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Additions to the annotated list of marine alien biota in the Mediterranean with special emphasis on Foraminifera and Parasites

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Abstract

The present work is an update of the annotated list (ZENETOS et al., 2006) based on literature up to April 2008. Emphasis is given to ecofunctional/taxonomic groups poorly addressed in the annotated list, such as the foraminiferan and parasites, while macrophytes are critically reviewed following the CIESM Atlas (VERLAQUE et al., in press). Moreover, in this update the bio-geographic area addressed includes the Sea of Marmara.

The update yields a further 175 alien species in the Mediterranean bringing the total to 903. As evidenced by recent findings, more and more previously known 'casual' aliens, are becoming established. Approximately 100 more species have become well established in the region, raising the number of established species to 496 versus 385 until 2005. In the period from January 2006 to April 2008 more than 80 published papers have resulted in the recording of 94 new aliens, which is interpreted as a new introduction every 9 days, a rate beyond the worst scenario.

Introduction

Biological invasions have become a hot issue in recent decades. An increasing trend towards aquatic invasions has been documented for all European Large Marine Ecosystems but is most pronounced in the Mediterranean Sea (STREFTARIS *et al.*, 2005; EEA, 2007a).

A compilation of the available information on the alien marine biota in the Mediterranean resulted in an annotated list that includes 745 alien species (ZENETOS *et al.*, 2006). This covered the groups: fish, zoobenthos (Polychaeta, Crustacea, Mollusca, Echinodermata, Sipuncula, Bryozoa and Ascidiacea) comparatively fully, and less so phytobenthos, phytoplankton and zooplankton. Little information was provided for taxa such as Foraminifera and Isopoda that have not been well studied in the Mediterranean. A gap in information was also noticeable as regards parasites.

Since then, new publications have: a) confirmed the establishment and further geographic expansion of rare species; b) reported on the occurrence of new alien species; c) enlightened on the introduction of little studied groups such as parasites, foraminiferans and d) critically reviewed higher taxa such as macrophytes. In parallel, publications based on molecular studies reconsider the status of species excluded in the annotated list, while publications on taxonomy have significantly changed the nomenclature of certain species.

The aim of the present work is to update the annotated list by reporting on

species presumably omitted in ZENETOS *et al.* (2006) and on the new species recorded in the 2006-2008 period and possible changes in their establishment success. Emphasis is put on foraminiferan and parasites, through collaboration with regional experts.

Methodology

The basis for the present work is the annotated list of marine alien species in the Mediterranean (ZENETOS *et al.*, 2006), called here after 'annotated list'. The list has been updated to incorporate species recorded up to April 2008. The species updates are presented in 10 units, which are ecofunctional/taxonomic groups, namely: 1: Phytoplankton, 2: Zooplankton, 3: Phytobenthos, 4: Zoobenthos/Polychaeta, 5: Zoobenthos/Crustacea, 6: Zoobenthos/Mollusca, 7: Zoobenthos/Foraminifera, 8: Zoobenthos/Miscellanea, 9: Parasites and 10: Fish.

Data have been mostly extracted from a simple information system, structured in ACCESS, which has been developed at the Hellenic Centre for Marine Research (internal use only). The database is updated on a monthly basis and results are reported to UNEP/MAP and the European Environment Agency (EEA) (UNEP/MAP, 2004; EEA, 2006). One of the main uses of the aforementioned system is the development of a trend indicator for marine and estuarine species in Europe for the SEBI2010¹ program (EEA, 2007a, b) and the Mediterranean (UNEP/MAP, 2007).

¹SEBI2010 Streamlining European Biodiversity Indicators: Framework of biodiversity indicators to assess progress towards the 2010 biodiversity target). Expert group on 'trends in invasive alien species': <http://biodiversity-chm.eea.eu.int/information/indicator/F1090245995>

A major difference with the ‘annotated list’ is the geographic coverage of the Mediterranean. The alien biota of the Sea of Marmara (KAMINSKI *et al.*, 2002; ÇINAR *et al.*, 2006a), which were omitted in the first compilation of data, are included in this work.

Concerning their establishment success, alien species are grouped into six broad categories, namely established, casual, questionable, cryptogenic, excluded and invasive, as defined in the ‘annotated list’. For foraminifera a finer distinction of the established category includes the rare species (those observed more than twice in several different localities but always few in number: one or two individuals) and the frequent ones (those species recorded many times in large quantities and showing a wide range of distribution patterns).

Besides the presentation of new species (i.e. species missing in ZENETOS *et al.*, 2006 and those recorded in the 2006-2008 period) with notes on the country of their occurrence, special attention is given to those species whose establishment success has altered compared to the ‘annotated list’. For example, in the light of molecular and/or detailed taxonomic studies, some previously assumed questionable or excluded species have been now moved to the cryptogenic or established category.

Nomenclature changes are presented under ‘name changes’. These are the result of the latest taxonomic studies (e.g. VAN AARTSEN 2004; 2006); group review papers (GOMEZ, 2008); molecular studies (e.g. VERLAQUE *et al.*, 2005) and web databases (GUIRY & GUIRY, 2008).

Thanks to collaboration with regional experts, emphasis has been placed on foraminiferan and parasites, two groups

poorly addressed in the ‘annotated list’, yet with many representatives among aliens. A full list of the experts per taxonomic group who contributed in various ways is provided in the acknowledgements.

Results

1. Phytoplankton

The validity of categorizing the diatoms and dinoflagellates reported in STREFTARIS *et al.* (2005) as alien phytoplankton in the European Seas was investigated by GOMEZ (2008) who concluded that the number of alien phytoplankton species in European Seas has been excessively inflated. Most of the discrepancies noted in GOMEZ (2008) had already been rectified in the ‘annotated list’. Exceptions were the cosmopolitan *Protoceratium reticulatum* reported as *Gonyaulax grindleyi*, and *Gyrodinium falcatum* also reported as *Gymnodinium fusus/Pselodinium vaubanii* which are now excluded from the Mediterranean aliens. In addition, the benthic/epiphytic dinoflagellates that were included among phytoplankton in the ‘annotated list’ are now moved to phytobenthos.

Warm-water species expand their geographical ranges or increase their abundances to detectable levels during warming periods. *Alexandrium tamarense*, *Chaetoceros coarctatus*, *Proboscia indica* and *Pyrodinium bahamense* are a few examples of marginal dispersal associated with climatic events rather than species introductions from remote areas. Again, these introductions are considered important even if only to document the impact of climatic changes, and are kept on our list. As a result four (4) *new* phytoplankton species have been added to the list ((Tables 1.1, 1.2).

Table 1.1
New alien phytoplanktonic species and changes in establishment success.

*species excluded in the 'annotated list'

Establishment success: C=casual; E=established; Q=questionable; CR=cryptogenic

| New species | Establishment success | Source |
|--|-----------------------|--|
| <i>Alexandrium concavum</i> (K.R. Gaarder) E. Balech | C | Tunisia: DALY YAHIA-KEFI <i>et al.</i> , 2001 |
| <i>Alexandrium kutnerae</i> (E. Balech) E. Balech | C | Tunisia: DALY YAHIA-KEFI <i>et al.</i> , 2001 |
| * <i>Proboscia indica</i> (Peragallo) Hernández-Becerril ^{*1} | CR/E | GOMEZ, 2008 |
| <i>Pseudosolenia calcar-avis</i> Schultze, 1858 | E | Sea of Marmara: ÇINAR <i>et al.</i> , 2006a |
| Change in establishment success | | |
| <i>Karenia mikimotoi</i> (Miyake & Kominami ex Oda) G. Hansen & Ø. Moestrup | From Q to CR/E | GOMEZ, 2008 |
| <i>Prorocentrum mexicanum</i> Osorio-Tafall | From C to CR/E | GOMEZ, 2008 |

¹ *Proboscia indica* (H. Peragallo) D.U. Hernandez-Becerril (= *Rhizosolenia indica*) was found previously in the Indian Ocean more than in the Mediterranean or Atlantic. It was historically considered as a variety of the cosmopolitan *Rhizosolenia alata* Brightwell.

Table 1.2
Name changes in phytoplankton.

| NEW NAME | OLD NAME | Source |
|--|--|-------------|
| <i>Protoceratium reticulatum</i> (Claparède & Lachmann) Butschli | <i>Gonyaulax grindleyi</i> Reinecke | GOMEZ, 2008 |
| <i>Karenia brevis</i> (C.C. Davis) G. Hansen & Ø. Moestrup | <i>Gymnodinium breve</i> C.C. Davis | GOMEZ, 2008 |
| <i>Karenia mikimotoi</i> (Miyake & Kominami ex Oda) G. Hansen & Ø. Moestrup | <i>Gymnodinium mikimotoi</i> Miyake & Kominami ex Oda | GOMEZ, 2008 |
| <i>Gymnodinium aureolum</i> (E. M. Hulburt) G. Hansen | <i>Gyrodinium aureolum</i> E.M. Hulburt | GOMEZ, 2008 |
| <i>Gyrodinium falcatum</i> Kofoid & Swezy | <i>Gymnodinium fusus</i> Schütt | GOMEZ, 2008 |
| <i>Proboscia indica</i> (H. Peragallo) D. U. Hernández-Becerril | <i>Rhizosolenia indica</i> H. Peragallo | GOMEZ, 2008 |

2. Zooplankton

The number of alien zooplanktonic species in the 'annotated list' has been

reduced by six since the benthic copepod species (*Canuellina insignis*, *Enhydrosoma hopkinsi*, *Robertsonia salsa*, *Scottolana longipes*, *Stenhelina inopinata*, *Stenhelina min-*

uta) reported by POR (1964; 1972) were erroneously placed among zooplankton. Eight (8) new alien species (Table 2) are added to the 'annotated list'. Five of these species occur on the Mediterranean coast of Egypt: *Abyla trigona*, *Sulculeolaria angusta*, *Olindias singularis*, *Rhabdosoma whitei*, *Aidanosagitta neglecta* (ZAKARIA 2004; 2006), one in South Turkey: *Ferosagitta galerita* (ÜNAL *et al.*, 2002; TERBIYIK *et al.*, 2007) and one in Tunisia: *Stomolophus meleagris* (DALY YAHIA *et al.*, 2003). It is interesting to note the finding of *Beroe ovata*, one of the worst Invasive Alien Species (IAS) in the Black Sea, now having been recorded from

the South Aegean Sea (SHIGANOVA *et al.*, 2007). The three copepods species, namely *Acartia hasanii*, *Paracartia ioannae* and *Paracartia janetae* (ÜNAL *et al.*, 2002) that were excluded from the 'annotated list', as unsupported records, retain their excluded status. After examination of specimens from the area, it was concluded that all specimens were copepodites (future females) of *Acartia clausi* and *Acartia tonsa* (A. Gubanov, pers. commun.).

The geographic expansion of reported species such as *Phyllorhiza punctata* (Ionian Sea: NAVANDI & KIKINGER, 2007), and the documented burst of alien zooplanktonic species in general, presum-

Table 2
New alien zooplanktonic species in the Mediterranean and changes in establishment success.

*species excluded in the 'annotated list'

Taxon: AMPH=Amphipoda; CHA=Chaetognatha; CTE=Ctenophora;

SIPH=Siphonophora; SCY=Scyphozoa

Establishment success: C=casual; E=established; Q=questionable

| Taxon | New species | Establishment success | Source |
|--|--|-----------------------|--|
| SIPH | <i>Abyla trigona</i> Quoy & Gaimard, 1827 | C | Egypt: ZAKARIA, 2004 |
| CHA | * <i>Aidanosagitta neglecta</i> ¹ | E | Egypt: H. ZAKARIA, pers. commun |
| CTE | <i>Beroe ovata</i> Mayer, 1912 | C | Greece: SHIGANOVA <i>et al.</i> , 2007 |
| CHA | <i>Ferosagitta galerita</i> (Dallot, 1971) | E | Turkey: TERBIYIK <i>et al.</i> , 2007 |
| SCY | <i>Olindias singularis</i> Browne, 1905 | E | Egypt: ZAKARIA, 2004 |
| AMPH | <i>Rhabdosoma whitei</i> Bate, 1862 | C | Egypt: ZAKARIA, 2006 |
| SIPH | <i>Stomolophus meleagris</i> (L. Agassiz, 1862) | C | Tunisia: DALY YAHIA <i>et al.</i> , 2003 |
| SIPH | <i>Sulculeolaria angusta</i> Totton, 1954 | E | Egypt: ZAKARIA, 2004 |
| Change in establishment success | | | |
| SCY | <i>Phyllorhiza punctata</i> von Lendenfeld, 1884 | From C to E | Greece: NAVANDI & KIKINGER, 2007 |

¹ Reported as *Sagitta neglecta*.

ably reflect the sensitivity of zooplankton to climatic changes.

