

NEW DATA CONCERNING THE PRESENCE OF LESSEPSIAN AND OTHER INDO-PACIFIC MIGRANTS AMONG THE MOLLUSCS IN THE MEDITERRANEAN SEA WITH EMPHASIZE ON THE SITUATION IN ISRAEL

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ABSTRACT

Two months after the publication of the mollusc part of the "CIESM Atlas of exotic species in the Mediterranean" 34 new Lessepsian migrants and other Indo-Pacific molluscs are added to the list of species encountered so far in the Mediterranean Sea. These additions are based on recently published records (11) and the study of new material in various collections in Israel and Italy (23). Brief notes are given on the correct identity of some species, the way the new species arrived in the Mediterranean; the habitat selection of some species; the displacement of native species by exotic ones, and the formation of an unique *Spondylus*-reef. The 190 species of Lessepsian migrants and other Indo-Pacific molluscs so far recorded from the Mediterranean Sea are enumerated in three lists (established species; species in need of confirmation and rejected species).

Keywords: Mollusca, Lessepsian migrants, Indo-Pacific species, distribution, behaviour, habitat selection, reef formation, Mediterranean Sea.

INTRODUCTION

The migration of Indo-Pacific mollusca in general and Erythrean ones in particular to the Mediterranean Sea has been a popular study object since the opening of the Suez Canal in 1869. A wealth of articles, ranging in size from short faunistic notes to a general, classic textbook (Por, 1978), has been devoted to this subject. Most of these data have been incorporated in the recently published "CIESM Atlas of Exotic Species in the Mediterranean" (Zenetos et al., 2004), which contains also a small number of migrants from other parts of the world.

In Israel the first paper entirely devoted to finds of Indo-Pacific mollusca along its Mediterranean coast has been published in the same year it became independent (Haas, 1948). It contained a number of true Lessepsian migrants and a strange variety of other Indo-Pacific molluscs, which have been found occasionally as single empty shells or valves on beaches and especially in harbours all over the world even before the opening of the Suez Canal (Philippi, 1836 & 1844). In the mean time the latter have been rejected of course as true migrants.

Barash & Danin (1973, 1977 & 1986) published additional lists of Indo-Pacific molluscs found in the Mediterranean, which contained many new records from Israel. Their annotated list of Mediterranean molluscs of Israel and [north] Sinai (Barash & Danin, 1992) hardly contained any additional records because it had been submitted for publication already in 1980!

A large number of additional records of Erythrean and Indo-Pacific species among the molluscs found along the coasts of Israel and Palestine (i.e. Gaza) have been published in short notes by various authors in a large number of malacological journals. Most of them have been incorporated in the CIESM Atlas (Zenetos et al., 2004). Unfortunately some published records have been missed or deliberately omitted, while others arrived too late in order to include them in the Atlas.

The purpose of this article is to bring our knowledge up to date concerning the presence of Lessepsian and other Indo-Pacific migrants in the Mediterranean Sea in general and along the coast of Israel in particular. Recent observations dealing with displacements of local Mediterranean species by exotic migrants will also briefly dealt with.

New, little known or noteworthy records of Lessepsian migrants and other Indo-Pacific molluscs in the Mediterranean Sea

The following list is mainly a compilation of overlooked or recently published finds and new records based on material in various collections in Israel. In addition a few notes are given on the correct identity of some of the exotic species.

The following abbreviations have been used:

HUJ – National Mollusc Collection, Hebrew University of Jerusalem, Israel

TAU – National Mollusc Collection, Tel Aviv University, Israel

CS – private collection Cristiano Solustri (Ancona, Italy)

IY – private collection of the late Isaac Yaron (now in TAU)

KH – private collection Kalman Hertz (Givatyyim, Israel)

UBZ – private collection Uri Bar-Ze'ev (Ramat Gan, Israel)

ZO – private collection Zvi Orlin (Kriyat Motzkin, Israel)

BIVALVIA

Family Arcidae

Barbatia trapezina (Lamarck, 1819)

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9233/1). This species is better known as *Barbatia decussata* (Sowerby, 1833). First record from the Mediterranean Sea.

Family Mytilidae

Leiosolenus hanleyanus (Reeve, 1857)

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9238/6). First record from the Mediterranean Sea.

Septifer bilocularis (Linnaeus, 1758)

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9231/5). A previous record of this species from Turkey (Albayrak & Çeviker, 2001), has turned out to have been based on misidentified specimens of the Erythrean species *Septifer forskali* Dunker, 1855 (Çeviker, 2002). First record from the Mediterranean Sea.

