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Origin and vectors of introduction of exotic molluscs in greek waters

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ABSTRACT. Exotic species of macrophytes, invertebrates and fish have become increasingly prominent in most coastal habitats in the Mediterranean Sea, the Greek waters included, over the last decades. It is well established that the introduction of non-indigenous species has significant ecological as well as economic impact in the Mediterranean Sea. A review of the exotic molluscan records in Greek waters revealed a total of 26 species (16 Gastropoda, 10 Bivalvia). Nine species are of Indo-Pacific and Erythrean origin, and are already well established in the Eastern Mediterranean. The occurrence of these species in the Greek Seas is attributed to progressive penetration through the Suez Canal, the so-called Lessepsian migration. Four species, namely the gastropods *Nerita sanguinolenta, Haminoea cyanomarginata, Melibe fimbriata* and the bivalve *Pseudochama corbieri*, are Red Sea endemic and Indo-Pacific biota, which have been first sighted in Greek waters and to date have a limited distribution in the entire Mediterranean. Another four species, the gastropods *Crepidula fornicata* and *Polycerella emertoni* and the bivalves *Petricola pholadiformis* and *Mya arenaria*, which originate from the Atlantic and occur in ports/lagoons, may have entered via shipping and/or aquaculture. The gastropods *Strombus persicus* and *Rapana venosa* and the bivalves *Anadara demiri* and *Crassostrea gigas* are of Pacific, Indian Ocean or Persian Gulf origin and the vector of their introduction, though not documented, is presumed to be shipping or aquaculture. The rate of molluscan introductions in Greek waters is increasing exponentially with time : 13 out of the 26 species have been recorded since 1990, and further studies may reveal many more.

KEY WORDS : *Mollusca, Exotic Species, Introduction, Greek Seas, Mediterranean*

INTRODUCTION

The vectors of introduction of exotic species to the Mediterranean are diverse : migration through the Suez Canal, thoroughly analyzed by Por (1978, 1990) also termed 'lessepsian migration' ; migration through the Gibraltar Straits (Cattaneo-Vietti & Thompson, 1989) ; transport on ship hulls and with ballast waters ; intentional introductions (mariculture) and accidental introductions accompanying intentionally introduced species ; market discards ; escape from aquaria (Zibrowius, 1992). The Suez Canal has been the largest pathway for the entry of invaders in the Mediterranean Sea and more than 300 Erythrean species – principally molluscs, fish, decapod crustaceans, polychaetes and algae - have become established in the Eastern Mediterranean, primarily in the Levantine Basin. The rate of these biological invasions has increased in recent decades, and "they collectively have significant ecological and economic impacts in the Mediterranean Sea" (Galil, 2000).

Given the rate and extent of the phenomenon, some national monitoring projects in countries bordering the Mediterranean have focused on introduced species. The International Commission for the Scientific Exploration of the Mediterranean Sea (CIESM) has published a digital atlas of exotic species in the Mediterranean (fish, crustaceans and molluscs). According to the updated information, the number of exotic molluscan species has increased from 44 (Por, 1978) to 137 (Gofas & Zenetos, 2003).

A review of the Greek marine exotic biota has revealed that molluscs predominate among the 78 exotic species that have been recorded to date (Pancucci - Papadopoulou et al., 2003). The first exotic mollusc reported from the Greek seas is the Erythrean bivalve species *Pseudochama corbieri* (Jonas, 1946) found in Saronikos Gulf in the South Aegean (Ralli-Tzelepi, 1946). The CIESM atlas enumerates 26 exotic molluscs (Zenetos et al., 2003).

The majority of the exotic Gastropod species recorded from the Greek Seas has arrived as Lessepsian invaders (Koutsoubas, 1992). However, other ways of invasion of these species should also be taken into consideration, e.g. invasion through human activities and/or entrance via the Gibraltar Straits (see review by Koutsoubas & Cinelli, 1997). Considering the rate of introduction, an updated inventory is needed of exotic molluscs, to include recent findings and extend the zoogeographical distributions, thus providing further insight to the modes of introduction. Furthermore, and despite intensive research effort into the marine biodiversity in the Greek Seas, especially during the last two decades, which has resulted in reliable molluscan inventories (e.g. Zenetos, 1996 ; Koutsoubas et al., 1997, 2000a, b ; Delamotte & Vardala-Theodorou, 2001) the ecological and economic impacts of the

molluscan invaders in the Greek Seas have not been recognized so far.