3. Phytobenthos

A total of 110 species (22 Chromobionta, 71 Rhodobionta, 16 Chlorobionta and 1 Plantae) constitute the main core of the CIESM Atlas of exotic macrophytes of the Mediterranean Sea (VERLAQUE *et al.*, in press). Comparing this information to the 'annotated list' has led to the addition to the new list of six cryptogenic species that were reported before the Suez Canal opening and assumed to be native by ZENETOS *et al.* (2006) (e.g.: *Asparagopsis taxiformis*, *Desmarestia viridis*) (Table 3.1); recent rapid changes in their Mediter-

anean distribution give evidence of a recent introduction of either a cryptic species similar to the Mediterranean one or an alien genotype from a remote population. In addition, seven species recently identified as new for the whole or a part of the Mediterranean Sea are also listed in Table 3.1. These include *Dictyota ciliolata* Sonder *ex* Kützing (reported from Catalonia: RULL LLUCH *et al.*, 2007); *Batophora* sp (reported from Italy: BOTTALICO *et al.*, 2006); and 5 species namely, *Microspongium tenuissimum* (Hauck) A.F. Peters; *Lomentaria flaccida* Tanaka; *Grateloupia minima* P.L. Crouan & H.M. Crouan; *Polysiphonia stricta* (Dillwyn) Greville and *Cladophora hutchinsioides* Hoek & Womersley, all collected in the Thau

Table 3.1

New alien phytobenthic species in the Mediterranean and changes in establishment success.

*excluded in the 'annotated list'. Countries of first observation concerned the populations assumed to be introduced.

Taxon: RHO=Rhodobionta, CHL=Chlorobionta, CHR=Chromobionta

Establishment success: C=casual; E=established; Q=questionable; CRf=cryptogenic frequent; CRr=cryptogenic rare

| Taxon | New species | Establishment success | Source |
|-------|--|-----------------------|--|
| RHO | <i>Acanthophora naydaformis</i> (Delile) Papenfuss | CRf/F | Egypt: VERLAQUE <i>et al.</i> , 2005 |
| RHO | <i>Antithamnionella boergesenii</i> (Cormaci & G. Furnari) Athanasiadis | E | Algeria: Verlaque <i>et al.</i> , in press |
| RHO | * <i>Antithamnionella elegans</i> (Berthold) J.H. Price & D.M. John | CRf/Q | Italy : VERLAQUE <i>et al.</i> , in press |
| RHO | * <i>Antithamnionella spirographidis</i> (Schiffner) E.M. Wollaston | CRf/Q | Italy : VERLAQUE <i>et al.</i> , in press |
| RHO | * <i>Asparagopsis taxiformis</i> (Delile) Trevisan de Saint-Léon | CRf | Egypt: VERLAQUE <i>et al.</i> , 2005 |
| RHO | * <i>Acrochaetium spathoglossi</i> Børgesen | Q | Egypt: VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Anotrichium okamurae</i> Baldock | E | VERLAQUE <i>et al.</i> , in press |
| CHL | <i>Caulerpa racemosa</i> var. <i>cylindracea</i> (Sonder) Verlaque, Huisman & Boudouresque | E | Libya: VERLAQUE <i>et al.</i> , in press |

(continued)

Table 3.1 (continued)

| Taxon | New species | Establishment success | Source |
|-------|--|-----------------------|--|
| CHL | <i>Caulerpa racemosa</i> var. <i>lamourouxii</i> f. <i>requienii</i> (Montagne) Weber-van Bosse | E | Israel: VERLAQUE <i>et al.</i> , in press |
| CHL | <i>Caulerpa racemosa</i> var. <i>turbinata</i> (J. Agardh) Eubank - <i>uvifera</i> (C. Agardh) J. Agardh | E | Tunisia: VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Chondria coeruleascens</i> (J. Agardh) Falkenberg ¹ | E | France: VERLAQUE <i>et al.</i> , in press |
| RHO | * <i>Ceramium bisporum</i> D.L. Ballantine ² | Q | Greece: SARTONI & BODDI, 2002 |
| CHL | <i>Cladophora hutchinsioides</i> Hoek & Womersley ³ | Q | France: VERLAQUE <i>et al.</i> , 2007 |
| CHR | * <i>Cladosiphon zosterae</i> (J. Agardh) Kylin | E | France: VERLAQUE <i>et al.</i> , in press |
| CHR | * <i>Desmarestia viridis</i> (O.F. Müller) J.V. Lamouroux | CRf | France: VERLAQUE <i>et al.</i> , in press |
| CHR | <i>Dictyota ciliolata</i> Sonder ex Kützing | E | Spain: RULL LLUCH <i>et al.</i> , 2007 |
| CHR | <i>Dictyota okamurae</i> (E.Y. Dawson) I. Hörnig, R. Schnetter & W.F. | E | France: VERLAQUE <i>et al.</i> , in press |
| CHR | * <i>Ectocarpus siliculosus</i> var. <i>hiemalis</i> (P.L. Crouan & H.M. Crouan) Foslie | CRr/Q | Italy: VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Feldmannophycus okamurae</i> (Yamada) Mineur, Maggs & Verlaque | E | France: VERLAQUE <i>et al.</i> , in press |
| RHO | * <i>Ganonema farinosum</i> (J.V. Lamouroux) K.C. Fan & Yung C. Wang | CRf | Egypt: VERLAQUE <i>et al.</i> , in press |
| RHO | * <i>Gracilaria arcuata</i> Zanardini | Q | Turkey: TASKIN <i>et al.</i> , 2008 |
| RHO | <i>Grateloupia minima</i> P.L. Crouan & H.M. Crouan ⁴ | Q | France: VERLAQUE <i>et al.</i> , 2007 |
| RHO | <i>Lomentaria flaccida</i> Tanaka | C | France: VERLAQUE <i>et al.</i> , 2007 |
| CHR | <i>Microspongium tenuissimum</i> (Hauck) A.F. Peters ⁵ | Q | France: VERLAQUE <i>et al.</i> , 2007 |
| RHO | <i>Nemalion vermiculare</i> Suringar | E | France: VERLAQUE <i>et al.</i> , in press |
| CHR | * <i>Pilayella littoralis</i> (Linnaeus) Kjellman | C | Italy: VERLAQUE <i>et al.</i> , in press |

(continued)

¹ Introduced in the Thau Lagoon

² probably confused with *C. codii*

³ the taxonomy of the genus *Cladophora* Kützing is so complicated that the confirmation of the identity of this macrophyte requires further investigation.

⁴ The determination of the alien or native status of Mediterranean populations requires further investigations.

⁵ The determination of the Atlantic or Mediterranean origin of the Thau populations requires further investigations

Table 3.1 (continued)

| Taxon | New species | Establishment success | Source |
|--|---|-----------------------|--|
| RHO | * <i>Polysiphonia fucoides</i> (Hudson) Greville | E | France: VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Polysiphonia stricta</i> (Dillwyn) Greville ⁶ | Q | France: VERLAQUE <i>et al.</i> , 2007 |
| CHR | * <i>Punctaria tenuissima</i> (C. Agardh) Greville | E | France: VERLAQUE <i>et al.</i> , in press |
| CHR | * <i>Spatoglossum variabile</i> Figari & De Notaris | Q | Israel: VERLAQUE <i>et al.</i> , in press |
| CHL | * <i>Ulva fasciata</i> Delile | E | Egypt: VERLAQUE <i>et al.</i> , in press |
| Change in establishment success | | | |
| RHO | <i>Antithamnionella sublittoralis</i> (Setchell & Gardner) Athanasiadis | From Q to E | VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Antithamnionella ternifolia</i> (J.D. Hooker & Harvey) Lyle | From C to E | VERLAQUE <i>et al.</i> , in press |
| CHL | <i>Caulerpa mexicana</i> Sonder ex Kützing | From C to E | VERLAQUE <i>et al.</i> , in press |
| CHL | <i>Ceramium strobiliforme</i> G.W. Lawson & D.M. John | From C to E | VERLAQUE <i>et al.</i> , in press |
| CHL | <i>Cladophora patentiramea</i> (Montagne) Kützing | From Q to E | VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Dasya sessilis</i> Yamada | From C to E | VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Dasyisiphonia</i> sp. | From C to E | VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Goniotrichiopsis sublittoralis</i> G.M. Smith | From Q to E | VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Grateloupia patens</i> (Okamura) Kawaguchi & Wang | From E to C | VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Laurencia caduciramulosa</i> Masuda & Kawaguchi | From Q to E | VERLAQUE <i>et al.</i> , in press |
| CHR | <i>Padina boryana</i> Thivy in W.R. Taylor | From C to E | VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Plocamium secundatum</i> (Kützing) Kützing | From C to E | Spain: RODRÍGUEZ PRIETO, unpublished |
| RHO | <i>Polysiphonia atlantica</i> Kapraun & J.N. Norris | From Q to E | VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Porphyra yezoensis</i> Ueda | From C to E | VERLAQUE <i>et al.</i> , in press |
| RHO | <i>Solieria dura</i> (Zanardini) F. Schmitz | From E to C | VERLAQUE <i>et al.</i> , in press |
| CHR | <i>Sphaerotrichia firma</i> (Gepp) A.D.Zinova | From C to E | Occurrence in Levantine, Aegean, Marmara, France |
| RHO | <i>Symphyocladia marchantioides</i> (Harvey) Falkenberg | From C to E | VERLAQUE <i>et al.</i> , in press |

⁶The determination of the Atlantic or Mediterranean origin of the Thau populations requires further investigation

Lagoon (VERLAQUE *et al.*, 2007). *Ulva ohnoi*, recorded in ballast water (Italy: FLAGELLA *et al.*, 2007) is not included in the CIESM atlas.

Concerning micro-phytobenthos, there have been few studies of the benthic/epiphytic species such as *Ostreopsis lenticularis*, *O. siamensis*, *O. ovata* in the Mediterranean compared to other regions and these species have simply been recorded when studies were carried out (i.e. MONTI *et al.*, 2007). According to GOMEZ (2008) these new entries should not be considered as recent species introductions in the Mediterranean Sea. However, in the absence of evidence we maintain them as aliens.

With the addition of the three afore-

mentioned species, thirty four (34) *new* phytobenthos species have been added to the 'annotated list'.

In the light of new data, changes have occurred in establishment success. Eleven of the previous casual records such as *Plocamium secundatum* (RODRÍGUEZ PRIETO, unpublished) are now classified as established (Table 3.1). On the other hand, eight (8) of the questionable species reported in the 'annotated list' and two of the 'established' are excluded in this work (Table 3.2). Additional species that are considered as non-aliens in the CIESM Atlas (VERLAQUE *et al.*, in press) are listed in Table 3.2. Name changes are presented in Table 3.3.

Table 3.2
Taxa excluded compared to the 'annotated list'.