Family Pteriidae

Pinctada margaritifera (Linnaeus, 1758)

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9237/1). First record from Israeli waters.

Family Malleidae

Malvufundus decurtatus (Lamarck, 1819)

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9234/1). First record from the Mediterranean Sea.

Family Isognomonidae

Isognomon ephippium (Linnaeus, 1758)

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9235/1). First record from the Mediterranean Sea.

Family Gryphaeidae

Hyotissa hyotis (Linnaeus, 1758)

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9241/many). First record from the Mediterranean Sea.

Parahyotissa imbricata (Lamarck, 1819)

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9239/2). First record from the Mediterranean Sea.

Family Ostreidae

Planostrea pestigris (Hanley, 1846)

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9240/1). First record from the Mediterranean Sea.

Family Plicatulidae

Plicatula chinensis Mörch, 1853

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9232/4). First record from the Mediterranean Sea.

Family Spondylidae

Spondylus nicobaricus Schreibers, 1793

Israel, Akhziv, beach, leg. Z. Orlin, 15 March 2002 (ZO/1 upper valve). First record from the Mediterranean Sea.

Spondylus spinosus Schreibers, 1793

Zenetos et al. (2004) mentioned *Spondylus cf. multisetosus* from Turkey, while referring to Çeviker (2001). Such specimens have also been encountered in Israeli waters in populations of *Spondylus spinosus*. In our opinion *S. cf. multisetosus* is only a form of *S. spinosus* in which the secondary and tertiary ribs have been developed more strongly. Besides variation in ornamentation *S. spinosus* may show the following variations in colour: dark reddish-brown with contrasting white spines (typical form), orange-brown with yellow to orange spines or unicoloured orange to dark reddish-brown. Even specimens are being found with one half of the shell being unicoloured, the other half with white or yellow spines.

Family Chamidae

Chama asperella Lamarck, 1819

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9248/4). First record from the Mediterranean Sea.

Chama aspersa Reeve, 1846

Mienis (2004c) recorded recently the finds of three loose upper valves from as many beaches along the coast of Israel: Tel Barukh, north of Tel Aviv, leg. H.K. Mienis, 28 February 2002 (HUJ 9003/1 valve); Bat Yam, leg. H.K. Mienis, 21 December 2003 (TAU 41967/1 valve) and Herzliyya, leg. H.K. Mienis, 1 January 2004 (TAU 42068/1 valve).

Chama brassica Reeve, 1846

Israel, taken from an off-shore gas production platform, 27 km west off Ashqelon, leg. A. Kotzer, March 2003 (HUJ 9246/1). First record from the Mediterranean Sea.

Chama pacifica Broderip, 1834

This is at the moment a very common species along the coast of Israel. It was found also attached to the pillars of the off-shore gas production platform, situated 27 km off Ashqelon (HUJ 9247/15). Most of the latter specimens belonged to the slender oblong form: *segmentina* Clessin, 1889.

Family Tellinidae

Angulus flacca (Römer, 1871)

Israel, off "Frutarom", south of Akko, at 15 m depth, leg. A. Dotan, 15 September 1997 (HUJ 9227/1). First record from the Mediterranean Sea.

Family Semelidae

Theora (Endopleura) lubrica Gould, 1861

Balena et al. (2002) have reported this Far-Eastern species from four localities in and near the harbour of Livorno, Italy.

Family Veneridae

Redicirce sulcata (Gray, 1838)

Israel, Ashdod, dredged from a depth of 55-92 m, leg. Ch. Lewinsohn, 2 June 1970 (TAU 6727/3 valves). First record from the Mediterranean Sea.

Timoclea marica (Linnaeus, 1758)

Bogi & Galil (1999: figs. 4-7) mentioned *Timoclea roemeriana* (Issel, 1869) from the Bay of Haifa. Zenetos et al. (2004) used the same identification and figures, however, according to Oliver (1992) two closely related species occur in the Red Sea: *Timoclea roemeriana* characterized by 30-34 grooves on the rim of the inner valve near the lunula and *Timoclea marica* (Linnaeus, 1758) with 14-16 similar grooves. A study of a large number of specimens has turned out that in the latter species the number of grooves may vary between 16 and 19. The figure in Bogi & Galil shows clearly a shell with 19 grooves. Two additional valves collected off Palmahim, depth 35 m, leg. B. Galil, 1 September 2001 (TAU 40688), turned out to have the same number of grooves: 19. Mienis (2003c) changed therefore the identification into *T. marica*.

GASTROPODA

Family Lottiidae

Patelloida saccharina (Linnaeus, 1758)

Israel, Shiqmona, leg. K. Hertz, 15 September 2001 (TAU 42057/1 & KH/2). First record from the Mediterranean Sea.