The present review aims to : 1) present an updated checklist of the exotic mollusc species in Greek Waters, 2) discuss in detail their origins, vectors and their rates of introduction, 3) examine zoogeographical patterns of these species in the Greek Seas and in the Eastern Mediterranean.

MATERIAL AND METHODS

The work is a combined effort to compile all past and recent records of exotic molluscs in the Greek Seas up until April 2002. To this end, part of the information is derived from : the ongoing CIESM ATLAS project (see www.ciesm.org/atlas) ; unpublished data of the authors' research efforts on molluscs in the Greek Seas over the last 20 years ; data originated from the gray literature (e.g. Technical Reports). Of the many terms (aliens, introduced, invaders, exotic, non-indigenous species) currently used to define species introduced from one sea to another via any vector of introduction, we have chosen to adopt the term exotic in the sense used by CIESM. The taxonomy used in this study is that used for Red Sea mollusc species (OLIVER, 1992 ; DEKKER & ORLIN, 2000). In order to define the rate of introduction of the exotic molluscs a special effort was made through the Goulandris Natural History Museum collections, the authors' research collections, and amateur collectors collections available to the authors to trace, to the degree possible, the true dates of appearance of the species in Greek waters. On presenting the zoogeographical distribution of the exotics within the Greek Seas, different physicochemical and dynamic processes were encountered leading to the division suggested by THEOCHARIS et al. (1993) i.e. Ionian Sea, the Sea of Kythira, the Aegean Sea and the Libyan Sea. Given the importance of ports, a more detailed division included Saronikos and Thermaikos Gulfs (in the South and North Aegean correspondingly) where the main Greek ports are situated.

RESULTS

Records and composition of exotic mollusc species in the Greek seas

The examined material in authors' collections along with a review of the relevant literature has revealed that to date 26 exotic mollusc species have been recorded from the Greek Seas. These species are presented in phylogenetic order in Table 1. Very few species, namely the gastropods *Strombus persicus, Bursatella leachi*, *Melibe fimbriata* and the bivalves *Brachidontes pharaonis, Pinctada radiata,* are well established in the Greek Seas. Certain other species i.e. *Crepidula fornicata, Rapana venosa, Bulla ampulla, Anadara demiri* and *Fulvia fragilis* are met in large populations but are locally established. The remaining species have been reported from a single site and usually from a single individual indicating that their presence in the Greek Seas could be considered as accidental.

Origin and vectors of introduction of exotic mollusc species in the Greek seas

Considering the origin of the exotic mollusc species recorded from the Greek Seas (Table 1) the majority are Erythrean ones (five species from Red Sea, three from Indian Ocean and Red Sea, four from Indo-Pacific Ocean and Red Sea), followed by those from the Indo-Pacific oceans (five species). Very few species (four) originate from the Atlantic Ocean.

Many of the Erythrean species, either well established in the Eastern Mediterranean (*Cylichna girardi, Bursatella leachi, Brachidontes pharaoni, Malfuvundus regulus, Gastrochaena cymbium*), or accidental (*Cellana rota, Trochus erythraeus, Murex forskoehli, Pseudochama corbieri*) occur in the Suez Canal and therefore their finding in the Greek coasts should be attributed to progressive penetration through the Suez Canal (Lessepsian migration) (Fig. 1). The same pathway (?Lessepsian) is suspected to be the mode of introduction of another seven mollusc species that are either Red Sea endemics (*Nerita sanguinolenta, Acteocina mucronata, Haminoea cyanomarginata*) or Indo-Pacific species (*Smaragdia souverbiana, Rapana rapiformis, Bulla ampulla, Melibe fimbriata*) (Fig. 1). These species, however, are absent from the Suez Canal and have, to date, a limited distribution in the Eastern Mediterranean. The Indo-Pacific oyster species *Crassostrea gigas* is the most widely distributed oyster introduced word-wide in temperate to tropical seas and its presence in the Greek Seas should be attributed to aquaculture. The opisthobranch Atlantic species *Polycerella emertoni* has been found in the Mediterranean in ports or lagoons close to ports, and shipping is speculated to be the most likely introduction vector. Finally certain species may have followed more than one route. In other cases pathways of introduction remain unknown, even if shipping is assumed to be the most likely vector of their transport since their occurrence is patchy and associated with ports and/or they are fouling organisms on ship hulls or ballast tanks (Fig. 1). The species with a two-mode introduction or introduction via shipping are presented in detail below :