+ reported as questionable in the 'annotated list'

++ reported as established in the 'annotated list'

| Taxon | Species | Reasoning |
|-------|---|--|
| RHO | + <i>Acanthophora muscoides</i> (Linnaeus) Bory de Saint-Vincent | Unsupported records |
| RHO | <i>Acrochaetium balticum</i> (Rosenvinge) Aleem & Schulz | Mistake |
| RHO | <i>Antithamnion densum</i> (Suhr) M.A. Howe | Mistake |
| RHO | <i>Antithamnion ogdeniae</i> Abbott | Indigenous species (<i>A. decipiens</i>) |
| RHO | ++ <i>Chondria collinsiana</i> M.A. Howe | Unsupported records |
| RHO | ++ <i>Chondria polyrhiza</i> F.S. Collins & Hervey | Unsupported records |
| RHO | <i>Ceramium giacconeii</i> Cormaci & G. Furnari | Indigenous species |
| RHO | <i>Ceramium graecum</i> Lazaridou & Boudouresque | Indigenous species |
| RHO | <i>Chondrus crispus</i> Stackhouse | Misidentification |
| RHO | <i>Gracilaria armata</i> (C. Agardh) Greville | Indigenous species |
| RHO | + <i>Hypnea variabilis</i> Okamura | Unsupported records |
| RHO | + <i>Laurencia chondrioides</i> Boergesen | Indigenous species |
| RHO | + <i>Laurencia intricata</i> J.V. Lamouroux | Indigenous species |
| RHO | <i>Laurencia japonica</i> Yamada | Mistake |
| RHO | + <i>Laurencia majuscula</i> (Harvey) A.H.S. Lucas | Indigenous species |
| RHO | <i>Laurencia microcladia</i> Kützinger | Indigenous species |
| CHL | + <i>Parvocaulis parvulus</i> (Solms-Laubach) S. Berger, U. Fettweiss, S. Gleissberg, L. B. Liddle, U. Richter, H. Sawitsky & G.C. Zuccarello | Indigenous species |

(continued)

Table 3.2 (continued)

| Taxon | Species | Reasoning |
|-------|---|---------------------|
| RHO | + <i>Polysiphonia kampsaxii</i> Boergesen | Unsupported records |
| RHO | <i>Polystrata fosliei</i> (Weber-van Bosse) Denizot | Indigenous species |
| RHO | <i>Pterothamnion simile</i> (J.D. Hooker & Harvey) Nägeli | Mistake |
| CHR | <i>Rosenvingea intricata</i> (J. Agardh) Børgesen | Indigenous species |
| CHR | + <i>Sargassum latifolium</i> (Turner) C. Agardh | Unsupported records |

Table 3.3
Name changes in macroalgae.

| New name | Old name | Source |
|---|--|-----------------------------------|
| <i>Acrochaetium robustum</i> Børgesen | <i>Audouinella robusta</i> ; reported as <i>Acrochaetium sargassicola</i> | VERLAQUE <i>et al.</i> , in press |
| <i>Acrochaetium spathoglossi</i> Børgesen | <i>Audouinella spathoglossi</i> , reported as <i>Kylinia spathoglossi</i> | VERLAQUE <i>et al.</i> , in press |
| <i>Acrochaetium subseriatum</i> Børgesen | <i>Audouinella subseriata</i> | VERLAQUE <i>et al.</i> , in press |
| <i>Anotrichium okamurae</i> Baldock | <i>Anotrichium furcellatum</i> (J. Agardh) Baldock) | VERLAQUE <i>et al.</i> , in press |
| <i>Antithamnion nipponicum</i> Yamada & Inagak | misreported to <i>A. pectinatum</i> | VERLAQUE <i>et al.</i> , in press |
| <i>Botryella parva</i> (Takamatsu) Kim | <i>Sorocarpus</i> sp | VERLAQUE <i>et al.</i> , in press |
| <i>Dasyisiphonia</i> sp. | reported as <i>Heterosiphonia</i> <i>japonica</i> | VERLAQUE <i>et al.</i> , in press |
| <i>Feldmannophycus okamurae</i> (Yamada) Mineur, Maggs & Verlaque | reported as <i>F. rayssiae</i> | VERLAQUE <i>et al.</i> , in press |
| <i>Grateloupia subpectinata</i> | <i>G. luxurians</i> | VERLAQUE <i>et al.</i> , 2005 |
| <i>Hypnea flagelliformis</i> Greville ex J. Agardh | misidentified as <i>Hypnea spicifera</i> (Suhr) Harvey | VERLAQUE <i>et al.</i> , in press |
| <i>Neosiphonia harveyi</i> (J. Bailey) M.-S. Kim, H.-G. Choi, Guiry & G.W. Saunders | <i>Polysiphonia harveyi</i> J. Bailey | VERLAQUE <i>et al.</i> , in press |
| <i>Cladophora herpestica</i> (Montagne) Kützing | <i>Cladophoropsis javanica</i> (Kützing) P.C. Silva | VERLAQUE <i>et al.</i> , in press |
| <i>Ulvaria obscura</i> (Kützing) Gayral | <i>Monostroma obscurum</i> (Kützing) J. Agardh | VERLAQUE <i>et al.</i> , in press |
| <i>Saccharina japonica</i> (Areschoug) C.E. Lane, C. Mayes, Druehl & G.W. Saunders | <i>Laminaria japonica</i> Areschoug | VERLAQUE <i>et al.</i> , in press |

4. Zoobenthos/Polychaeta

After the publication by ZENETOS *et al.* (2006), 10 additional alien polychaete species were reported from the Mediterranean (Table 4). *Chaetozone corona*, *Pseudopolydora paucibranchiata* and *Timarete punctata* were found along the Aegean and Levantine coasts of Turkey (ÇINAR & ERGEN, 2007; ÇINAR, 2007; DAGLI & ÇINAR, 2008); *Syllis bella*, *Exogone breviantennata* and *Syllis cf. mayeri* from the Lebanon coast (Levantine Sea) (AGUADO & SANMARTÍN, 2007); *Novafabricia infratorquata* from the Mediterranean coast of Spain and Italy (BICK, 2005; LICCIANO & GIAN-

GRANDE 2006); *Hesionura serrata* and *Erinaceusyllis serratosetosa* from Spain (CARDELL & MENDEZ, 1996; SAN MARTÍN, 2003) and *Megalomma claparedei* from Italy (GIANGRANDE & LICCIANO, 2008). Among the species, only *T. punctata*, *E. breviantennata* and *Megalomma claparedei* are Lessepsian immigrants; the others have probably been introduced into the area by shipping. The spionid worm, *Pseudopolydora paucibranchiata*, which was previously misidentified as *P. antennata* (ÇINAR *et al.*, 2006c), invaded the polluted soft bottom of the inner part of Izmir Bay, reaching to a population density of 6180 ind.m⁻² in June 2004 (DAGLI & ÇINAR, 2008).

Table 4

New alien polychaeta species in the Mediterranean and changes in establishment success.

Establishment success: C=casual; E=established; Q=questionable; CRf=cryptogenic frequent

| New species | Establishment success | Source |
|---|-----------------------|------------------------------------|
| <i>Chaetozone corona</i> Berkeley & Berkeley 1941 | CRf | Turkey: ÇINAR & ERGEN, 2007 |
| <i>Pseudopolydora paucibranchiata</i> Okuda 1937 | E | Turkey: DAGLI & ÇINAR, 2008 |
| <i>Syllis bella</i> (Chamberlin, 1919) | E | Lebanon: AGUADO & SAN MARTIN, 2007 |
| <i>Hesionura serrata</i> (Hartmann-Schröder, 1960) | C | Spain: CARDELL & MENDEZ, 1996 |
| <i>Timarete punctata</i> (Grube, 1859) | E | Turkey: ÇINAR, 2007 |
| <i>Exogone breviantennata</i> Hartmann-Schröder, 1959 | E | Lebanon: AGUADO & SAN MARTIN, 2007 |
| <i>Erinaceusyllis serratosetosa</i> (Hartmann-Schröder, 1982) | C | Spain: SAN MARTÍN, 2003 |
| <i>Megalomma claparedei</i> Gravier, 1908 | C | Italy: GIANGRANDE & LICCIANO, 2008 |
| <i>Novafabricia infratorquata</i> (Fitzhugh, 1983) | E | Spain: BICK, 2005 |
| <i>Syllis cf. mayeri</i> Musco et Giangrande, 2005 ¹ | Q | Lebanon: AGUADO & SAN MARTIN, 2007 |
| Change in establishment success | | |
| <i>Epidiopatra hupferiana</i> Augener, 1918 | From Q to C | Italy: Cantone pers. commu |
| <i>Isolda pulchella</i> Müller, 1858 | From Q to C | Italy: Cantone pers. commu |

¹ First description of species. Taxonomic position is questionable

According to ÇINAR (2007), the previous report of *Cirriiformia semicineta* (Ehlers, 1905) from the Levantine coast by LAUBIER (1966), might in fact belong to *Timarete punctata*. *Linopherus incarunculata* (Peters, 1858) reported by GALIL, (2007) is excluded as it is considered as misspelling of *Linopherus acarunculata*, (BEN ELIAHU, 1976).

Although there have been many attempts, the Mediterranean polychaete fauna is largely unknown. Therefore, the species that are distributed in the mid-eastern Atlantic cannot be considered as alien species, as they might have been previously overlooked or misidentified in the region. The minute syllid species are a good example. The recent great efforts to understand the syllid fauna in the Mediterranean have doubled the number of species that we had known in the region. For example, *Eri-naceusyllis belizensis* and *Syllides bansei*, both of Caribbean Atlantic origin, were first reported from the Mediterranean coast of Spain (OLANO *et al.*, 1998; ALOS, 1984) and then subsequently from the other coasts of the Mediterranean, including the Aegean Sea (ÇINAR & ERGEN, 2002; ÇINAR, 2003). Similarly, representatives of other families of tropical Atlantic origin, such as *Neanthes agulhana*, were recorded on the Cadiz Coast and Malaga (SARDA, 1985) and recently found along the Italian Coast (Ionian Sea GIANGRANDE unpublished data), and *Paranaitis wahlbergi*, of north Atlantic origin, were recorded in Ibiza (VIETEZ *et al.*, 2004).

5. Zoobenthos/Crustacea

Based on CORBERA (1994), who cast doubt on the origin of *Iphinoe crassipes haifae* because the species was present off the north-eastern coast of the

Iberian Peninsula, this questionable species has been excluded from our list. On the other hand, *Penaeopsis serrata*, excluded in the 'annotated list', is added here. It is argued that it had probably not been discovered earlier due to its deep-water habitat (MURA *et al.*, 2003). Six benthic copepods (*Canuellina insignis*, *Enhydrosoma hopkinsi*, *Robertsonia salsa*, *Scottolana longipes*, *Stenhelina inopinata*, *Stenhelina minuta*) reported in the Bardawil Lagoon (POR, 1964; 1972) that were erroneously placed among zooplankton in the 'annotated list' are also added to the zoobenthos.

Altogether, research has a) brought to light 10 new alien species (Table 5), belonging mostly to Decapoda and b) expanded the distribution of some species considered as casual so far, thus leading to their classification as established. Two of these new species, namely *Eocuma rosea* and *Urocaridella pulchella* are new to science (CORBERA & GALIL, 2007; YOKEŞ & GALIL, 2006b). However, diagnostic characters place them with other species of the same genera known from the Indo-Pacific Ocean and it is thus suggested that they entered the Mediterranean through the Suez Canal (CORBERA & GALIL, 2007; YOKEŞ & GALIL, 2006b).

6. Zoobenthos /Mollusca

Mollusca is one of the best studied groups (ZENETOS *et al.*, 2004) with significant contribution among alien biota in the Mediterranean (ZENETOS, 2008). The number of molluscan alien species recorded by December 2005 was estimated to be 196 (ZENETOS *et al.*, 2006). The rate of increase, compared to the 139 reported by GOFAS & ZENETOS (2003), was attributed to the increased

Table 5

New alien crustacean species in the Mediterranean and changes in establishment success.

* species excluded in the 'annotated list'.

Taxon: AMP=Amphipoda; CIR=Cirripedia; CUM=Cumacea; DEC=Decapoda; ISO=Isopoda; STO=Stomatopoda.