Family Fissurellidae

Diodora funiculata (Reeve, 1850)

Singer (2002) and Mienis (2002b) have reported this well-known Keyhole limpet from the Persian Gulf and Arabian Sea from the coast of Israel. The first specimens dated back to 1998, which were found near Palmahim. Other localities listed were Rishon le Ziyon, Bat Yam, Yafo and Shefayim. In the meantime it has also been found near Herzliya, leg. K. Hertz, 26 December 2003 (KH/1) and Shiqmona, leg. K. Hertz, 15 September 2001 (KH/1). This species seems to be well established along the coast of Israel.

Family Trochidae

Ethminolia hemprichi (Issel, 1869)

Israel, Haifa, shipyards, leg. I. Yaron, 27 April 1970 (IY 1229 = TAU 46993/1). First record from the Mediterranean Sea.

Trochus niloticus Linnaeus, 1767

Mienis (2003g) reported two specimens of this large Topshell from the beach of Tel Aviv-Yafo, leg. A. Hadar, 1948/1968 (TAU 40611/2). These shells dropped probably in the sea when they were off loaded for the local, already long vanished, pearl button industry.

Family Rissoidae

Rissoina ambigua (Gould, 1849)

Turkey, Yanikas, near *Posidonia* beds at a depth of 12 m, leg. By a scuba diver, 2003 (CS/1). First record from the Mediterranean Sea.

Family Cerithiidae

Cerithium columna Sowerby 1834

Mienis (2003b) reported the find of a single shell of this species from Israel, Caesarea, beach, 3 July 1966 (TAU 26920/1).

Rhinoclavis sinensis (Gmelin, 1791)

Israel, Palmahim, beach, leg. K. Hertz, 15 February 2003 (KH/1 juvenile shell). First record from the Mediterranean Sea.

Family Hipponicidae

Hipponyx conicus (Schumacher 1817)

Three samples of the well-known Horseshoe limpet are present in the collection of the Tel Aviv University: Israel, Dor, at a depth of 1-2 m, leg. S. Arkin, September 1980 (TAU 19723/1 juv.);

Ashdod, on *Cerithium echinatum*, 27 m depth, leg. A. Kaplan, 10 December 1954 (TAU 32890/3 juv.) and on "*Fusus*", leg. P.S. Tsurriel, 23 January 1971 (IY 1881 = TAU 47068/1), however, none of these records seem to be reliable for one reason or another (Mienis, 2004a).

Family Strombidae

Tricornis tricornis (Lightfoot, 1786)

Israel, Tel Aviv, beach, leg. Z. Lewy, about 1960/70 (Z. Lewy, pers. info). He found a very large fragment of a recent shell. First record from the Mediterranean Sea.

Family Cypraeidae

Erosaria turdus (Lamarck, 1810)

A thriving colony has been discovered recently near Djerba, Tunisia (Wimart-Rousseau & Wimart-Rousseau, 2004).

Family Muricidae

Ergalatax contracta (Reeve, 1846)

Israel, Yafo, Ajami-beach, leg. K. Hertz, 25 August 2001 (KH/1). Also known to occur in Lebanon (Houart, personal information in Zenetos et al., 2004: 15). First records from the Mediterranean Sea.

Murex forskoehlii Röding, 1798

The Erythrean Spiny Murex or Forsskål's Venus comb has become in recent years (since 2001) a common species along the coast of Israel. It is found mainly at depths of 10-20 m, on sandy bottoms (Mienis, 2003e).

Rapana venosa (Valenciennes, 1846)

Israel, Mikhmoret, beach, leg. U. Bar-Ze'ev, 16 August 2002 (UBZ/1). First record from the Mediterranean coast of Israel.

Family Buccinidae

Cantharus tranquebaricus (Gmelin, 1791)

Mienis (2003d) recorded three specimens of this Indian species from the Marina of Herzliyya, Israel, leg. G. Ben-Zion, 10 July 2003 (KH/1) and idem, 17 July 2003 (KH/1 & TAU TAU 41881/1).

Engina mendicaria (Linnaeus, 1758)

Israel, Shiqmona, beach, leg. U. Bar-Ze'ev, December 2003 (TAU 47504/1). Additional specimens found near Shiqmona during the period 2001-2003 are in the collections of KH and UBZ. First records from the Mediterranean Sea.