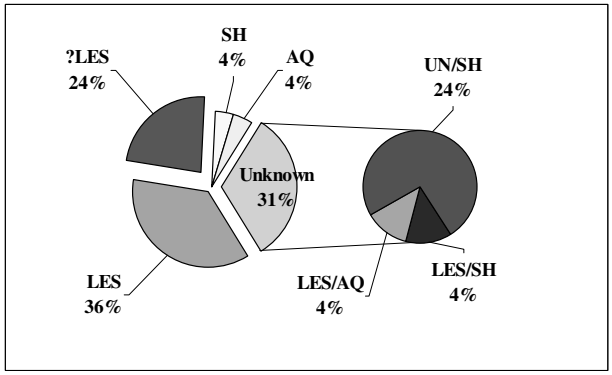

Fig. 1. – Vectors of introduction of exotic mollusc species recorded in Greek Seas. LES = Lessepsian migration ; AQ = Aquaculture ; SH = Shipping ; UN = Unknown

TABLE 1

Findings, Records, Composition and Origin of Exotic Mollusc species in Greek Seas. º : Species in authors' collections ; * : Additional record in the Greek Seas – this study ; is. = island ; G = Gulf

Exotic Mollusc Species	1st Finding	Citations in the Greek Seas	Sites of Greek Seas Reported	Origin
GASTROPODA				
PROSOBRANCHIA				
NACELLIDAE				
Cellana rota (Gmelin, 1791)	1989	Fountoulakis & Sabelli, 1999	Saronikos G.	IO, RS
NERITIDAE				
Smaragdia souverbiana (Montrouzier, 1863)	1994	Buzzurro & Greppi, 1994	Rhodes is.	IP, RS
Nerita sanguinolenta Menke, 1829	1968	Nordsieck, 1973	Karpathos is.	RS
TROCHIDAE				
Trochus erythraeus Brocchi, 1821	1994	Cosenza & Fasulo, 1997	Crete is.	RS
STROMBIDAE				
º*Strombus persicus* Swainson, 1821	1986	Nicolay, 1986	Rhodes is, **Argolikos G., **Lakonikos G.	PG, AS
CALYPTRAEIDAE				
º*Crepidula fornicata* (Linnaeus, 1758)	1994	Delamotte & Vardala-Theodorou, 1994	Saronikos G., Evoikos G.	WA
MURICIDAE				
Murex forskoehli Roeding, 1798	1966	Settepassi, 1967	Saronikos G.	RS, AS
º*Rapana venosa* (Valenciennes, 1846)	1991	Koutsoubas & Voultsiadou-Koukoura 1991	Thermaikos G.	PO
Rapana rapiformis (Von Born, 1778)	1970	Barash & Danin, 1988/89	Rhodes is.	IP
OPISTHOBRANCHIA				
BULLIDAE				
º*Bulla ampulla* Linnaeus, 1758	1999	Vardala-Theodorou, 1999	Saronikos G., **Argolikos G.	IP
HAMINOEIDAE				
Haminoea cyanomarginata Heller & Thompson, 1983	2001	Gosliner & Mollo *(unpublished data)*	**Korinthiakos G.	RS
CYLICHNIDAE				
Acteocina mucronata (Philippi, 1849)	1997	Storsberg, 1997	Naxos is.	RS
RETUSIDAE				
Cylichna girardi (Audouin, 1826)	1994	Cosenza & Fasulo, 1997	Crete island	IP
APLYSIIDAE				
º*Bursatella leachi* De Blainville, 1817	1986	Barash & Danin, 1986; Koutsoubas, 1992	Chios is., Lesvos is., **Thermaikos G., **Chalkidiki	IP
POLYCERIDAE				
º*Polycerella emertoni* Verrill, 1881	1995	Koutsoubas et al, 2000a	Gialova lagoon	EA
TETHYIDAE				
º*Melibe fimbriata* Alder & Hancock, 1864	1982	Thompson & Crampton, 1984; Koutsoubas & Cinelli, 1997	Astakos G., Kefallonia is., Korinthiakos G., Milos is.	IP
BIVALVIA				
PTEROMORPHIA				
ARCIDAE				
º*Anadara demiri* (Piani, 1981)	**1993	Zenetos, 1994	Thermaikos G.	IO
MYTILIDAE				
º*Brachidontes pharaonis* (Fischer P., 1870)	**1975	Koroneos, 1979; Tenekides, 1989	Rhodes is., Saronikos G., Evoikos G.	IO, RS
OSTREIDAE				
Crassostrea gigas (Thunberg, 1793)	1989	Dimitrakis, 1989	Patraikos G., Korinthiakos G.	PO
PTERIIDAE				
º*Pinctada radiata* (Leach, 1814)	1963	Serbetis, 1963; Nordsieck, 1969; Kallopissis, 1981; Kinzelbach, 1985; Barash & Danin, 1988/89; Zenetos, 1996	Rhodes is., Karpathos is., Saronikos G., Evoikos G., Lesvos is., **Lakonikos G.	IP, RS
MALLEIDAE				
Malvufundus regulus (Forskål, 1775)	2001	Giannuzzi-Savelli et al., 2001	Simi is.	IP, RS
HETERODONTA				
CHAMIIDAE				
Pseudochama corbieri (Jonas, 1846)	1946	Ralli-Tzelepi, 1946	Saronikos G.	RS
CARDIIDAE				
º*Fulvia fragilis* (Forsskål in Niebuhr, 1775)	1999	Vardala-Theodorou, 1999	Saronikos G.	IO, RS
PETRICOLIDAE				
º*Petricola pholadiformis* Lamarck, 1818	1994	Delamotte & Vardala-Theodorou, 1994	Evoikos G.	WA
MYIIDAE				
º*Mya arenaria* Linnaeus, 1758	**1984	Zenetos et al. 2003	Saronikos G.	EA
GASTROCHAENIDAE				
º*Gastrochaena cymbium* (Spengler, 1783)	**1974	Tenekides, 1989	Saronikos G.	IP, RS