Establishment success: C=casual; E=established; Q=questionable

| Taxon | New species | Establishment success | Source |
|--|--|-----------------------|--|
| DEC | <i>Charybdis feriata</i> (Linnaeus, 1758) | C | Spain: ABELLÓ & HISPANO, 2006 |
| STO | <i>Clorida albolitura</i> Ahyong & Naiyanetr, 2000 | C | Israel: AHYONG & GALIL, 2006 |
| CUM | <i>Eocuma rosae</i> Corbera & Galil, 2007 ¹ | Q | Israel: CORBERA & GALIL, 2007 |
| DEC | <i>Fenneropenaeus merguensis</i> (De Man, 1888) | C | Turkey: ÖZCAN <i>et al.</i> , 2006 |
| DEC | <i>Grapsus granulatus</i> H. Milne-Edwards, 1853 | C | Tunisia: ZAOUALI <i>et al.</i> , 2007a |
| DEC | * <i>Penaeopsis serrata</i> Bate, 1881 | Q | Sardinian Channel: MURA <i>et al.</i> , 2003 |
| CUM | <i>Scherocumella gurneyi</i> (Calman, 1927) | C | Israel: CORBERA & GALIL, 2007 |
| DEC | <i>Sirpus monodi</i> Gordon, 1953 | C | Greece: PANCUCCI-PAPADOPOULOU & NALETAKI, 2007 |
| CIR | <i>Tetraclita squamosa</i> Pilsbry, 1916 | C | Tunisia: ZAOUALI <i>et al.</i> , 2007b |
| DEC | <i>Urocaridella pulchella</i> Yokeş & Galil, 2006 ² | E | Turkey: YOKEŞ & GALIL, 2006b |
| Change in establishment success | | | |
| ISO | <i>Apanthura sandalensis</i> Stebbing, 1900 | From C to E | Israel: NEGOESCU, 1981 |
| DEC | <i>Dorippe quadridens</i> (Fabricius, 1793) | From E to C | Record based on a single animal: GALIL, 2005. |
| AMP | <i>Gammaropsis togoensis</i> (Schellenberg, 1925) | From C to E | Turkey: BAKIR <i>et al.</i> , 2007 |
| ISO | <i>Paradella diana</i> Menzies, 1962 | From C to E | Turkey: ÇINAR <i>et al.</i> , 2008 |
| DEC | <i>Plagusia squamosa</i> (Herbst, 1790) | From C to E | Tunisia: ZAOUALI <i>et al.</i> , 2007a |

¹ First description of the species

² First description of the species

interest of malacologists and the relatively easy collection/identification of mollusca. However, 31 species were classified as questionable. The questionable taxa were reported mostly from the Israeli coast; the records were based on a single specimen or a few empty shells. In the 2006-2007

period, nine of them (Table 6.1) were reported as casual in other areas or even as having become established, such as *Chama aspera* (MIFSUD & OVALIS, 2007; OVALIS & ZENETOS, 2007) or *Nanostrea exigua* (MIENIS, 2008). The fact is that some of these species are present in collec-

Table 6.1

New alien molluscan species in the Mediterranean and changes in establishment success.

*Species excluded in the 'annotated list'

Establishment success: C=casual; E=established; Q=questionable;

| New species | Establishment success | Source |
|---|-----------------------|---|
| <i>Acanthopleura gemmata</i> (de Blainville, 1825) | Q | Libya: ZAOUALI <i>et al.</i> , 2007b |
| <i>Anadara granosa</i> (Linnaeus, 1758) | C | Greece: YOUNG <i>et al.</i> , 2007 |
| <i>Atys angustatus</i> Smith, 1872 | E | Turkey: VAN AARTSEN & GOUD, 2006a |
| <i>Bractechlamys vexillum</i> (Reeve, 1853) | C | France: WGITMO, 2006 |
| <i>Cerithidium perparvulum</i> (Watson 1886) | E | Israel: BOGI & GALIL, 2006 |
| <i>Chrysallida micronana</i> Öztürk & van Aartsen, 2006 | C | Turkey: ÖZTÜRK & VAN AARTSEN, 2006 |
| <i>Circe scripta</i> (Linnaeus, 1758) | C | Greece: YOUNG <i>et al.</i> , 2007 |
| * <i>Conus arenatus arenatus</i> Hwass, 1792 | C | Israel: MIENIS, 2008 |
| <i>Conus inscriptus</i> Reeve, 1843 | C | Greece: YOUNG <i>et al.</i> , 2007 |
| <i>Conus rattus</i> Hwass, 1792 | C | Israel: MIENIS, 2008 |
| <i>Mytilopsis sallei</i> Recluz, 1849 | C | Egypt: HOFFMAN <i>et al.</i> , 2006 |
| <i>Nassa situla</i> (Reeve, 1846) | C | Israel: MIENIS, 2008 |
| <i>Nassarius concinnus</i> (Powys, 1835) | C | Israel: MIENIS, 2008 |
| <i>Nassarius stolatus</i> (Gmelin, 1791) | C | Greece: YOUNG <i>et al.</i> , 2007 |
| <i>Parviturbo dibellai</i> Buzzurro & Celalupo, 2006 | C | Turkey: BUZZURRO & CELALUPO, 2006 |
| * <i>Petricola hemprichi</i> (Issel, 1869) | C | Turkey: CEVIKER & ALBAYRAK S., 2006 |
| <i>Sepia gibba</i> Ehrenberg, 1831 | C | Israel: MIENIS, 2008 |
| <i>Sepia pharaonis</i> Ehrenberg, 1831 | Q | Known only from cuttlebones: MIENIS 2003a |
| <i>Strombus vittatus vittatus</i> Linnaeus, 1758 | C | Turkey: KABASAKAL <i>et al.</i> , 2005 |
| <i>Trivirostra triticum</i> Schilder, 1932 | C | Israel: MIENIS, 2008 |
| Change in establishment success | | |
| <i>Acteocina crithodes</i> Melvill & Standen, 1907 | From Q to C | Turkey: MIENIS, 2004 |
| <i>Angulus flacca</i> (Roemer, 1871) | From Q to C | Israel: MIENIS, 2004 |
| <i>Atys cylindricus</i> (Helbling, 1779) | From Q to C | Israel: MIENIS, 2004 |
| <i>Chama aspera</i> Reeve, 1846 | From C to E | Turkey: MIFSUD & OVALIS, 2007 |
| <i>Chama asperella</i> Lamarck, 1819 | From Q to E | Greece: OVALIS & ZENETOS, 2007 |
| <i>Chromodoris quadricolor</i> (Rüppell & Leuckart, 1828) | From C to E | Turkey: ÖZTÜRK & CAN, 2006. |
| <i>Ergalatax contracta</i> (Reeve, 1846) | From E to C | R. HOUART, pers. Commun. |
| <i>Ethminolia hemprichi</i> (Issel, 1869) | From Q to C | MIENIS, 2004 Great Bitter Lake, HOFFMAN <i>et al.</i> , 2006 |

(continued)

Table 6.1 (continued)

| New species | Establishment success | Source |
|--|-----------------------|------------------------------------|
| <i>Nanostrea exigua</i> Harry, 1985 | From Q to E | Israel: MIENIS, 2008 |
| <i>Nerita sanguinolenta</i> Menke, 1829 | From C to E | Turkey: MUTAF <i>et al.</i> , 2007 |
| <i>Pinctada margaritifera</i> (Linnaeus, 1758) | From E to C | MIENIS, 2004 |
| <i>Rhinoclavis sinensis</i> (Gmelin, 1791) | From Q to C | MIENIS, 2004 |
| <i>Rissoina ambigua</i> (Gould, 1849) | From Q to C | MIENIS, 2004 |
| <i>Septifer bilocularis</i> (Linnaeus, 1758) | From Q to C | Turkey: ALBAYRAK & CALGAR, 2006 |

tions from the Mediterranean and are frequently reported in periodicals of Malacological Societies (*ARION*, *BASTERIA*, *GLORIA MARIS*, *HALIOTIS*, *LEVANTINA*, *NAUTILUS*, *NEPTUNEA*, *NOVAPEX*, *SPIRULA*, *TRITON*, etc.).

The ‘annotated list’ has been updated based on contributions that include summaries of findings of invasive molluscs in the Mediterranean, such as MIENIS (2004; 2008) and DELONGUEVILLE & SCAILLET (2007), or just sparse records of new alien species (MIENIS, 2003a, 2003b, 2005). From the latest publications it appears that the centre of bio-invasions, which used to be the Israeli coast, is spreading northward. Most of the new records refer to the Levantine coast of Turkey (Table 6.1) where more alien mollusca are met, including species excluded in the CIESM Atlas (ZENETOS *et al.*, 2004) such as *Petricola hemprichi* (CEVIKER & ALBAYRAK, 2006) and *Conus arenatus arenatus* (MIENIS, 2008). Newly-established species in areas along the coast of Turkey include *Chromodoris quadricolor* (CAN, 2006) and *Nerita sanguinolenta* (MUTAF *et al.*, 2007). Eight new species are reported as occasional new visitors along the Mediterranean coast of Israel (Table 6.1) including a variation of the well established gastropod

Rhinoclavis kochi var. *recurva* and the rare *Planaxis griseum* (MIENIS, 2008). Another hotspot area for alien biota is the Saronikos Gulf. The presence of four alien molluscan species (shells only), new to the Mediterranean, is attributed to shipping in combination with climatic change (YOUNG *et al.*, 2007).

Meanwhile taxonomic studies have led to nomenclature changes of several species (Table 6.2). There are now approximately 216 alien mollusca in the Mediterranean - twenty (20) *new* molluscs since the ‘annotated list’.

7. Zoobenthos /Miscellanea

Twenty (20) *new* species are added to the ‘annotated list’; the main invading groups are echinodermata, ascidia and bryozoa (Table 7). Most of the new species are fouling organisms reported from port areas.

Echinodermata: The number of alien echinodermata has doubled with the present records from 5 to 11. Four of the newcomers were reported in the 2006-2007 period while *Prionocidaris babulosa* and *Asterias rubens* were reported earlier (Table 7). *Asterias rubens* is a well-established species in the Sea of Marmara, known since 1990 (YUCE & SADLER,

Table 6.2
Name changes in mollusca.

| New name | Old name | Source |
|---|---|--|
| <i>Cerithidium diplax</i> (Watson, 1886) | <i>Clathrofenella ferruginea</i> (A. Adams, 1860) | VAN AARTSEN, 2006 |
| <i>Cyrnola lendix</i> (A. Adams 1863) | <i>Styloptygma beatrix</i> Melvill, 1911 | VAN AARTSEN & GOUD, 2006b |
| <i>Diplodonta bogii</i> Van Aartsen, 2004 | <i>Diplodonta subrotunda</i> Issel, 1869 | VAN AARTSEN, 2004 |
| <i>Ergalatax junionae</i> Houart, 2008 | <i>Ergalatax obscura</i> Houart, 1996 | HOUART, 2008 |
| <i>Melibe viridis</i> (Kelaart, 1858) | <i>Melibe fimbriata</i> Alder & Hancock, 1864 | GOSLINER & SMITH, 2003 |
| <i>Monoitigma lauta</i> (A. Adams, 1853) | <i>Adelacteon fulvus</i> (A. Adams, 1851) | VAN AARTSEN & HORI, 2006 |
| <i>Leucotina natalensis</i> Smith, 1910 | <i>Adelacteon amoenus</i> (A. Adams, 1851) | VAN AARTSEN & HORI, 2006 |
| <i>Timoclea marica</i> (Linnaeus, 1758) | <i>Timoclea maurica</i> | Spelling mistake in ZENETOS <i>et al.</i> , 2006 |

2000). MORTENSEN (1927) reported that it was found accidentally in the Mediterranean but did not specify a locality. ALBAYRAK, (1996) reports it from the Bosphorus Straits. The suggestion that *A. rubens* was introduced by shipping (ZIBROWIUS, 2002) is reasonable. Its planktotrophic larvae may have been transferred in the ballast waters on ships. Other ship-mediated introductions include *Eucidaris tribuloides* (TANTI & SCHEMBRI, 2006), *Prionocidaris babulosa* (SCHEMBRI, 1978), while there remain the introductions of *Diadema setosum*, and *Ophiocoma scolopendrina* (YOKEŞ & GALIL, 2006a; ZAOUALI *et al.*, 2007b) presumably via the Suez Canal.

Bryozoa: Three new bryozoan species are reported, all three presumably ship-transferred and reported close to harbour areas. *Bowerbankia gracillima* of Atlantic origin, reported from Lazio, Italy (D'HONDT & CHIMENZ GUSSO, 2006); *Celleporaria brunnea* and *Cellepo-*

raria pilaefera, of Indo-Pacific origin, reported near Alsancak Harbour, Aegean Turkey and Rinella, Malta, respectively (KOCAK, 2007; AGIUS *et al.*, 1977).

Hydrozoa: Two species are added to the 'annotated list' namely: *Eudendrium carneum*, which has been recorded from the western Mediterranean in recent years (GILI, 1986; BAVESTRELLO & PIRAINO, 1991) and *Sertularia marginata* found in the eastern Mediterranean (PICARD, 1958).

