFELKE & HEWITT, 2007; WILLIAMS & SMITH, 2007).

In Greece, there has been a sharp increase in alien marine macrophytes over the last four decades (TSIAMIS *et al.,* 2008), as well as the augmentation of other alien marine organisms, such as fish and benthic invertebrates (ZENETOS *et al.,* 2005; CORSINI-FOKA & ECONOMIDIS, 2007). However, there is still information missing and there are many gaps in our knowledge of alien marine macrophytes in Greece; this is due to the immensely long coastline and lack of research programs focusing on the subject.

The aim of the present study is to contribute to the knowledge of alien marine macrophytes in the Greek seas, since Greece represents an important geographical link between the Levantine Sea, the Black Sea, the Adriatic Sea and the Western Mediterranean basin. To the last published list of alien marine macrophytes from the Greek coasts (TSIAMIS *et al.,* 2008), we add new records, pointing out revised species and debatable cases, as well as giving detailed maps of their current range expansion in the Greek seas.

Methods

The list reported in the review paper by TSIAMIS *et al.* (2008, Table 1) was used as primary basis for the present work. According to that list, 31 alien macrophytic species had been recorded on Greek coasts until 2007, of which 9 were classified as 'established', 8 as 'casuals' and 14 as 'debatable' cases. Since then, field samplings focusing on alien marine macrophytes have been carried out along various Greek coasts, in both the Ionian and the Aegean Seas, aiming at an updated expansion range of alien macrophytes. Consequently, new entries and additional records of alien taxa have been included in this study, giving an updated list with records up to August 2009. Location, date, and collection data for the new records are given for each established alien species. In addition, the list has been critically reviewed and several records have been revised. For example, some previously assumed debatable taxa have now been moved to the established category, while some other records are now considered as excluded from the list of aliens. Moreover,

Table 1
Alien marine macrophytes in Greece classified as established (E) and casual (C). Taxon: CHL= Chlorobionta, CHR= Chromobionta, RHO= Rhodobionta, STR= Streptobionta. Taxa in Bold correspond to new entries for the list and to changes in the status since TSIAMIS et al. (2008, Table 1). D=debatable.

Group	Species	Status	
		2008	2009
RHO	***Antithamnionella elegans* (Berthold) J.H. Price *et* D.M. John**	D	E
RHO	*Asparagopsis armata* Harvey [a]	E	E
RHO	***Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon**	D	E
RHO	*Bonnemaisonia hamifera* Hariot [b]	C	C
CHL	*Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman *et* Boudouresque	E	E
CHL	***Caulerpa racemosa* var. *lamourouxii* f. *requienii* (Montagne) Weber van Bosse**	C	E
RHO	*Ceramium strobiliforme* G.W. Lawson *et* D.M. John	C	C
RHO	***Chondria curvilineata* F.S. Collins & Hervey** [c]	D	C
CHL	*Codium fragile* (Suringar) Hariot subsp. *fragile* [d]	E	E
CHR	*Colpomenia peregrina* Sauvageau	E	E
STR	*Halophila stipulacea* (Forsskål) Ascherson	E	E
RHO	***Hypnea cornuta* (Kützing) J. Agardh**	C	E
RHO	*Hypnea spinella* (C. Agardh) Kützing	E	E
RHO	***Laurencia caduciramulosa* Masuda *et* Kawaguchi**	D	C
RHO	*Lophocladia lallemandii* (Montagne) F. Schmitz	E	E
RHO	***Neosiphonia harveyi* (J. Bailey) M.-S. Kim, H.-G. Choi, Guiry & G.W. Saunders**	**-**	**C**
RHO	***Sarconema scinaioides* Børgesen**	C	E
CHR	*Stypopodium schimperi* (Buchinger ex Kützing) Verlaque et Boudouresque	E	E
RHO	*Womersleyella setacea* (Hollenberg) R.E. Norris	E	E

[a] Most records are based only on a '*Falkenbergia*' life-history phase arbitrarily attributed to "*F. rufolanosa*", the sporophyte of *A. armata.*
[b] Only the tetrasporophyte phase was found (SKOUFAS & TSIRIKA, 2003).
[c] Misidentified as *C. collinsiana* M.A. Howe (ATHANASIADIS, 1987). Although ATHANASIADIS's material was not re-examined, his description agrees with *C. curvilineata* and not with *C. collinsiana.*
[d] Synonym of *Codium fragile* subsp. *tomentosoides* (van Goor) P.C. Silva.

alien species considered previously not introduced as well as unpublished records by regional experts have been also included in this study, thus giving a more precise view of alien marine macrophytes in Greece.

Following the same classification (TSIAMIS *et al.,* 2008), alien macrophytes have been grouped into four broad categories according to their establishment success, namely 'established' (permanent, self-maintaining populations), 'casual' (recorded only once), 'debatable' (insufficient

information, highly probable records requiring confirmation, and cryptic introductions) and 'excluded' (native species, misidentifications). Updated range expansion maps are given for the established and casual alien taxa, taking into account both our own and already published records for each taxon (only some references of interest are cited due to space limitations). On the other hand, debatable and excluded species are briefly discussed, with, however, special attention paid to new entries and revised cases.