Lessepsian migration – Shipping

The Indo-Pacific bivalve *Fulvia fragilis* seems to have followed the typical distribution of a Lessepsian migrant. It has been recorded in the Suez Canal, in the coasts of Israel, Tunisia and S. Turkey (www.ciesm.org/atlas). However, its recent finding in Saronikos Gulf, and in particular in Peiraew port, suggests transport via shipping, as all other areas in the Mediterranean from where it has reported are also in the vicinity of ports.

Lessepsian migration – Aquaculture

The pearl oyster *Pinctada radiata* was intentionally introduced to Greece for mariculture purposes, and has since established thriving populations in the sites where it was firstly imported for aquaculture (i.e. Lesvos island, Evoikos Gulf, Saronikos Gulf), but its recent finding in Rhodes island and Lakonikos Gulf, where aquaculture activities are absent, supports the Lessepsian mode of introduction.

Unknown – Shipping

The gastropod *Strombus persicus* from the Persian Gulf and Arabian Sea, was first recorded in the Mediterranean not far from the oil terminal in the south Turkish Bay of Iskenderun. The species has not been recorded from the Red Sea, and its introduction in the Mediterranean could be attributed to ships coming from the Persian Gulf (Oliverio, 1995). However, the species has planktotrophic larvae thus ensuring long-distance dispersal. Galil & Zenetos (2002) argue that the rapid geographic expansion and successful establishment of this species in the Levantine basin is typical of a Lessepsian invader. The slipper limpet *Crepidula fornicata* is assumed to have been introduced in the Mediterranean by shipping related to oyster/mussel commerce for farming. Its occurrence is rather local in the Mediterranean (e.g. French coasts near Toulon, Sicily - Zibrowius, 1992). Presumably there were separate introductions of cultivated bivalves from the French Atlantic coast to the French Mediterranean lagoons, and from unknown origin to the Italian and Maltese sites (Galil & Zenetos, 2002). The species has a broad adaptive ability, extensive period of reproduction with direct fecundation (through piling), together with the absence of specific predators (Blanchard & Erhold, 1999). Its record from Saronikos Gulf and in particular close to Peiraeus port is related rather to shipping, as there is no oyster/mussel farming in the broader area. *Rapana venosa* a gastropod native to the Sea of Japan was introduced in the Black Sea accidentally in the 40s and most possibly independently in the Adriatic in the 70s. It has been speculated that the planktonic larvae of the species arrived through ballast water in commercial ships, but a more likely scenario is that egg masses may have been transported with the products of marine farming i.e. oysters or mussels. Its discovery in the northern Aegean Sea near natural oyster and mussel banks in the bay of Thessaloniki (major port in the North Aegean) in the 90s (Koutsoubas & Voultsiadou - Koukoura, 1991) is most possibly related to shipping but transfer via the Dardanelle's strait should not be excluded. The bivalve *Anadara demiri*, originating from the China Seas, was reported to dominate the degraded benthic ecosystems in Izmir Bay (Demir, 1977) and Thessaloniki Gulf (Zenetos, 1994). The species seems to be well established in these areas but its distribution in the Mediterranean remains spotty. Though shipping seems to be the most likely vector of introduction since the species, at least in the Aegean, had been found in ports, its recent finding in the Central Adriatic does not exclude other introduction modes. *Petricola pholadiformis* and *Mya arenaria* are bivalves imported for mariculture in Mediterranean lagoons. However, their occurrence in Greek waters should be rather attributed to shipping since the records of the species are from areas near ports and away from areas where marine farms are located.