Ascidacea: Six new ascidians are reported. Of them, *Styela clava* is classified among the top worst invasive IAS in Europe (EEA, 2007b). The proximity of commercial shell fisheries to the discovered populations in S. France, and the absence of *S. clava* from other harbours and marinas along the coast, suggests that the species may have been introduced by shellfish transfer (DAVIS & DAVIS, 2008). Several colonies of *Distaplia bermudensis* were observed from the Taranto Seas (Mar Pic-

Table 7
New alien zoobenthic species (Miscellanea taxa) in the Mediterranean
and changes in establishment success.

Taxon: ECH=Echinodermata; BRY=Bryozoa; HYD=Hydrozoa; ASC=Ascidiacea; SIP=Sipuncula;
PLA=Platyelminthes.

Establishment success: C=casual; E=established; Q=questionable; CR=Cryptogenic

| Taxon | New species | Establishment success | Source |
|-------|---|-----------------------|--|
| ECH | <i>Acanthaster planci</i> (Linnaeus, 1758) | C | France: WGITMO, 2006 |
| ECH | <i>Asterias rubens</i> Linnaeus, 1755 | E | Turkey: YUCE & SADLER, 2000 |
| ECH | <i>Diadema setosum</i> (Leske, 1778) | C | Turkey: YOKE & GALIL, 2006a |
| ECH | <i>Eucidaris tribuloides</i> (Lamarck, 1816) | E | Malta: TANTI & SCHEMBRI, 2006 |
| ECH | <i>Ophiocoma scolopendrina</i> (Lamarck, 1816) | C | Libya: ZAOUALI <i>et al.</i> , 2007b |
| ECH | <i>Prionocidaris babulosa</i> (Lamarck, 1816) | C | Malta: SCHEMBRI, 1978 |
| BRY | <i>Bowerbankia gracillima</i> Hinks, 1880 | C | Italy: D'HONDT & CHIMENZ GUSSO, 2006 |
| BRY | <i>Celleporaria brunnea</i> (Hincks, 1884) | C | Turkey: KOCAK, 2007 |
| BRY | <i>Celleporaria pilaefera</i> (Canu & Bassler, 1929) | Q | Malta: AGIUS <i>et al.</i> , 1977 |
| HYD | <i>Eudendrium carneum</i> Clarke, 1882 | E | Spain: GILL, 1986 |
| HYD | <i>Sertularia marginata</i> (Kirchenpauer, 1864) | C | Lebanon: PICARD, 1958 |
| ASC | <i>Botrylloides violaceus</i> Oka, 1927 | E | Italy: ZANIOLO <i>et al.</i> , 1998 |
| ASC | <i>Cystodytes philippinensis</i> Herdman 1886 | CR | MELIANE, 2002 |
| ASC | <i>Distaplia bermudensis</i> Van Name, 1902 | E | Spain: PERES, 1957 Italy: MASTROTOTARO & BRUNETTI, 2006 |
| ASC | <i>Ecteinscidia styeloides</i> (Traustedt, 1882) | E | MASTROTOTARO & TURSI, 2006 |
| ASC | <i>Perophora multiclathrata</i> (Sluiter, 1904) | E | MONNIOT, 1983 |
| ASC | <i>Styela clava</i> Herdman, 1882 | E | France: DAVIS & DAVIS, 2008 |
| ASC | <i>Botrylloides violaceus</i> Oka, 1927 | E | Italy: ZANIOLO <i>et al.</i> , 1998 |
| POR | <i>Paraleucilla magna</i> Klautau <i>et al.</i> , 2004 | E | Italy: LONGO <i>et al.</i> , 2007 |
| SIP | <i>Apionsoma misakianum</i> Ikeda, 1904 ¹ | Q | Turkey: AÇIK, 2007 |
| PLA | <i>Boninia neotethydis</i> Curini-Galletti & Campus, 2007 | E | Israel: CURINI-GALLETTI & CAMPUS, 2007 |

(continued)

¹Origin uncertain

Table 7 (continued)

| Taxon | New species | Establishment success | Source |
|--|---|-----------------------|--|
| Change in establishment success | | | |
| SIP | <i>Aspidosiphon elegans</i> (Chamisso & Eysenhardt, 1821) | From Q to E | Turkey: AÇIK, 2008 |
| ASC | <i>Microcosmus squamifer</i> Michaelsen, 1927 | From Q to E | TURON <i>et al.</i> , 2007 |
| ASC | <i>Eusynstyela hartmeyeri</i> Michaelsen, 1904 | From C to Q | IZQUIERDO-MUNOZ <i>et al.</i> , in press |
| ASC | <i>Ascidia cannelata</i> Oken, 1820 | From C to E | IZQUIERDO-MUNOZ <i>et al.</i> , in press |

colo and Mar Grande) since 2000 (MASTROTOTARO & BRUNETTI, 2006). *Botryllus schlosseri*, a cosmopolitan species normally present in the Mediterranean Sea, was erroneously cited as established in the 'annotated list'. In contrast, *Botrylloides violaceus*, native to Northwest Pacific, is recorded from the Venice Lagoon in Italy (ZANIOLO *et al.*, 1998). *Perophora multiclathrata* and *Ecteinascidia styeloides* have only been found in harbours (MONNIOT, 1983, MASTROTOTARO & TURSÌ 2006) while Cystodytes philippinensis is a cryptogenic species probably confused with *C. dellechiaiei* (MELIANE, 2002). *Symplegma viride*, a casual species in the 'annotated list' is excluded as synonym of *Symplegma brakenhielmi* (IZQUIERDO-MUNOZ *et al.*, in press). *Ascidia savigny* is also excluded as a misidentification of *Ascidia cannelata* (A. Ramos-Espla, pers. commun.).

Porifera: Current research on the Lebanese coast has brought to life five species that are new for the Mediterranean but which are widely distributed in the tropics. However, these species do not appear to be Lessepsian immigrants, but are interpreted as remnants of an ancient

thermophilous fauna that survived in the easternmost part of the Mediterranean (VACELET *et al.*, 2007). On the other hand, the calcareous sponge *Paraleucilla magna* has been detected at different Mediterranean sites (Taranto, Porto Cesareo, Brindisi and Naples). Its record in well-studied areas where several benthic surveys have previously been carried out suggests a recent introduction of the species into the Mediterranean Sea (LONGO *et al.*, 2007).

Sipuncula: *Aspidosiphon elegans*, a rare species to date, has recently established viable populations on the Levantine coast of Turkey (AÇIK, 2008). The status of a second *Apionsoma* species *A. (A.) misakianum*, though widely distributed in the Aegean Sea (not confined to a recipient area such as harbours or near canals) was most probably previously confused with the other *Apionsoma* species in the Mediterranean Sea. The previous reports of *Apionsoma* species should be re-examined to determine the real distributional boundary of *A. (A.) misakianum* within the Mediterranean basins (AÇIK, 2007).

Platyelminthes: Based on specimens

collected in the Mediterranean and the Red Sea coasts of Israel, a new Lessepsian flatworm (*Boninia neotethydis*) was described (CURINI-GALLETTI & CAMPUS, 2007). An Indo-Pacific origin of the species is supported by the history of its records. In 1998 the species was common in the Mediterranean, particularly in shelly, very coarse sediments at the bottom of rocky pools, and among clumps of the mussel *Brachidontes pharaonis*.

8. Zoobenthos /Foraminifera

In the Mediterranean, very little attention was paid to alien foraminifera until the early 1990s. Since then, they have been reported from many localities such as the Adriatic Sea (CIMERMAN & LANGER, 1991), Italy: the Tyrrhenian Sea (SGARRELLA & MONCHARMONT-ZEI, 1993), Israel (HYAMS *et al.*, 2002), Egypt (SAMIR *et al.*, 2003), Greece (DEBENAY *et al.*, 2005; TRIANTAPHYLLOU *et al.*, 2005) and the Maltese Islands (YOKEŞ *et al.*, 2007). The greatest amount of information however, comes from the Turkish coast. Recent studies have revealed the presence of many alien benthic foraminifera species on the southern and western Mediterranean coasts of Turkey (MERIÇ & AVŞAR, 2001; MERIÇ *et al.*, 2002 a, b, c; 2003 a, b; 2004 a, b), and in the Dardanelles (MERIÇ *et al.*, 2008a) and the Sea of Marmara (KAMINSKI *et al.*, 2002; MERIÇ *et al.*, 2005, 2007). In the 'annotated list' only seven species have been reported with the authors acknowledging the difficulty in properly documenting the records of foraminiferans in the area and identifying the need for an update. Table 8 summarizes information on alien foraminifera

recorded in the Mediterranean, also providing the geographic range they have been reported from at country level.

A summary of the Turkish alien foraminifera is provided in MERIÇ *et al.*, 2008d. Most of the alien foraminifer species observed in the Mediterranean Sea are of Indo-Pacific origin presumably introduced via the Suez Canal. The most abundant species are *Sorites orbiculus* and *Amphistegina lobifera*. Some researchers reported the presence of *Amphistegina* in Haifa-Israel, Greece and the Gulf of Gabes without indicating a specific species (LANGER & HOTTINGER, 2000). *Iridia diaphana*, which is rarely observed in the Northern Aegean Sea, is suggested as being of Atlantic origin and widely distributed in the Mediterranean (LOEBLICH & TAPAN, 1988). The species *Pulleniatina obliquiloculata* occurs both in the Atlantic and Indo-Pacific; however, its absence from the Red Sea fauna suggests that it has been introduced and has spread into the Mediterranean from the Atlantic via Gibraltar. In contrast, the species *Cushmanina striatopunctata*, also known to have a wide distribution in the Atlantic and in the Indo-Pacific (HOTTINGER *et al.*, 1993; LOEBLICH & TAPAN, 1994), is absent from the western Mediterranean, which suggests that the eastern Mediterranean population has an Indo-Pacific origin. Thus, it might have been introduced from the Red Sea and settled in the Dardanelles Straits. Like *Agglutinella* and *Amphistegina* spp., it may also establish a population in the Sea of Marmara.

In total, 45 alien foraminiferan species (49 including 4 identified at the genera level) are found in the Mediterranean. 32 genera and 42 species are suggested to have an Indo-Pacific origin, whereas, only 2 genera and 2 species are of Atlantic origin.

Table 8
Alien Foraminiferan species in the Mediterranean.

+ species reported in the 'annotated list'.