Results

By August 2009, the total number of alien marine macrophytes recorded on Greek coasts (32 taxa) had slightly increased when compared to TSIAMIS *et al.* (2008) (31 taxa); moreover, the proportion of each category differs with 14 established (E), 5 casual (C) and 13 debatable (D) species (Tables 1 & 2). With 23 taxa listed, Rhodobionta is the best represented group, followed by Chlorobionta (4 taxa) and Chromobionta (4 taxa), while seagrasses (Streptobionta) are represented by only one species. One new entry (C) and two putative additions (D) are considered here, while three other taxa previously assumed casuals (TSIAMIS *et al.,* 2008) are now considered as debatable. Moreover, there are also two taxa previously assumed introduced and are now excluded from the list of aliens. Distribution records and range expansion are given for each established (Fig. 1) and casual (Fig. 2) alien marine macrophyte in Greece. Location, date, and collecting data for the new records are given for each established alien species (Table 3).

Table 2

Alien marine macrophytes in Greece classified as debatable. Taxon: CHL= Chlorobionta, CHR= Chromobionta, RHO= Rhodobionta. Taxa in Bold correspond to new entries for the list.

TAXON	SPECIES	COMMENT
RHO	*Acanthophora nayadiformis* (Delile) Papenfuss	native (or) cryptic introduction
RHO	***Anotrichium okamurae* Baldock ?**	native (or) cryptic introduction
RHO	*Antithamnionella spirographidis* (Schiffner) E.M. Wollaston	needs confirmation
RHO	*Ceramium bisporum* D.L. Ballantine	needs confirmation
RHO	*Chondria coerulescens* (J. Agardh) Falkenberg	native (or) cryptic introduction
RHO	***Chondria pygmaea* Garbary & Vandermeulen**	highly probable presence, needs observation
RHO	*Ganonema farinosum* (J.V. Lamouroux) K.C. Fan *et* Yung C. Wang	native (or) cryptic introduction
RHO	*Hypnea valentiae* (Turner) Montagne [a]	needs confirmation
CHR	*Padina boryana* Thivy [b]	needs confirmation
RHO	*Polysiphonia atlantica* Kapraun *et* J.N. Norris	high risk of confusion with Mediterranean species
RHO	*Polysiphonia fucoides* (Hudson) Greville	native (or) cryptic introduction
CHR	*Pylaiella littoralis* (Linnaeus) Kjellman [c]	needs confirmation
CHL	*Ulva fasciata* Delile	native (or) cryptic introduction

[a] from Casual to Debatable compared to TSIAMIS *et al.,* 2008
[b] from Casual to Debatable compared to TSIAMIS *et al.,* 2008
[c] from Casual to Debatable compared to TSIAMIS *et al.,* 2008