Rate of introduction of exotic mollusc species in the Greek seas

Thirteen out of the 26 exotic mollusc species have been recorded in the Greek Seas in the last decade (50% of the total number of exotic molluscs recorded so far from these seas) thus implying an exponential rate of introduction of these species in the Greek waters (Fig. 2). It is worth mentioning that only during last year two species, namely the gastropod *Haminoea cyanomarginata* and the bivalve *Malvufundus regulus,* have been recorded from the Greek Seas (Gosliner & Molo unpublished data and Giannuzzi-Savelli et al., 2001 correspondingly).

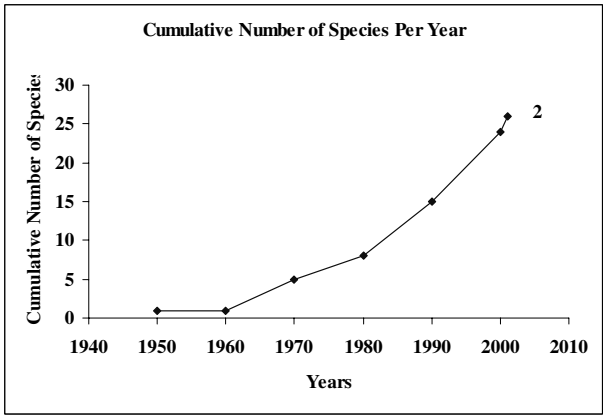

Fig. 2. – Rate of introduction of exotic mollusc species in the Greek Seas.

Comparing the appearance of the exotic mollusc species in the Greek Seas *vs* the Mediterranean Sea, we note that six species (*Smaragdia souverbiana, Nerita sanguinolenta, Rapana rapiformis, Haminoea cyanomarginata, Melibe fimbriata, Pseudochama corbieri*) are Red Sea endemic and Indo-Pacific biota that have been firstly sighted in Greek waters and then in the rest of the Mediterranean Sea. With the exception of *Melibe fimbriata*, these species have a limited distribution in the entire Mediterranean to date. On the contrary some of the very first exotic mollusc species in the Mediterranean Sea that entered that sea via the Suez Canal, colonized its eastern part and became locally abundant in the Levantine basin i.e. Lessepsian migrants, such as *Murex forskoehli, Brachidontes pharaonis, Pinctada radiata* and *Malvufundus regulùs* then later appeared in Greek waters after a time lapse of 60 to 98 years.

Zoogeographical patterns of the exotic mollusc species in the Greek seas

Twenty one exotic mollusc species have been recorded from the Aegean Sea, four from the Ionian Sea, two from the Sea of Kythira and one from the Libyan Sea (Fig. 3). Within the Aegean, the southern part is richer (19 species), and two major centres can be distinguished there : a) the Saronikos and Argolikos Gulfs, which are in the route of many ships towards Peiraeus (the biggest Greek

port), where 11 species have been recorded and b) the Dodekannese islands, which are located close to the Levantine basin, the main area of distribution of exotic species within the Mediterranean, where seven species have been recorded. Also in the North Aegean, two major centres can be seen ; a) Thermaikos Gulf (three species) and b) Evoikos Gulf (four species), which are both areas where major ports are located.