Establishment success: C=casual; R=Established/Rare; F=Established/Frequent

| Species | Establishment success | Source |
|--|-----------------------|--|
| <i>Acervulina inhaerens</i> Schultze | R | Turkey: MERIÇ <i>et al.</i> , 2004 a |
| <i>Agglutinella arenata</i> (Said) | C | Turkey: KAMINSKI <i>et al.</i> , 2002 |
| <i>Agglutinella compressa</i> El-Nakhal | R | Egypt: SAMIR <i>et al.</i> , 2003 |
| <i>Agglutinella robusta</i> El-Nakhal | R | Egypt: SAMIR <i>et al.</i> , 2003 |
| <i>Agglutinella soriformis</i> El-Nakhal | R | Egypt: SAMIR <i>et al.</i> , 2003 |
| + <i>Amphisorus hemprichii</i> Ehrenberg | F | YANKO, 1995; Egypt: SAMIR <i>et al.</i> , 2003; Turkey: MERIÇ <i>et al.</i> , 2008c |
| <i>Amphistegina lessonii</i> D'Orbigny | R | Greece: HOLLAUS & HOTTINGER, 1997; Israel: HYAMS <i>et al.</i> , 2002 |
| + <i>Amphistegina lobifera</i> Larsen | F | Israel: YANKO <i>et al.</i> , 1993; Turkey: MERIÇ & AVŞAR, 2001; Malta: YOKEŞ <i>et al.</i> , 2007 |
| <i>Amphistegina madagascariensis</i> (D'Orbigny) | C | Egypt: SAMIR <i>et al.</i> , 2003 |
| <i>Articulina alticostata</i> Cushman | C | Turkey: MERIÇ <i>et al.</i> , 2004a |
| + <i>Astacolus insolithus</i> (Schwager) | C | Turkey: MERIÇ <i>et al.</i> , 2004a |
| + <i>Astacolus sublegumen</i> (Parr) | C | Turkey: MERIÇ <i>et al.</i> , 2004a |
| <i>Borelis</i> sp | R | Israel: HYAMS <i>et al.</i> , 2002 |
| <i>Clavulina angularis</i> D'Orbigny | R | Israel: YANKO <i>et al.</i> , 1993; Turkey: AVŞAR <i>et al.</i> , 2001 |
| <i>Clavulina</i> cf. <i>multicamerata</i> Chapman | R | Turkey: MERIÇ <i>et al.</i> , 2008c |
| <i>Cushmanina striatopunctata</i> (Parker & Jones) | R | Turkey: MERIÇ <i>et al.</i> , 2008b |
| <i>Cyclorbiculina compressa</i> (D'Orbigny) | C | Turkey: MERIÇ <i>et al.</i> , 2008c |
| <i>Cymbaloporeta plana</i> (Cushman) | R | Turkey: MERIÇ <i>et al.</i> , 2008c |
| <i>Cymbaloporeta squamosa</i> (D'Orbigny) | R | Turkey: MERIÇ <i>et al.</i> , 2008c |
| <i>Edentostomina cultrata</i> (Brady) | R | Israel: YANKO <i>et al.</i> , 1993; Turkey: MERIÇ <i>et al.</i> , 2004a |
| <i>Elphidium</i> cf. <i>charlottense</i> (Vella) | R | Turkey: MERIÇ <i>et al.</i> , 2008c |
| <i>Elphidium striatopunctatum</i> (Fichtel & Moll) | R | Israel: YANKO <i>et al.</i> , 1993; Turkey: AVŞAR <i>et al.</i> , 2001 |
| <i>Entosigmomorphina</i> sp | R | Turkey: MERIÇ <i>et al.</i> , 2008c |
| <i>Euuvigerina</i> sp | R | Turkey: MERIÇ <i>et al.</i> , 2004b |
| <i>Haddonina</i> sp | F | Turkey: MERIÇ <i>et al.</i> , 2008c |
| <i>Hauerina diversa</i> Cushman | F | Israel: YANKO <i>et al.</i> , 1993; Turkey: AVŞAR <i>et al.</i> , 2001; |
| <i>Heterocyclus tuberculata</i> (Mobius) | R | Israel: YANKO, 1995; Turkey: AVŞAR <i>et al.</i> , 2001 |

(continued)

Table 8 (continued)

| Species | Establishment success | Source |
|---|-----------------------|--|
| ⁺ <i>Heterostegina depressa</i> D'Orbigny | F | Italy: MONCHARMONT-ZEÏ, 1968; Greece: MORARIU & HOTTINGER, 1988; Israel: YANKO <i>et al.</i> , 1993; Turkey: AVŞAR <i>et al.</i> , 2001 |
| <i>Iridia diaphana</i> Heron-Allen & Earland | F | Turkey: MERİÇ <i>et al.</i> , 2008a |
| <i>Miliolinella cf. hybrida</i> (Terquem) | R | Turkey: MERİÇ <i>et al.</i> , 2008c |
| <i>Nodopthalmidium antillarum</i> (Cushman) | F | Israel: YANKO, 1995; Turkey: MERİÇ <i>et al.</i> , 2008c |
| <i>Operculina ammonoides</i> (Gronovius) | C | Israel: YANKO, 1995 |
| <i>Peneroplis antillarum</i> D'Orbigny | C | Israel: HYAMS <i>et al.</i> , 2002 |
| <i>Peneroplis arietinus</i> (Batsch) | F | Turkey: MERİÇ <i>et al.</i> , 2008c |
| ⁺ <i>Planogypsina acervalis</i> (Brady) | R | Turkey: MERİÇ <i>et al.</i> , 2004a |
| ⁺ <i>Planogypsina squamiformis</i> (Chapman) | R | Turkey: MERİÇ <i>et al.</i> , 2004a |
| <i>Planorbulinella larvata</i> (Parker & Jones) | C | Israel: YANKO, 1995 |
| <i>Pseudomassilina reticulata</i> (Heron-Allen & Earland) | R | Israel: YANKO <i>et al.</i> , 1993; Turkey: AVŞAR <i>et al.</i> , 2001 |
| <i>Pulleniatina obliquiloculata</i> (Parker & Jones) | R | Turkey: MERİÇ <i>et al.</i> , 2004b |
| <i>Pyramidulina catesbyi</i> (D'Orbigny) | R | Israel: YANKO <i>et al.</i> , 1993; Turkey: AVŞAR <i>et al.</i> , 2001 |
| <i>Pyramidulina perversa</i> (Schwager) | R | Turkey: MERİÇ <i>et al.</i> , 2008c |
| <i>Pyrgo denticulata</i> (Brady) | R | Israel: YANKO <i>et al.</i> , 1993; Egypt: SAMIR <i>et al.</i> , 2003; Turkey: MERİÇ <i>et al.</i> , 2008c |
| <i>Quinqueloculina cf. mosharrafai</i> Said | R | Turkey: MERİÇ <i>et al.</i> , 2008c |
| <i>Schlumbergerina alveoliniformis</i> (Brady) | R | Turkey: MERİÇ <i>et al.</i> , 2008c |
| <i>Sorites orbiculus</i> Ehrenberg | F | Italy: HOFKER, 1930, Greece: CHERIF, 1970; France: BLANC VERNET <i>et al.</i> , 1979; Italy: CRAPON-DE CAPRONA & BENIER, 1985; Adriatic: CIMERMAN & LANGER, 1991; Israel: YANKO, 1995; Turkey: AVŞAR <i>et al.</i> , 2001; Egypt: SAMIR <i>et al.</i> , 2003 |
| <i>Sorites variabilis</i> Lacroix | F | Israel: YANKO <i>et al.</i> , 1993; Turkey: MERİÇ <i>et al.</i> , 2008c |
| <i>Spiroloculina angulata</i> Cushman | F | Israel: YANKO <i>et al.</i> , 1993; Turkey: AVŞAR <i>et al.</i> , 2001 |
| <i>Spiroloculina antillarum</i> D'Orbigny | F | Israel: YANKO <i>et al.</i> , 1993; Turkey: AVŞAR <i>et al.</i> , 2001; Egypt: SAMIR <i>et al.</i> , 2003; Greece: DEBENAY <i>et al.</i> , 2005 |
| <i>Triloculina cf. fichteliana</i> D'Orbigny | R | Turkey: MERİÇ <i>et al.</i> , 2004a |

9. Parasites

Unlike the recent increase in reports of introduced free-living marine species, reports of parasites invading marine environments are relatively uncommon. When species are introduced into a new territory their parasites may also follow, forming a biotic unit called 'symbiota' (GALLI *et al.*, 2005). Parasites are potentially able to control host populations and reduce host density by affecting their growth, reproduction, and survival (TORCHIN & MITCHELL, 2004). They can also affect community structure by indirectly acting on predation or competition (MOURITSEN & POULIN, 2006).

A recent study examining all parasites from different groups of animals (molluscs, crustaceans, fish, birds, mammals, amphibians and reptiles) showed that the number of parasite species found in exotic populations is roughly half the number found in native populations (TORCHIN *et al.* 2003). In the same study, it was shown that introduced populations were less heavily parasitized in terms of average prevalence (percentage of hosts infected with one or more individuals of a parasite species (BUSH *et al.*, 1997). The parasites with a lower probability of colonizing new areas tended to be those that were less prevalent in native populations. The success of establishment of parasites (both in new geographical areas and new hosts) has been described in detail by PASTERNAK *et al.* (2007) and PAIS *et al.* (2007) who illustrated that it may depend on: 1) how often the host population has been introduced into the new area; 2) the complexity of the parasite life-cycle; 3) the age of the host (according to BAUER (1991) younger fish, fry or fingerlings, are less infected than adults) and 4) global climatic change.

Few scientists have been only looking for parasitological aspects in the wild, while investigations have focused mostly on the micro- and macro- parasites of Indo-Pacific immigrants, the most popular hosts being *Siganus luridus* and *S. rivulatus* and more recently *Fistularia commersoni*. As knowledge concerning the original distribution of parasites is not complete, we propose cross-comparison of parasitological data regarding both native and alien hosts. We consider as alien the parasites detected only on alien hosts, or recognized as aliens from the authors of the research. Parasites recorded from both native and alien fish are regarded as of unknown origin. In particular, we consider of unknown origin the genera *Ceratomyxa*, *Entamoeba*, *Hexamita* (syn *Octomitus*) and *Ortholinea*, which in fact were found on both Red Sea and Mediterranean hosts.

To date, 14 species of parasites have been recognized as Lessepsian (BARICHE & TRILLES, 2006; TRILLES & BARICHE, 2006; GALIL & LÜTZEN 1995; PAIS *et al.*, 2007; PASTERNAK *et al.*, 2007; PAPERNA, 1972; DIAMANT *et al.*, 1999). The most representative group belongs to the class Monogonoidea (Table 9.1). In the Red Sea, monogonoids have been studied principally by PAPERNA (1965, 1972a,b,c), PAPERNA *et al.* (1984), DIAMANT & PAPERNA (1986), and DIAMANT (1989), and more recently by KRITSKY *et al.* (2007) and KRITSKY & GALLI (2007); In Mediterranean Sea Monogonoidea were investigated by DIAMANT (1989) and PASTERNAK *et al.* (2007).

The first documented case of a monogonoidean invading a new biogeographical region by 'natural' extension of its host range is that of the gill ectoparasite *Polylabris cf. mamaevi* infecting rabbitfish,

Table 9.1
Alien parasite species in the Mediterranean.

+ species reported in the 'annotated list'.

Taxon: CRU=Crustacea; MON=Monogeneoidea/Platyelminthes; DIG= Digenea/ Platyelminthes;

PRO=Protozoa. Establishment success: C=casual; E=established; Q=questionable

| Taxon | Species | Establishment success | Source |
|-------|---|-----------------------|--|
| CRU | <i>Anilocra pilchardi</i> Bariche & Trilles, 2006 | C | Lebanon: BARICHE & TRILLES, 2006 |
| CRU | <i>Cymothoa indica</i> (Schiodte. & Meinert, 1884) | C | Lebanon: TRILLES & BARICHE, 2006 |
| CRU | + <i>Heterosaccus dollfusi</i> Boschma, 1960 | E | Israel: GALIL & LÜTZEN 1995 |
| CRU | + <i>Mytilicola orientalis</i> Mori, 1935 | E | France: HIS, 1977 |
| CRU | + <i>Mycicola ostrea</i> Hoshina & Sigiura, 1953 | E | France: POLLIO, 1981 |
| DIG | <i>Allolepidapedon fistulariae</i> Yamaguti, 1940 | C | Italy: PAIS <i>et al.</i> , 2007 |
| DIG | + <i>Hysteroleciitha sigani</i> Manter, 1969 | Q | Israel: FISCHTHAL 1980 |
| MON | <i>Polylabris cf mamaevi</i> Ogawa & Egusa, 1980 | E | Israel: DIAMANT, 1989 Paperna, 1972 |
| MON | <i>Tetrancistrum polymorphus</i> (Paperna, 1972) | E | Israel: PAPERNA, 1972d |
| MON | <i>Tetrancistrum suezicum</i> (Paperna, 1972) | E | Israel: PAPERNA, 1972d |
| MON | <i>Tetrancistrum strophosolenum</i> Kritsky, Galli & Tingbao 2007 | E | Israel: DIAMANT <i>et al.</i> , 1999 |
| MON | <i>Lecithochirium magnicaudatum</i> Fischthal & Kuntz, 1963 | C | Israel: FISCHTHAL 1980 |
| MON | <i>Monilicaecum ventricosum</i> Yamaguti, 1942 | C | Israel: FISCHTHAL 1980 |
| MON | <i>Glyphidohaptor plectocirra</i> (Paperna, 1972) | E | Israel: PAPERNA, 1972d |
| MON | <i>Lecithochirium magnicaudatum</i> Fischthal & Kuntz, 1963 | C | Israel: FISCHTHAL 1980 |
| MON | <i>Monilicaecum ventricosum</i> Yamaguti, 1942 | C | Israel: FISCHTHAL 1980 |
| MON | + <i>Neothoracocotyle acanthocybii</i> (Meserve, 1938) | C | Italy: ROMEO <i>et al.</i> , 2005 |
| PRO | + <i>Hirudinella ventricosa</i> (Pallas, 1774) | C | Italy: ROMEO <i>et al.</i> , 2005 |
| PRO | <i>Balantidium sigani</i> Diamant & Wilbert, 1985 | Q | Israel: DIAMANT <i>et al.</i> , 1999 |
| PRO | <i>Nosema ceratomyxa</i> Diamant & Paperna, 1985 | Q | Israel: DIAMANT <i>et al.</i> , 1999 |
| PRO | + <i>Bonamia ostrea</i> (Pichot <i>et al.</i> , 1979) | C | Spain: MONTES & LAMA, 1993 |
| PRO | <i>Perkinsus atlanticus</i> (Levine 1978) | E | Spain: SANTMARTÍ <i>et al.</i> , 1995 |
| PRO | <i>Marteilia refringens</i> Cavalier-Smith, 2002 | C | Spain: RIERA <i>et al.</i> , 1995 |

Siganus rivulatus. The prevalence levels of *P. cf. mamaevi* in the Israeli Mediterranean rabbitfish populations were very high, approximately three times greater than those found in the native populations of the northern Red Sea. The subfamily Protomicrocotylinae, to which *Polylabris* belongs, is almost entirely restricted to warmer waters of the Indo-west Pacific Ocean. Both host and parasite are Lessepsian immigrants that have co-invaded the Mediterranean Sea via the Suez Canal. The greater abundance of *P. cf. mamaevi* in the invading (Mediterranean) populations is probably due to the changed, new environment, possibly impacting on host resistance to the parasite and encouraging heavier infections (PASTERNAK *et al.*, 2007).