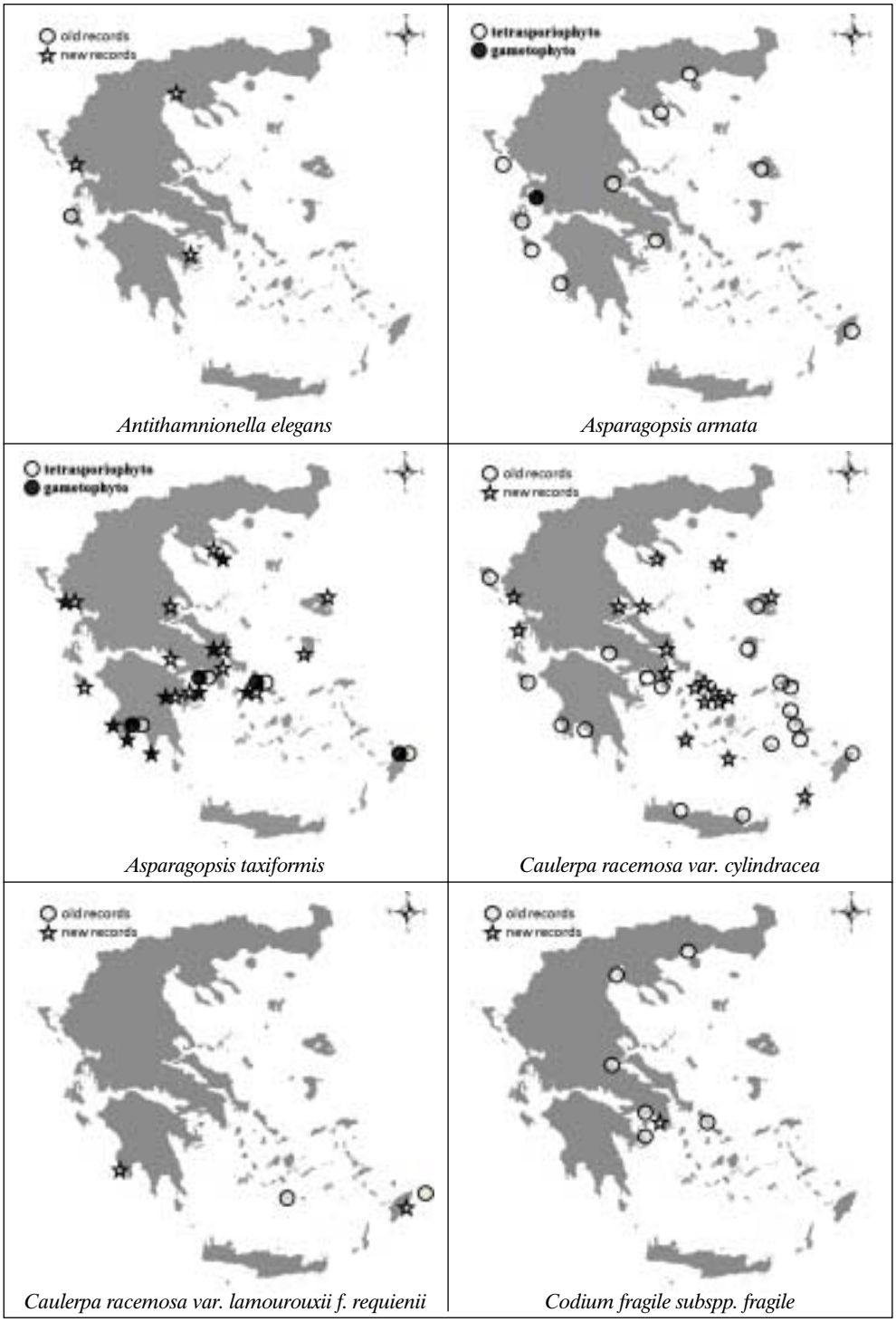

Fig. 1: (continued)

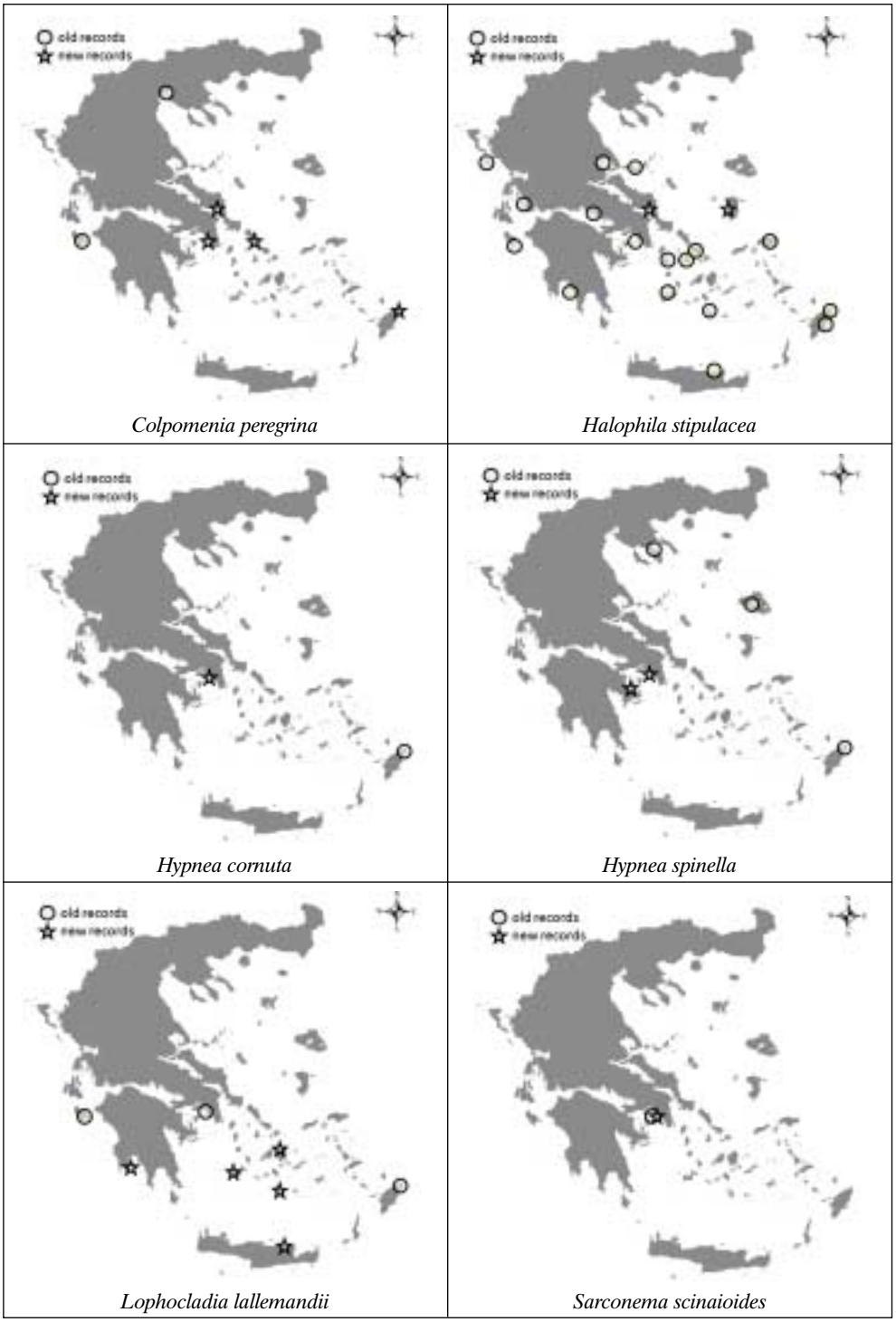

Fig. 1: (continued)