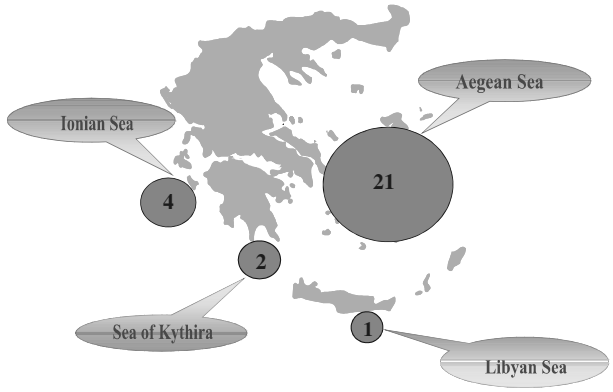

Fig. 3. – Number of exotic mollusc species recorded from the different Greek Seas

DISCUSSION

Twenty six exotic molluscan species (16 Gastropoda and 10 Bivalvia) have been collected in the Greek Seas during the last decades. These comprise less than 2.4% of the total number of mollusc species recorded so far in Greek Waters (1095 species – DELAMOTTE &. VARDALA-THEODOROU, 2001).

The majority of the exotic mollusc species in Greek waters (61%) originate from the Indo-Pacific region or are distributed in these oceans and the Red Sea. The next major component are Red Sea endemics (19%). This is also the case for other marine taxa with exotic representatives in the Mediterranean (POR, 1978). A major problem when dealing with exotic mollusc species is to dismiss the Mediterranean species that occur also in the Indo-Pacific region, as 'tethyan relicts' (CATTANEO-VIETTI & THOMPSON, 1989). A review of the palaeontological records shows that none of the exotic mollusc species reported so far from the Greek waters were present in the area during the Pleistocene. Were the aforementioned species present in the Mediterranean at earlier geological periods, they should be found as fossils either under the recent mean sea level, if they lived during the last glaciation, or above mean sea level, if they lived during warm periods. On reviewing the literature referring to the Upper Pleistocene marine fossil Mollusca, from the warm periods of Tyrrhenian-Eutyrrhenian and Neotyrrhenian in Greek Seas, the aforementioned species did not occur as fossils (VARDALA-THEODOROU, 1999). This implies that the exotic mollusc species found so far in the Greek Seas are not relicts of the past.

Only four out of the 26 exotic molluscs in the Greek Seas (*Crepidula fornicata*, *Polycerella emertoni, Petricola pholadiformis* and *Mya arenaria*) are species originating from the Atlantic, which have extended their distribution via different pathways into the Mediterranean. This point strengthens the statements of previous authors that although the major pool of exotic species invading the Mediterranean is Erythrean biota, the discovery of each species new to the inventory of the exotic flora and fauna species should be interpreted with caution and its origin be carefully examined (ZIBROWIUS, 1992 ; GALIL, 2000).

Molluscs are one of the 'leading' groups of the Lessepsian migration, together with decapod crustaceans and fishes (POR & DIMENTMAN, 1989). OLIVERIO (1995) has discussed the use of the term "Lessepsian migration" and concluded that this should not be used indiscriminately for any species of Indo-Pacific origin found in the Mediterranean. A sensible use of the term is for species that have worked their way through the Suez Canal and then spread progressively into the Mediterranean. It is in this sense that almost 35% of the Greek exotic mollusc species (*Cellana rota, Trochus erythraeus*, *Murex forskoehli*, *Cylichna girardi, Bursatella leachi, Brachidontes pharaoni, Pseudochama corbieri, Malvufundus regulus, Gastrochaena cymbium*), which are also successful in the Canal itself, could be considered as true Lessepsian migrants. Another seven Erythrean origin species (*Nerita sanguinolenta, Acteocina mucronata, Haminoea cyanomarginata*, *Smaragdia souverbiana*, *Rapana rapiformis, Bulla ampulla, Melibe fimbriata*) are suspected to have penetrated via the same pathway, but because of no up-to-date records in the Suez Canal and their limited distribution in the entire Mediterranean, they are classified as suspected Lessepsian migrants.