One Red Sea Digenea, *Allolepidapedon fistulariae*, was found by PAIS *et al.* (2007). *A. fistulariae* was reported for the first time from the Mediterranean Sea, parasitizing the bluespotted cornetfish *Fistularia commersonii*. The finding of this Indo-Pacific digenean, acquired by juvenile or adult fish predated on second intermediate hosts, would suggest that *F. commersonii* colonized the Mediterranean by actively swimming individuals and not by passive planktonic larvae (PAIS *et al.*, 2007).

Cymothoids (Isopoda) are a group of crustaceans typically parasitic of teleost fish. However, they are poorly studied animals and some groups remain completely undescribed. Studies of parasitic isopods from Lebanon have revealed the occurrence of two introduced species *Anilocra pilchardi* and *Cymothoa indica* (BARICHE & TRILLES, 2006; TRILLES & BARICHE, 2006) from the Indo-Pacific region parasitizing mainly barracudas (Sphyraenidae).

The global transport of marine bivalves for aquaculture has led to widespread introductions of parasitic copepods. Some parasitic copepods that infect shellfish have been widely introduced with the transport and culture of bivalves. *Mytilicola orientalis* and *Mycicola ostrae* are both parasitic copepods of the Pacific oyster, *Crassostrea gigas* in Asia, where they are native. Both species infect native bivalves and *M. orientalis* is considered a serious pest (STREFTARIS & ZENETOS, 2006).

Protistan parasites have often caused significant and widespread effects in marine systems and aquaculture operations. Some of these pathogens are likely to be introduced species. However, for other pathogens there is limited evidence of an exotic source. The protistan reported as aliens in the Mediterranean are the species *Bonamia ostreae*, *Perkinsus atlanticus* and *Marteilia refringens*, all introduced accidentally with aquaculture.

Bonamia ostreae is an intracellular haplosporidian parasite in European flat oysters *Ostrea edulis* that occurs on both coasts of the United States and causes significant mortality in Europe (MARTY *et al.*, 2006); since 1990 *Perkinsus atlanticus* has been responsible for abnormal mortalities of *Ruditapes decussatus* in Spain (SANTMARTÍ *et al.*, 1995; SAGRISTÀ *et al.*, 1996); *Marteilia refringens* is a haplosporidium protozoan parasite affecting the digestive system of the flat oyster. In Europe this disease is commonly known as Aber disease, digestive gland disease of the European oyster, or marteiliosis. Infection with *Marteilia refringens* produces high mortality, associated with sporulation in the epithelial cells of the digestive tubules. An intermediate host or a free-living stage is thought to be required in the lifecycle of this parasite. *Marteilia refrin-*

gens can occur in some oysters without causing disease.

Table 9.1 summarizes the information known to the authors where fourteen (14) additions have been made to the 'annotated list'. In the absence of further evidence, one of the crustaceans rated as casual in the 'annotated list', namely the cirripedia *Loxothylacus texanus* known to parasitise on *Callinectes sapidus* is excluded in this work as an unsupported record. This brings the number total of known

alien parasites in the Mediterranean to 21. Undoubtedly, more introduced marine parasites exist than are reported (TORCHIN & KURIS, 2005). Partly, this may be because, unlike their introduced hosts, parasites are often difficult to observe and thus some alien parasites go unreported.

The hosts analysed are illustrated in Table 9.2 while the most recent nomenclature changes are presented in Table 9.3.

Table 9.2
Alien parasites with their hosts.

Taxon: CRU=Crustacea; MON=Monogeneoidea/Platyelminthes; DIG= Digenea /Platyelminthes; PRO=Protozoa

| Taxon | Species | host |
|-------|-------------------------------------|--|
| CRU | <i>Anilocra pilchardi</i> | <i>Sardina pilchardus</i> <i>Boops boops</i> <i>Pagellus acarne</i> <i>Pagellus erythrinus</i> <i>Engraulis encrasicolus</i> |
| CRU | <i>Cymothoa indica</i> | <i>Sphyaena chrysotaenia</i> |
| CRU | <i>Heterosaccus dollfusi</i> | <i>Charybdis longicollis</i> |
| CRU | <i>Mytilicola orientalis</i> | Oyster beds |
| CRU | <i>Myicola ostrea</i> | Oyster beds |
| DIG | <i>Allolepidapedon fistulariae</i> | <i>Fistularia commersonii</i> |
| MON | <i>Polylabris cf mamaevi</i> | <i>Siganus rivulatus</i> |
| MON | <i>Tetrancistrum polymorphus</i> | <i>Siganus rivulatus</i> <i>Siganus luridus</i> |
| MON | <i>Tetrancistrum suezicum</i> | <i>Siganus rivulatus</i> |
| MON | <i>Tetrancistrum strophosolenum</i> | <i>Siganus rivulatus</i> |
| MON | <i>Glyphidohaptor plectocirra</i> | <i>Siganus rivulatus</i> <i>Siganus luridus</i> |
| MON | <i>Hysterolecitha sigani</i> | Siganidae |
| PRO | <i>Balantidium sigani</i> | <i>Siganus rivulatus</i> |
| PRO | <i>Nosema ceratomyxae</i> | <i>Siganus rivulatus</i> |
| PRO | <i>Bonamia ostrea</i> | Oyster beds |
| PRO | <i>Perkinsus atlanticus</i> | <i>Ruditapes philippinarum</i> <i>Tapes decussatus</i> <i>Tapes semidecussatus</i> |
| PRO | <i>Marteilia refringens</i> | Oyster beds |

Table 9.3
Name changes in parasites.

| New name | Old name | Source |
|---|---|----------------------------|
| <i>Tetrancistrum polymorphus</i> (Paperna, 1972) | <i>Pseudohaliotrematoides polymorphus</i> <i>eilaticus</i> : Paperna, 1972 <i>Pseudohaliotrematoides polymorphus</i> <i>eilaticus</i> : KTARI & KTARI (1974) | KRITSKY <i>et al.</i> 2007 |
| <i>Tetrancistrum suezicum</i> (Paperna, 1972) | <i>Pseudohaliotrematoides polymorphus</i> <i>suezicus</i> : Paperna, 1972 <i>Pseudohaliotrematoides polymorphus</i> <i>suezicus</i> : KTARI & KTARI (1974) (misspelling); <i>Pseudohaliotrematoides</i> <i>suezicus</i> Paperna, 1972 | KRITSKY <i>et al.</i> 2007 |
| <i>Tetrancistrum strophosolenum</i> Kritsky, Galli & Tingbao, 2007 | <i>Pseudohaliotrematoides nagatyi</i> Diamant, 1985 (nomen nudum) <i>Pseudohaliotrematoides polymorphus</i> ssp.: DIAMANT & PAPERNA (1986); <i>P. nagatyi</i> : Diamant (1989) (nomen nudum) <i>Pseudohaliotrematoides polymorphus</i> "nagatyi" of DIAMANT <i>et al.</i> (1999) | KRITSKY <i>et al.</i> 2007 |
| <i>Glyphidohaptor plectocirra</i> (Paperna, 1972) | Synonyms. <i>Pseudohaliotrema plectocirra</i> Paperna, 1972; <i>Tetrancistrum plectocirra</i> : Lim, 2002 | KRITSKY & GALLI 2007 |

10. Fish

To the 110 species in the 'annotated list' sixteen (16) records have been added in the 2006-April 2008 period (Table 10) and one is excluded in this work. The established aliens increased from 63 to 69, the casual aliens from 42 to 50 and the number of questionable aliens (5) remaining the same, thus bringing the total number of alien fish to 125 species.

Glaucostegus halavi, which was previously excluded from the list of alien fish by GOLANI *et al.* (2002 and whose vector of introduction was stated to be evidently from the Red Sea (BEN SOUISSI *et al.*, 2007), has recently been found off southern Tunisia. Among questionable species in the

'annotated list', *Torpedo sinuspersici* was recently evaluated by some authors as a casual Lessepsian species (i.e. SERENA, 2005; GALIL, 2008). However, the single specimen reported from Syria (SAAD *et al.*, 2004) was not supported by any taxonomical information to confirm species identification, thus retaining its questionable occurrence until substantiated by further studies. The status of the bigeye thresher shark (*Alopias superciliosus*), that was classified as questionable due to uncertainty regarding its origin, is still not clear despite recent records from the Mediterranean Sea. Some morphological characters of the species (i.e. very large eyes reaching the dorsal surface of head; the v-shaped ridge on the head; long snout etc.) clearly distin-

Table 10
New alien fish species and changes in establishment success.

* species excluded in the 'annotated list'

Establishment success: C=casual, E=established, Q= questionable

| New species | Establishment success | Source |
|--|-----------------------|--|
| <i>Apogon queketti</i> Gilchrist, 1903 | C | Turkey: ERYILMAZ & DALYAN, 2006 |
| <i>Apogon smithi</i> (Kotthaus, 1970) | E | Israel: GOLANI <i>et al.</i> , 2008 |
| <i>Bregmaceros atlanticus</i> Goode & Bean, 1886 | E | Turkey: YILMAZ, <i>et al.</i> , 2004; FILIZ <i>et al.</i> , 2007 Israel: GOREN & GALIL, 2006 |
| <i>Cephalopis taeniops</i> (Valenciennes, 1828) | C | Libya: BEN ABDALLAH <i>et al.</i> , 2007 |
| <i>Cyclopterus lumpus</i> Linnaeus, 1758 | C | Croatia: DULČIĆ & GOLANI, 2006 |
| <i>Dasyatis marmorata</i> (Steindachner, 1892) | Q | Israel: GOLANI & CAPAPÉ, 2004 |
| <i>Decapterus russelli</i> (Rüppell, 1830) | E | Israel: GOLANI, 2006 |
| * <i>Glaucostegus halavi</i> ¹ | C | Tunisia: BEN SOUSSI <i>et al.</i> , 2007 |
| <i>Monotaxis grandoculis</i> (Forsskål, 1775) | C | Turkey: BILECENOĞLU, 2007 |
| <i>Nemipterus randalii</i> Russell, 1986 ² | E | Israel: GOLANI & SONIN, 2006 Turkey: BILECENOĞLU & RUSSELL, in press |
| <i>Pagrus major</i> (Temminck & Schlegel, 1843) | C | Croatia: DULČIĆ & KRALJEVIC, 2007, Greece: CORSINI-FOKA & ECONOMIDIS, 2007 |
| <i>Papillogobius melanobranchus</i> (Fowler, 1934) | C | Egypt: KOVAČIĆ & GOLANI, 2007 |
| <i>Parupeneus forsskali</i> (Fourmanoir and Guézé, 1976) | C | Turkey: ÇINAR <i>et al.</i> , 2006b Malta (?): SCIBERRAS & SCHEMBRI, 2007 |
| <i>Platax teira</i> (Forsskål, 1775) | C | Turkey: BILECENOĞLU & KAYA, 2006 |
| <i>Sciaenops ocellatus</i> (Linnaeus, 1766) | C | Israel: GOLANI & MIRES, 2000 |
| <i>Zenopsis conchifera</i> (Lowe, 1852) | C | Tunisia: RAGONESE & GIUSTO, 2007 |
| Change in establishment success | | |
| <i>Coryglops ochetica</i> (Norman, 1927) | From C to E | Egypt: KOVAČIĆ & GOLANI, 2007 |
| <i>Hippocampus fuscus</i> Rüppell, 1838 | From C to E | Turkey: BILECENOĞLU, pers.obs. |
| <i>Torquigener flavimaculosus</i> Hardy & Randall, 1983 | From C to E | Greece: CORSINI-FOKA <i>et al.</i> , 2006 |

¹ Recorded as *Rhinobatos halavi* by BEN SOUSSI *et al.* (2007)

² Recorded as *N.japonicus* by GOLANI & SONIN (2006)

guish *A. superciliosus* from its Mediterranean congeneric *A. vulpinus*, so the probability that it was previously overlooked is

not justified. TORTONESE (1956) stated that the bigeye thresher shark is a typical species of the tropical Atlantic, and its

absence in the Mediterranean (at least until the 1980's) was indicated in two monumental works (HUREAU & MONOD, 1973; WHITEHEAD *et al.*, 1984). Although a range expansion of *A. superciliosus* during the last two decades from western and central basin to eastwards is evident (see CLO *et al.*, 2008), a probable introduction via the Gibraltar Strait requires verification.