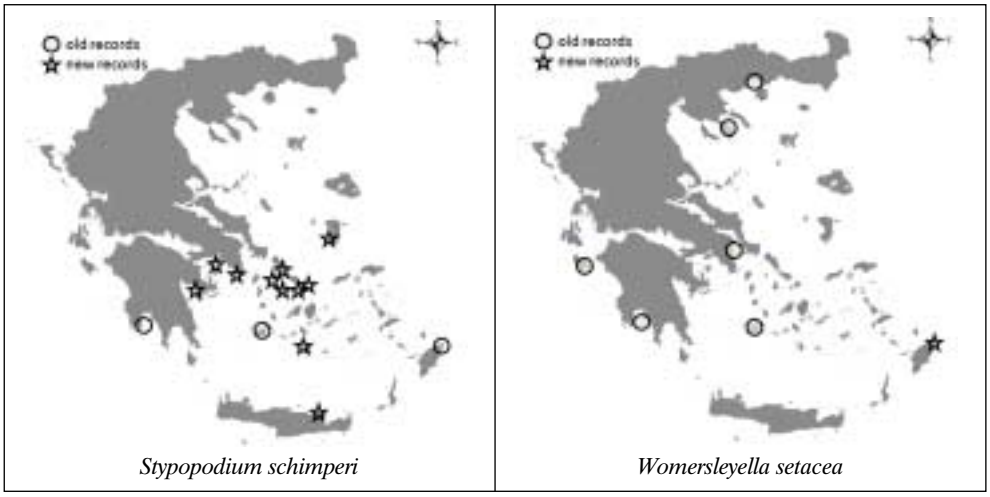

Fig. 1 (continued): Distribution records and range expansion of established alien marine macrophytes in Greece until 2009. Both old (published) and new records are given.

Fig. 2: Casual alien marine macroalgae in Greece until 2009.

Table 3
Data for the new records of established alien marine macrophytes in Greece up to August 2009.

Taxon	Location	Depth	Substrate	Date	Collector
Antithamnionella elegans	Neoi Epivates, Thermaikos Gulf	1m	epiphyte	July 2007	K. Tsiamis
	Parga port	1m	epiphyte	October 2008	K. Tsiamis
	Selonda, Epidauros Gulf	1m	epiphyte	January 2009	K. Tsiamis
Asparagopsis taxiformis * = only the tetrasporophytic phace found	*Antikyra, Korinthiakos Gulf	1m	epiphyte	October 2006	K. Tsiamis
	*Vourvourou, Sithonia	2m	epiphyte	August 2007	K. Tsiamis
	*Keri, Zakinthos Isl.	1m	epiphyte	September 2008	K. Tsiamis
	*Nies, Pagasitikos Gulf	2m	epiphyte	September 2008	K. Tsiamis
	Parga port	1m	epiphyte/rocky	October 2008	K. Tsiamis
	*Sxoinias, Attiki	1m	epiphyte	November 2008	K. Tsiamis
	Selonda, Epidauros Gulf	1-3m	epiphyte/rocky	January 2009	K. Tsiamis
	*Vourlias, Argolikos Gulf	1m	epiphyte	January 2009	K. Tsiamis
	Nauplio port, Argolikos Gulf	1m	rocky	February 2009	K. Tsiamis
	*Skala Kydonion, Lesvos Isl.	1m	epiphyte	March 2009	K. Tsiamis
	Koroni port	1m	rocky	April 2009	G. Bardamaskos
	Pilos Port	1m	rocky	April 2009	G. Bardamaskos
	Aliveri, Evoikos Gulf	1-2m	epiphyte/rocky	June 2009	K. Tsiamis
	Porto Coufo, Sithonia	1-3m	rocky	June 2009	K. Tsiamis
	Gerolimenas, Messiniakos Gulf	1-2m	rocky	June 2009	K. Tsiamis
	Gyaros Isl.	1-15m	rocky	July 2009	M. Salomidi
	Near Pyrgi, Chios Isl.	2m	rocky	August 2009	S. Katsanevakis
Caulerpa racemosa var. cylindracea	Kimolos Isl., port	1m	rocky	July 2006	M. Salomidi
	Karpathos Isl., port	1m	rocky	August 2006	A. Zenetos
	Agia Paraskevi, Skiathos Isl.	1m	rocky	August 2006	K. Tsiamis
	Korthi, Andros Isl.	1m	epiphyte	June 2008	K. Tsiamis
	Moudros bay, Limnos Isl.	1m	rocky	August 2008	S. Orfanidis
	Poros, Leukada Isl.	1m	rocky	August 2008	K. Tsiamis
	Nies, Pagasitikos Gulf	2m	sandy/rocky	September 2008	K. Tsiamis
	Parga port	1m	rocky	October 2008	K. Tsiamis
	Sxoinias, Attiki	1-15m	rocky	November 2008	K. Tsiamis
	Skala Kydonion, Lesvos Isl.	1-3m	rocky	March 2009	K. Tsiamis
	Aliveri, Evoikos Gulf	1m	rocky	June 2009	K. Tsiamis
	Tristinika, Sithonia	1m	rocky	June 2009	K. Tsiamis
	Gyaros Isl.	1-15m	rocky	July 2009	M. Salomidi
	Kaldera, Santorini Isl.	1-3m	Rocky / epiphyte	August 2009	K. Tsiamis
	Rinia, Dilos Isl.,	1-15m	rocky	August 2009	S. Katsanevakis
	Tragonisi, Mikonos Isl.	1-15m	rocky	August 2009	S. Katsanevakis
	Aspro & Stroggili, Syros Isl.	1-15m	rocky	August 2009	S. Katsanevakis
	Tinos Isl., south coasts	1-15m	rocky	August 2009	S. Katsanevakis