Besides introduction through the Suez Canal, the next major vectors of introductions of exotic marine biota in the Eastern Mediterranean are shipping and then aquaculture (GALIL & ZENETOS, 2002). This pattern is also valid for the exotic molluscs recorded in Greek waters, although to be able to draw the line further investigation is needed. Shipping has been considered the vector of introduction for the opisthobranch mollusc *Polycerella emertoni* and aquaculture for the bivalve species *Crassostrea gigas*. However, transport via shipping routes and mariculture are considered to be the most likely vectors of introduction of exotic mollusc species in the Greek waters in certain cases for which a two-mode introduction scheme has been assumed, where the true vector is still unknown. Even if these two vectors are not the true vectors of introduction of exotic mollusc species in different parts of the Greek Seas, they may have been involved in combination with other pathways of introductions. For *Strombus persicus* and *Fulvia fragilis* Lessepsian migration has been suggested by PASSAMONTI (1996), GALIL & ZENETOS (2002) and shipping by OLIVERIO (1995). Although in the present study their vector of introduction has been characterized as unknown, *Crepidula fornicata, Rapana venosa, Anadara demiri, Petricola pholadiformis* and *Mya arenaria* were sampled in areas close to major ports, therefore shipping should be considered as the true vector of their introduction in the Greek waters. The pearl oyster *Pinctada radiata* has been imported in Greek waters for aquaculture (KALOPISSIS, 1981) and viable populations have successfully established in the wild, but progressive penetration through the Suez Canal should

not be excluded as the species has been recorded in other areas of the Eastern Mediterranean ; recently it was found in Rhodes island in the South Aegean where aquaculture is absent. To further extend the discussion on the subject, new findings suggest caution even when dealing with species that have been considered without doubt as true Lessepsian migrants. For example the small mussel *Brachidontes pharaonis*, a species that originates from the Indian Ocean and is widely spread throughout the Red Sea (OLIVER, 1992), was among the first migrants noticed in the Eastern Mediterranean. Based on the origin of the species and its present distribution, progressive penetration through the Suez Canal was considered obvious and hence its characterization as a Lessepsian migrant was not questioned. However, preliminary results of molecular studies have shown that although Red Sea genotypes are present in the Mediterranean Sea, non-Red Sea genotypes are fairly common in that sea also, and the frequency of the latter increases as we get further from the Suez Canal (ABELSON, pers. commun.). This suggests that ship transport from elsewhere may have occurred for this species rather that natural migration through the Suez Canal. The importance of these two vectors and in particular shipping in introduction of mollusc species in an area of the Greek seas extends beyond the issue of exotic species, since these vectors may have also contributed to spread of species originally native in a restricted part of the Mediterranean. Such a case is that of the pulmonate gastropod *Siphonaria pectinata* (Linnaeus, 1758), originally restricted to the Alboran Sea and the Western coasts of Algeria and now thriving in Saronikos gulf in the South Aegean (GOFAS & ZENETOS, 2003).

The rate of invasion of exotic mollusc species in the Greek waters has increased in recent decades, in agreement with data for the rate of biological invasions in the whole Mediterranean (GALIL, 2000). The increased rate of invasion in the Greek Seas could be the result of a synergy of different reasons, the most important of which are the following : a) the intensive research on the marine biota of the Greek Seas during the last 20 years and especially after 90s, which led to the discovery of many molluscs not reported previously in this area of the Mediterranean, b) the increased anthropogenic activities in the Greek Seas over the last decade such as aquaculture and tourism (contributing factors to increase of maritime traffic).

Among the Greek Seas, the Aegean and in particular the South Aegean is the area where the majority of the exotic mollusc species is distributed. This difference between the two parts of the Aegean should be attributed to : (i) the prevailing environmental conditions (e.g. higher temperatures and salinities in relation to the North Aegean - POULOS et al., 1997), which are favourable for the distribution and settlement of these species, (ii) the vicinity of the South Aegean with the Levantine Basin in connection with the hydrological regime within the Eastern Mediterranean i.e. sea currents running from the coasts of Egypt anticlockwise south of the Turkey coasts up to Rhodes island and then to the South Aegean. The influx of the Levantine Intermediate Water in the South Aegean through the Kassos straits and then to the other Greek Seas (KONTOYIANNIS et al., 1999) certainly enriches these waters with elements of Indo-Pacific and/or Red Sea origin, which have already been established in the Levantine Basin. (iii) the more intensive research carried out in the South Aegean. Despite the fact that the number of exotic mollusc species in the North Aegean has increased over the last decade, it seems that the Lessepsian migration – the major vector of introduction of exotic mollusc species in the Greek Seas – has not yet proceeded to that part of the Aegean Sea. Only two out of the seven species recorded in the North Aegean i.e. the opisthobranch gastropod *Bursatella leachi* and the bivalve *Brachidontes pharaonis* could be considered as true Lessepsian migrants, while the presence of the other species in this area is in most cases connected with anthropogenic activities i.e. shipping and/or aquaculture. The scarcity of Lessepsian migrants in the North Aegean Sea has also been noticed for other benthic groups such as anthozoans (VAFIDIS et al., 1994) and crustaceans (KOUKOURAS et al., 1992).