Tortonese's stingray (*Dasyatis tortonesei*) was listed among questionable fish in the 'annotated list', but should be excluded due to its distribution being restricted to the Mediterranean (WHITEHEAD *et al.*, 1984). The validity of the species is still a matter of dispute (COMPAGNO, 1999). On the other hand, the eastern Atlantic originated *Dasyatis marmorata* is now included on our list as a questionable alien species. Its first record from Gulf of Gabès in southern Tunisia (MAURIN & BONNET, 1970) was followed by specimens captured along Israeli coasts (GOLANI & CAPAPÉ, 2004). Although *D. marmorata* has never been evaluated as an alien fish (GOLANI *et al.*, 2002; SERENA, 2005), its pattern of zoogeographical distribution is similar to other tropical Atlantic originated fishes such as *Enchelycore anatina*, *Arius parkii* and *Acanthurus monroviae* (GOLANI & CAPAPÉ, 2004). The taxonomy of the species, which was previously mentioned under the names of *Dasyatis pastinaca marmorata* and *D. chrysonota*, is currently not clear.

The antenna codlet (*Bregmaceros atlanticus*) finding from Turkey (YILMAZ *et al.*, 2004) did not put forward the possible origin of the species, but GOREN & GALIL (2006) evaluated the species as alien, which is likely to have arrived in the Mediterranean with discharged ballast water. The antenna codlet is currently quite abundant at the northeastern Mediter-

anean and several specimens may be observed during bottom trawl catch compositions. The species has recently been found in the Aegean Sea (FILIZ *et al.*, 2007).

The record of *Nemipterus japonicus* (Bloch, 1791) of GOLANI & SONIN (2006) is invalid as it is considered a misidentification of *N. randalli* Russell, 1986 (for a full account, see BILECENOĞLU & RUSSELL, in press; LELLI *et al.*, in press).

Even though *Decapturnus russelli* and *Apogon smithi* are known by single records from the Mediterranean Sea, they were rated as established following GOLANI (2006) and GOLANI *et al.* (2008), respectively. According to a recent review of alien fish from the Maltese islands, SCIBERRAS & SCHEMBRI (2007) noted the possible occurrence of *Parupeneus forsskali*, which was hitherto known by a single report from Turkey (ÇINAR *et al.*, 2006b). However, the relevant record from Malta should be evaluated as questionable due to lack of preserved material and information.

Aphanius dispar was considered as a Lessepsian immigrant for many years. It is one of the worst alien fish in the eastern Mediterranean according to some authors (i.e. GOREN & GALIL, 2005; GALIL, 2008), since the species and its hybrids have replaced the native killifish, *A. fasciatus*, along the Mediterranean coast of Israel. On the other hand, GOLANI *et al.* (2002) excluded *A. dispar* from the list of exotic species, based on a comparative electrophoretic study by KORNFIELD & NEVO (1976) who suggested that the species was a permanent Mediterranean resident. Based on evidence presented by the latter authors that the occurrence of *A. dispar* in the Mediterranean precedes the opening of Suez Canal, we are retaining the species within excluded taxa in the 'annotated list'.

Discussion

Biological invasions have been recognised as one of the priority issues of concern to the health of marine ecosystems in the Mediterranean (EEA, 2006). ZENETOS *et al.* (2006) reported approximately 745 alien species in an annotated list, up to December 2005. The figures presented in ZENETOS *et al.* (2006) were criticised by Prof D.F. Por (pers. Commun.) who argues that they present an artificial inflation because the Lessepsian immigrants are mixed with aliens introduced in other ways. In his opinion, the tropical immigrants fit in well in the impoverished and sub-tropical Levantine basin. GALIL (2008) claims a total of 558 alien metazoan species in the Mediterranean Sea, ignoring the 745 that were already assembled in the 'annotated list'. The latest figures documented in this work reveal an even more spectacular increase in the number of marine alien species in the Mediterranean.

In addition to the 94 new species, reported in the period 2006-2008, the 'annotated list' is further enriched with 81 records reported before 2005, which had either escaped the author's attention, and thus are missing from the 'annotated list': or had been rated as excluded but have to be reinstated as aliens according to recent taxonomic/molecular studies. On the other hand, a few species (17 in all) included in the 'annotated list' are excluded in this work as cosmopolitan taxa/ unsupported records/ indigenous species. To sum up, a total of 903 alien species are to date present in the Mediterranean; their breakdown per eco-functional/taxonomic group is presented in Figure 1. To these, we could add a few fresh/brackish water species that occasionally occur in estuarine/coastal areas. In the latter category, some mollusca and fish are

included. Among mollusca, we refer to the bivalvia *Dreissena polymorpha* and *Anodonta woodiana* and the gastropoda *Potamopyrgus antipodarum*, *Congerius leucophaeta* and *Ferrissia wautieri*, all cryptogenic species well established in the Mediterranean. Among fish, *Micropterus salmoides*, *Acipenser baeri*, *Acipenser gueldenstaedtii* have been reported from coastal areas in Greece (CORSINI-FOKA & ECONOMIDIS, 2007) and France (WGITMO, 2006). Worth noting is that the planktonic alien species appear to be underestimated. According to Prof. S. Lakkis (Lebanon) approximately two hundred alien phyto- and zooplanktonic species have been collected from the Lebanese coast between 1970 and 2005. However, a critical evaluation is needed based on voucher specimens before these species can be rated as aliens in the Mediterranean.

Excluding the parasites and foraminiferans that are treated in detail in this work, hence the increase is 3- fold to 6- fold respectively, an increase of approximately 10-25% is observed in the other groups. Thus, the rate of biological invasions is highest in phytobenthos (24%) followed by zooplankton (16%), fish (13%) and zoobenthos (13%). These newcomers are mostly of tropical and subtropical origin, which presumably indicates the 'tropicalization' of the Mediterranean. Indeed, it has been argued that present-day warming ultimately favours the spread of warm-water species through direct and indirect effects, and especially by changing water circulation. It is impossible at present to foresee to what extent the exuberance of warm-water species will affect the trophic web and the functioning of marine ecosystems in the Mediterranean Sea of tomorrow (BIANCHI, 2007). The eastern Mediterranean is still the favourite destina-

tion for alien species, but the centre of introduction seems to have spread from Israel to Turkey. This observation suggests a shift from Lessepsian migration to ship-mediated transfer, a further argument towards the ‘tropicalisation’ hypothesis for the Mediterranean.

Besides the *new* species presented in this work, changes in their establishment success are also indicated. The state of establishment success, as in April 2008, is presented in Figure 1. On considering the overall increase, the percentage of the established species to the total alien species has remained stable (about 55% vs 52% reported by December 2005). However, the fact that more than 30 species have changed their establishment status to ‘established’ indicates that alien species are becoming all the more permanent inhabitants in the Mediterranean. In con-

trast to the ‘annotated list’ (385 established species), there are to date 496 established alien species, an increase of 29%.

GALIL (2008) reports approximately 80 species in the 2000-2007 period. This seems an underestimate. Based on the publications of the recent 28 months (Jan 2006-April 2008), it is here demonstrated that there are 94 new records (14 fish, 1 phytoplankton, 3 zooplankton, 59 zoobenthos, 13 macrophytes and 4 parasites), indicating a rate of 1 new entry every 9 days (1.3 weeks). This rate of introduction is in agreement with STREFTARIS *et al.* (2005) who noticed an increasing pattern in the rate of introduction over the years 1998-2003. In particular, they calculated the time span for alien species’ introduction in the Mediterranean to be 5.2 weeks in 1998 vs 2.9 weeks in 2003.

The increasing trend in bio-invasions

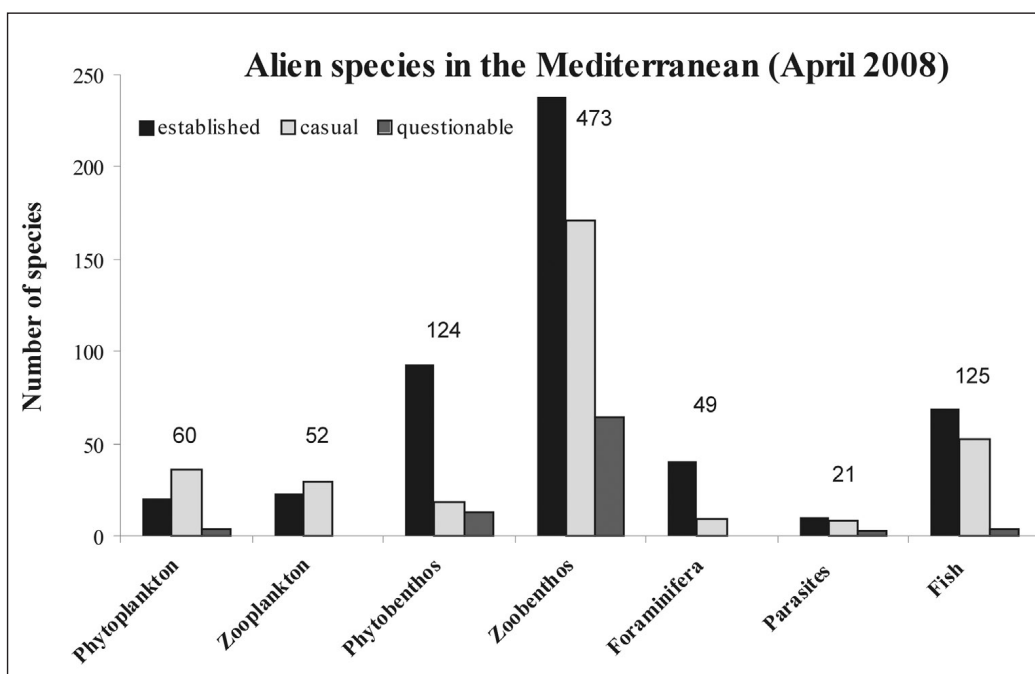


Fig. 1: Number of marine alien biota in the Mediterranean and their establishment success. Numbers indicate totals per group.

that has been mostly attributed to climatic change worldwide is partly due to the awareness and response of the scientific community on the issue, resulting in: a) taxonomic competence and multinational collaboration on projects and/or publications - tracing/identifying aliens has never been an easy task; and b) the development of electronic scientific journals that promote prompt publication of findings related to alien species. One good example is the new electronic journal *Aquatic Invasions AI*: an important part of the developing European early warning system on aquatic invasive species. Fourteen out of the 94 new marine alien species in the Mediterranean were first recorded in the 2006-2007 volumes of *AI*.

Conclusions

- A total of 903 alien species by April 2008 in the Mediterranean.
- The rate of biological invasions in the Mediterranean not only has not paused but is increases astronomically. 94 species within 28 months means 1 new species entry every 9 days!
- The newcomers are becoming all the more permanent inhabitants. 496 established species in 2008 versus 385 in 2005 means a 29% increase in the number of permanent visitors!

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