(continued)

Table 3 (continued)

Taxon	Location	Depth	Substrate	Date	Collector
Caulerpa racemosa var. lamourouxii	Sapienza Isl., Messiniakos Gulf	50m	rocky	April 2009	K. Tsiamis
	Ladiko, Rhodes Isl.	2-3m	rocky	July 2009	K. Tsiamis
Codium fragile subsp. fragile	Glyfada, Saronikos Gulf	0,5m	rocky	July 2009	K. Tsiamis
Colpomenia peregrina	Apollakia, Rhodes Isl.	1m	rocky	June 1994	P. Panayotidis
	Andros Isl., port	1m	rocky	June 2008	K. Tsiamis
	Aliveri, Evoikos Gulf	1m	epiphyte	June 2009	K. Tsiamis
	Vouliagmeni, Saronikos Gulf	0,2m	rocky	August 2009	K. Tsiamis
Halophila stipulacea	Aliveri, Evoikos Gulf	3m	sandy	June 2009	K. Tsiamis
	Elinta, Chios Isl.	5m	sandy	August 2009	S. Katsanevakis
Hypnea cornuta	Agios Kosmas, Saronikos Gulf	0,2m	epiphyte	June 2007	K. Tsiamis
	Agios Kosmas, Saronikos Gulf	0,2m	sandy	August 2009	K. Tsiamis
Hypnea spinella	Agios Kosmas, Saronikos Gulf	0,5m	epiphyte	June 2006	K. Tsiamis
	Selonda, Epidauros Gulf	0,5m	epiphyte	January 2009	K. Tsiamis
Lophocladia lallemandii	Tsigrado, Milos Isl.	1m	rocky	July 2007	K. Tsiamis
	Koukouras, Messiniakos Gulf	1m	rocky	July 2008	K. Tsiamis
	Naxos Isl., port	1m	rocky	October 2008	V. Roussis
	Istron, Crete Isl.	1m	rocky	October 2008	V. Roussis
	Red beach, Santorini	1m	rocky	August 2009	K. Tsiamis
Sarconema scinaioides	Agios Kosmas, Saronikos Gulf	0,2m	rocky-sandy	September 2008	K. Tsiamis
Stypopodium schimperi	Korthi, Andros Isl.	2m	rocky	June 2008	K. Tsiamis
	Istron, Crete Isl.	1m	rocky	September 2008	V. Roussis
	Aigina Isl., Saronikos Gulf	1-26m	rocky	September 2008	M. Salomidi
	Vourlias, Argolikos Gulf	1m	rocky	January 2009	K. Tsiamis
	Glaronisi, Gyaros Isl.	1-15m	rocky	July 2009	M. Salomidi
	Legraina, Attiki	2-5m	rocky	July 2009	K. Tsiamis
	Thirasia, Santorini Isl.	0,5m	rocky	August 2009	K. Tsiamis
	Chios Isl., west coasts	0-10m	rocky	August 2009	S. Katsanevakis
	Rinia Isl, Cyclades	0-15m	rocky	August 2009	S. Katsanevakis
	Tragonisi, Mikonos Isl.	0-15m	rocky	August 2009	S. Katsanevakis
	Aspro & Stroggili, Syros Isl.	0-15m	rocky	August 2009	S. Katsanevakis
Womersleyella setacea	Rhodes Port, Rhodes Isl.	1m	epiphyte	January 2006	K. Tsiamis

New entries and putative additions

Anotrichium okamurae Baldock ?

In 1939, the Mediterranean range of *Anotrichium furcellatum* J. Agardh, a species described from Amalfi in Naples (AGARDH, 1842, as *Griffithsia furcellata*), seemed to be expanding so rapidly that FELDMANN-

MAZOYER & MESLIN (1939) queried whether the species now present was really the one described by J. Agardh. The scenario of expansion of this species in the Mediterranean Sea resembles that of *Asparagopsis taxiformis* and *Caulerpa racemosa*. In the present case two taxa have probably been confused under the name of *A. furcellatum:* the native taxon described from Naples and a species (*A. okamurae*) originally described from Japan, probably introduced from the Pacific at an unknown time and exhibiting an invasive behaviour (*A. okamurae* originally described from Japan; OKAMURA 1934, as *Monospora tenuis*) (VERLAQUE *et al.,* in press). In Greece, where *A. furcellatum* was frequently recorded in the Ionian and Aegean Seas, three hypotheses have to be considered: either we have the native taxon, or the introduced species, or both taxa. Pending new information, the Greek records of *A. furcellatum* are provisionally attributed to *A. okamurae* ? as a debatable case (Table 2).

Chondria pygmaea Garbary & Vandermeulen (not yet observed but presence highly probable)

GARBARY & VANDERMEULEN (1990) first described *Chondria pygmaea* from Eilat in the Red Sea as an epiphyte on the seagrass *Halophila stipulacea* (Forsskål) Ascherson. In the Mediterranean Sea, *C. pygmaea* was found among the epiflora of the introduced *H. stipulacea* each time it was studied (CORMACI *et al.,* 1992; ALONGI *et al.,* 1993; KASHTA & PIZZUTO, 1995; RINDI *et al.,* 1999). Considering the wide distribution of the introduced seagrass in Greece (Fig. 1), the occurrence of *C. pygmaea* in this region is highly probable. Pending confirmation by observation, we provisionally range *C. pygmaea* in the debatable category (Table 2).