The number of exotic mollusc species recorded from the Greek Seas is moderate when compared with that recorded from other areas of the Eastern Mediterranean. The areas with the largest number of exotic species are the Israeli coasts (95 species), the coasts of SE Turkey (68 species), Cyprus (32 species), the coasts of Egypt (31 species) and the coasts of Lebanon and Syria (29 species). All these areas are located in the Levantine Basin, which constitutes a separate subsystem in the Eastern Mediterranean (POR & DIMENTMAN, 1989). It has been assumed that the prevailing environmental conditions in that basin i.e. high temperature and salinity, make this area unsuitable for many western Mediterranean species (SARA, 1985) and presumably species of Atlantic origin as well. Consequently this area of the Mediterranean is a favourable place for the tropical species that arrive there, since there are few ecological obstacles to prevent their establishment (GALIL, 2000). Indeed the Erythrean biota, coming mainly through the Suez Canal in that sea, accentuates its subtropical character (TORTONESE, 1985). POR (1978) was the first to suggest that Lessepsian migrants represent at least 10% of the species inventory of the Levantine Basin, while a similar ratio (9.4%) has been suggested by BARASH & DANIN (1986) for the molluscs. Similarly, the introduction of exotics has increased by about 10% the biodiversity of molluscs along the Lebanese coasts where out of 298 recorded species 29 are exotics (BITAR & KOULI-BITAR, 1999, 2001) and SE Turkey coasts where from a restricted area (Tasuçu area) out of 371 mollusc species 40 belong to exotics (BUZZURRO & GREPPI, 1996). In Cyprus however, the exotic molluscs contribute only 5% to the malacofauna diversity. Out of the 627 species known to date (CECALUPO & QUADRI, 1996 ; BUZZURRO & GREPPI, 1997) only 32 are exotics (www.ciesm.org/atlas).

Another reason that has been suggested for the low number of exotic mollusc species in other areas than the Levantine Basin of the Eastern Mediterranean (KOUTSOUBAS, 1992), is the restricted period of life for the molluscan planktonic larvae – when referring to their natural spreading capacities – which restricts the distribution of such species over long distances. Areas isolated (due to deep trenches) from the continental coasts, such as islands, are difficult for non-indigenous species to approach.

It is well documented that the presence of exotic species in the Mediterranean has significant ecological and economic impacts in that sea (POR & DIMENTMAN, 1989 ; ZIBROWIUS, 1992 ; GALIL, 2000). TOM & GALIL (1991) have pointed out the impact of certain exotic mollusc species, which have entered the Mediterranean via Lessepsian migration, on benthic communities in the Israeli coasts. Of the exotic mollusc species distributed in the Greek Seas, the prosobranch gastropod *Rapana venosa* first established in Thermaikos Gulf (KOUTSOUBAS & VOULTSIADOU-KOUKOURA, 1991), and has since spread out. According to the local Fisheries and Aquaculture Associations it has become a considerable nuisance in the oyster and mussel beds in the area in a similar way to what has been reported for the Black Sea where the species was first noticed and progressively established (ZIBROWIUS, 1992). The bivalve *Anadara demiri* has been reported to dominate the degraded benthic ecosystems in Thessaloniki Gulf (ZENETOS, 1994), a fact strengthening the opinion of GALIL (2000) that polluted or physically degraded environments are more prone to invasion than are pristine sites. However, in order to precisely track and better understand the changes in the Greek marine biota, and in particular Mollusca, both its autochthonous and allochthonous components should be further investigated.

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