Neosiphonia harveyi (J. Bailey) M.-S. Kim, H.-G. Choi, Guiry & G.W. Saunders

This species was first described as *Polysiphonia harveyi* from the NW Atlantic (USA, Connecticut, BAILEY, 1848). It is presently considered to be widespread in the world, and is regarded as introduced in the Atlantic Ocean and the Mediterranean Sea (MAGGS & STEGENGA, 1999; CHOI *et al.,* 2001; VERLAQUE *et al.,* in press). Based on an analysis of *rbc*L sequences, MCIVOR *et al.* (2001) concluded that Japan is its native region. In the Mediterranean Sea, *Neosiphonia harveyi* is more common in the western basin than in the eastern basin. In Greece, the species has been reported only once from the Gulf of Thessaloniki (C. MAGGS, pers. com. in VERLAQUE *et al.,* in press) (Table 1, casual category).

Revised species, now considered as debatable

There are three species, originally considered as casuals (TSIAMIS *et al.,* 2008), which have been revised and now considered as debatable:

Hypnea valentiae (Turner) Montagne

Hypnea valentiae has been originally described from the Red Sea (TURNER, 1809, as *Fucus valentiae*). Its introduction into the Mediterranean Sea was unequivocally identified for the first time in 1996 in France (Thau Lagoon), and successively in Italy (Venice and Mar Piccolo di Taranto) (VERLAQUE *et al.,* in press). In Greece, *H. valentiae* was first recorded in 1894 from Rhodes Island (REINBOLD, 1898), but it turned out to be a misidentification of *H. cornuta* (Kützing) J. Agardh. More specifically, REINBOLD (1898) wrote: 'Die exemplare zeigten die für diese art characteristischen spinulae stellulaeformes.', that is: 'The specimens bear the charac-

teristic stellate spines of the species'. Such stellate spines, which never occur in *H. valentiae,* are typical of *H. cornuta.* However, there are several other records of *H. valentiae* from Greece (BOGDANOS & DIAPOULIS, 1984; DIAPOULIS & HARITONIDIS, 1987), but in the absence of detailed specimen descriptions and the complex taxonomy of the genus we cannot consider these data as sufficient to establish the presence of *H. valentiae* in Greece. Therefore, pending new observations, we consider *H. valentiae* as debatable in Greece.

Padina boryana Thivy

The records of this species from Amorgos, Attica and Crete in Greece (see NIZAMUDDIN, 1981, as *Padina tenuis* Bory de Saint-Vincent) remain unconfirmed. Pending new observations, the occurrence of *P. boryana* in Greece should be considered as debatable.

Pylaiella littoralis (Linnaeus) Kjellman

There are only two records of this alga in Greece: one in the Aegean Sea (ANAGNOSTIDIS, 1968, with reservation), which probably corresponds to a misidentification of an *Ectocarpus* species (A. ATHANASIADIS, pers. com.), and one in the Ionian Sea (SCHNETTER & SCHNETTER, 1981). Moreover, according to VERLAQUE *et al.* (in press) several populations of this species could be native in the Mediterranean Sea. Therefore, pending new observations in Greece, *P. littoralis* should be considered as debatable.

Excluded species

Chorda filum (Linnaeus) Stackhouse

According to GERLOFF & GEISSLER (1974) and ATHANASIADIS (1987), the single record of *Chorda filum* from Lesvos Island in the N. Aegean Sea (CANDARGY, 1899) is probably based on a misidentification. We agree with their remark.

Neosiphonia sphaerocarpa (Børgesen) M.S. Kim *et* I.K. Lee

Originally described from St. Thomas (Virgin Islands) in the Caribbean Sea (BØRGESEN, 1918, as *Polysiphonia sphaerocarpa*) and presently distributed worldwide in warm seas, *Neosiphonia sphaerocarpa* was first recorded in the Mediterranean Sea in 1970 from Tunisia (BEN ALAYA, 1970, misspelled *P. sphaerocaspa*), and successively in Corsica (VERLAQUE, 1989, as *P. sphaerocarpa*), the Balearic Islands (BALLESTEROS, 1992), and Milos Island in Greece (LAZARIDOU, 1994). CORMACI *et al.* (2004) considered *N. sphaerocarpa* to be introduced. However, the species is distributed worldwide and molecular data are needed to locate its place of origin. Moreover, the identification of the species is not easy. Consequently the absence of *N. sphaerocarpa* in the Mediterranean prior to 1970 could simply mean that it was overlooked or mistaken for another *Polysiphonia* species. Pending further investigations, we provisionally consider this species as native in the Mediterranean Sea.

Discussion

Distribution and dynamics

Since TSIAMIS *et al.* (2008), a large expansion has been observed for most established alien species, reaching 68 new distribution records on various Greek coasts (Table 3). The most rapid and broadest expansion was observed for *Asparagopsis taxiformis,* a red alga with an heteromorphic diplohaplontic life cycle, including a gametophytic and a tetrasporophytic phase,

the latter known as *'Falkenbergia'* phase. *A. taxiformis* was found recently in Greece (TSIAMIS & PANAYOTIDIS, 2007), but since then it has exhibited rapid spread, especially in the South Aegean Sea. It is often found on shallow rocky bottoms, through low to high abundance. As far as its origin is concerned, at least two cryptic taxa of different origin (Atlantic and Indo-pacific origin) coexist under the name of *A. taxiformis* in the Mediterranean Sea (ANDREAKIS *et al.,* 2004, 2007; NÍ CHUALÁIN *et al.,* 2004). On the basis of their low survival rates in winter temperatures the Greek populations probably belong to the invasive Indo-Pacific strain (BARDAMASKOS *et al.,* 2008). The sister species, *A. armata,* may have a broader distribution in Greece, but as the majority of Greek records refer to the *Falkenbergia* phase, which is nearly indistinguishable from the *Falkenbergia* phase of *A. taxiformis* (NÍ CHUALÁIN *et al.,* 2004), these records could actually either correspond to *A. taxiformis* or *A. armata.*

Caulerpa racemosa var. *cylindracea* is by far the most common alien marine macrophyte in Greece, presenting an extensive spread along the majority of the Greek coasts. This warm-temperate *Caulerpa,* originating from SW Australia (VERLAQUE *et al.,* 2003), can be found in various types of bottom, from surface down to a depth of 40 m, in both polluted and pristine sites. It often exhibits high abundances near ports and fishing harbors. Conversely, the sister taxon *C. racemosa* var. *lamourouxii* f. *requienii* has a very restricted distribution, found only four times in Greece. Its distribution requires further consideration since this taxon can be easily confused with *C. racemosa* var. *cylindracea.* Its discovery in the Ionian Sea represents the westernmost distribution record in the Mediterranean Sea, revealing a possible recent westward expansion of the taxon during recent years.

Populations of *Codium fragile* subsp. *fragile,* originating from the N. Pacific Ocean (CARLTON & SCANLON, 1985), are relatively restricted in Greece, found only at specific sites but usually in high abundance. Most sites where it is observed are located near ports and polluted environments. It can be found on shallow rocky bottoms. The Indo-Pacific brown alga *Colpomenia peregrina* is known in Greece only through very few local records, although its distribution could be wider since it can be easily confused with the native species *C. sinuosa* (Mertens ex Roth) Derbès & Solier. The pantropical red alga *Hypnea spinella* also exhibits a restricted distribution with very low abundance, found usually near ports as an epiphyte on other macrophytes. Moreover, the Lessepsian immigrant *Hypnea cornuta* is very rare in Greece, found only twice in the Aegean Sea: in 1894 in Rhodes Isl. (Reinbold 1898, as *H. valentiae*) and after about one century (in 2007) in the Saronikos Gulf by the authors.

The Lessepsian seagrass *Halophila stipulacea* shows a wide distribution in Greece, however, it is absent from the far N. Aegean Sea, probably because of the lower seawater temperature. It can be found on sandy bottoms at various depths, usually with the native seagrass *Cymodocea nodosa* (Ucria) Ascherson. Occasionally, it can be abundant. The Lessepsian red alga *Lophocladia lallemandii,* has spread extensively during recent years in Greece, mainly in the S. Aegean Sea. It is usually found as an epiphyte during summer, especially at a depth of several meters. Similarly, *Stypopodium schimperi,* another Lessepsian immigrant, has exhibited a rapid expansion in the Aegean Sea in recent years (see also KATSANEVAKIS & TSIAMIS, in press),

revealing a gradual immigration from the Levantive Sea towards the Western Mediterranean basin. It grows on rocky bottoms, from surface to several meters depth.

Although it had been found in Greece only once (SCHNETTER & SCHNETTER, 1981) up till now, the red alga *Antithamnionella elegans* was detected three times during the last year: once in the Ionian Sea and twice in the Aegean Sea, all cases sterile and near shipping traffic, reflecting a possible spread of the species during recent years by vegetative propagation. In addition, the Lessepsian red alga *Sarconema scinaioides,* which was reported from Greece only in the Saronikos Gulf in the early 1980's (DIAPOULIS *et al.,* 1985), was re-found at the same location after about 30 years, in 2008 (see also TSIAMIS *et al.,* 2009); thus, revealing an established population in the area which still survives after 3 decades. Finally, the Indo-Pacific red alga *Womersleyella setacea,* found in various locations in both the Aegean and the Ionian Seas, seems to have been stable in Greece since 2007. The taxon is usually found at a depth of several meters.

In total, all established alien macrophytes (14 taxa) have been found in the S. Aegean Sea, most of them being present in the Saronikos Gulf. Similarly, most records of established alien species come from the South Aegean Sea, while the fewest come from the North Aegean Sea (Fig. 3). These findings

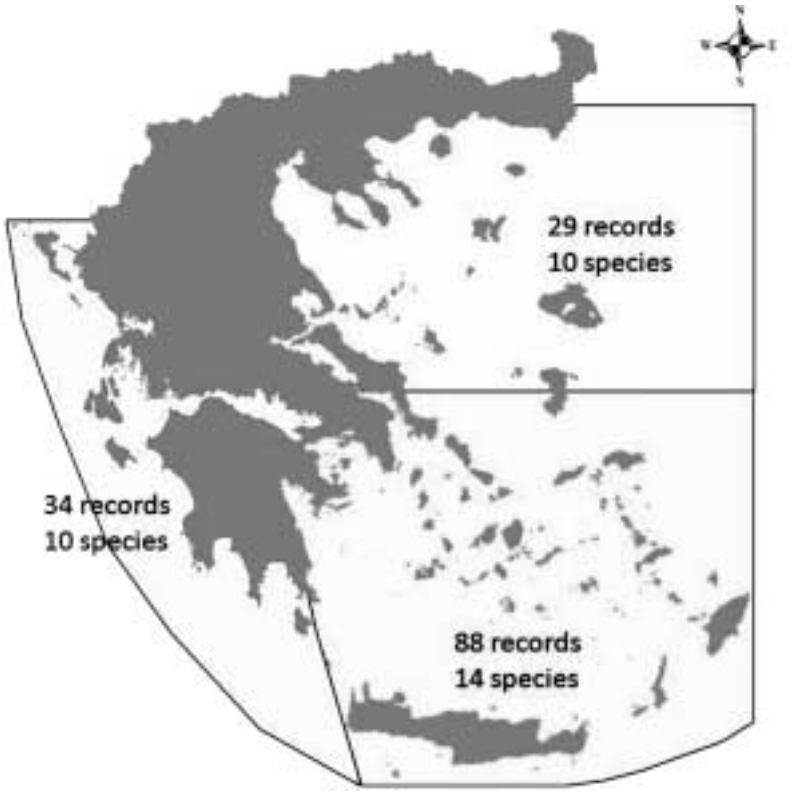

Fig. 3: Records of established alien marine macrophytes in Greece until 2009.

reflect (i) the more extensive surveys on alien marine macrophytes in the S. Aegean Sea (the Saronikos Gulf, Rhodes Island); (ii) the role of Piraeus port, which is the largest port in Greece, as a major site for introduction via shipping; and (iii) the role of the South Aegean Sea as migration route for the Lessepsian species coming from the Levantine coast (see also PANCUCCI-PAPADOPOULOU *et al.,* 2005).

Finally, we note an interesting increase in established species, from 9 taxa in 2008 (TSIAMIS *et al.,* 2008) to 14 taxa in 2009. This is because of new records and findings, leading to the inclusion of originally casual (*Caulerpa racemosa* var. *lamourouxii* f. *requienii, Hypnea cornuta, Sarconema scinaioides*) and debatable species (*Antithamnionella elegans, Asparagopsis taxiformis*) in the established category. Thus, established alien marine macrophytes in Greece exhibit higher abundance than originally thought.

Impact on benthic assemblages

The direct impact has not been documented yet for any alien marine macrophyte in Greece. However, there are several cases where losses of biodiversity and alterations of communities are evident, especially in the case of the invasive alien taxa. In such cases there is displacement of the native flora and monopolization of substrates by the alien invaders. *Caulerpa racemosa* var. *cylindracea* often exhibits such behavior, especially in stressed ecosystems, as well as in rather deep sandy bottoms. *Codium fragile* subsp. *fragile* and *Asparagopsis taxiformis* display invasive behavior exclusively in cases of ports and harbors, where nitrophilous Chlorobionta, such as *Ulva* spp., also thrive. This supports the view that invasive species are favored in ecosystems already disturbed by human activities (OCCHIPINTI-AMBROGI & SAVINI, 2003; DUNSTAN & JOHNSON, 2007; VALENTINE *et al.,* 2007).

An invasive behavior was also observed for *Womersleyella setacea,* but only once, in the N. Aegean Sea in the middle 1990's (ATHANASIADIS, 1997); however, similar cases could have been overlooked due to its rather deep habitat. In addition, there are also indications of invasive behavior of the seagrass *Halophila stipulacea* on sandy bottoms due to its high abundances; however, no displacement of native species due to *H. stipulacea* has hitherto been reported in the Mediterranean Sea.

Finally, invasive behavior of the brown alga *Stypopodium schimperi* is known along the Levantine coasts (BOUDOURESQUE & VERLAQUE, 2002), although such behavior was not observed for any Greek site, at least not until July 2009, when extremely high abundances and occasionally monopolization of the substrate were detected in Rhodes Island.

Until now, in Greece, there is not any scientific proof of a negative impact of the invasive marine macrophytes on human activities, such as fisheries and tourism, although a few local cases have been reported where fishermen blamed invasive species, such as *Codium fragile* subsp. *fragile,* for the reduction of fish abundance.

Conclusion

In conclusion, there are at least 14 alien marine macrophytes that are established in Greece. Most of them are still in progress along the Greek coasts, and further expansion, as well as new introductions, can be expected in the near future. Taking into account that the arrival of invasive alien species has brought about severe changes in the marine communities in other parts of the

Mediterranean Sea (BOUDOURESQUE & VERLAQUE, 2002; SCHAFFELKE & HEWITT, 2007), the spread of these aliens along the Greek coasts, especially from the South Aegean Sea towards both the Ionian and the North Aegean Sea, should be monitored. Moreover, more knowledge about their biology, ecology and impact on the native communities would be helpful to elucidate more aspects of alien introductions.

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