Family Nassariidae

Nassarius obvelatus (Deshayes in Laborde, 1834)

Zenetos et al. (2004) listed this species as *Nassarius arcularia plicatus* (Röding, 1798) overlooking the fact that Dekker & Orlin (2000) have correctly listed this Erythrean species as *Nassarius obvelatus*. Its presence in the Eastern Mediterranean has still to be confirmed by additional finds.

Family Costellariidae

Vexillum (Costellaria) cadaverosum (Reeve, 1844)

Israel, Mediterranean coast, leg. P.S. Tsurriel, 23 January 1871 (IY 1882 = TAU 47067/1). This sample has been reported briefly as *Vexillum (Costellaria) pacifica* (Reeve, 1845), a junior synonym of *cadaverosum*, and is most probably supplied with erroneous data concerning its locality (Mienis, 2004a).

Vexillum (Pusia) depexum (Deshayes in Laborde, 1834)

Mienis (1985) mentioned a single specimen from the beach of Bat Yam. During a revision of the Mediterranean material present in the National Mollusc Collection of the Tel Aviv University a second specimen of Mediterranean origin was discovered: Israel, Akhziv, leg. N. Katz, 8 July 1964 (TAU 9311/1) (see Mienis, in press-a). First record from the Mediterranean Sea.

Family Turridae

Lienardia mighelsi Iredale & Tomlin, 1917

Mifsud & Ovalis (2003) reported the find of many fresh specimens of this Indo-Pacific species at a depth of 60 m off Bozcaada Island, Turkey. According to Dekker & Orlin (2000) its presence in the Red Sea has still to be confirmed.

Family Cylichnidae

Acteocina crithodes Melvill & Standen, 1907

Turkey, Yanikas, near *Posidonia* beds at a depth of 12 m, leg. By a scuba diver, 2003 (CS/1). First record from the Mediterranean Sea.

Family Retusidae

Retusa desgenettii (Audouin, 1826)

Bogi & Galil (2002) mentioned many specimens from four different localities along the coast of Israel.

Family Haminoeidae

Atys cylindricus (Helbling, 1779)

Israel, Shiqmona, beach, leg. K. Hertz, 25 June 2002 (KH/3). First record from the Mediterranean Sea.

Family Bullidae

Bulla ampulla Linnaeus, 1758

Zenetos et al. (2004) recorded this large Bubble shell from one locality each in the following four countries: Israel, Greece, Turkey and Cyprus. Mienis (2004b) could add five additional finds from the coast of Israel done in the period 2002/03.

CEPHALOPODA

Family Sepiidae

Sepia pharaonis Ehrenberg, 1831

Numerous cuttlebones of this *Sepia* were reported from beaches near Tel Aviv (over a length of 23 km) and south of Haifa (over a length of 13 km) in the spring of 2003 (Mienis, 2003h).

Family Loliginidae

Sepioteuthis lessoniana Lesson, 1830

Salman (2002) recorded a specimen caught in the Bay of Iskenderun, Turkey. Recently Andrey Aronov, a student at the Tel Aviv University, filmed a specimen with the help of a video camera, while diving off the coast of Israel in the spring of 2004. First record from the Mediterranean coast of Israel.

Family Octopodidae

Octopus cf. aegina Gray, 1849

Salman et al. (1999) reported 13 specimens belonging to the *Octopus aegina*-complex (including *Octopus kagoshimensis* Ortmann, 1888) from three different locations in the vicinity of Mersin, Turkey. In the National Mollusc Collections two other specimens belonging to this complex were located: Israel, Atlit, 4 December 1934 (HUJ 9219/1) and off Reading, Tel Aviv, depth 20 m, leg. B. Galil, 9 December 2003 (TAU 47230/1) (Mienis, in press-b). First records from Israeli waters.

Octopus cyaneus Gray, 1849

Two specimens of this interesting cephalopod have been caught so far along the Mediterranean coast of Israel: Akko-South, off "Frutarom", at a depth of 14 m, leg. A Dotan, 23 February 1998 (HUJ 12837/1) and off Mikhmoret, winter 1997/98 (aquarium Nautical School Mevo'ot Yam, Mikhmoret) (Mienis, 2003f).

DISCUSSION

The CIESM Atlas of exotic molluscs in the Mediterranean Sea (Zenetos et al., 2004), published in March 2004, contained the full descriptions of 126 species of Indo-Pacific origin (*Spondylus spinosus* and *S. cf. multisetosus* have been combined into one species) and another 4 species were only mentioned by name in the introduction as having been reported too late in order to

include them still in the Atlas. In addition they mentioned briefly 26 Indo-Pacific species, which were rejected by them as spurious records, misidentifications or as species of which the origin is not clear (for instance circum-tropical species). This brings the total number of Indo-Pacific species recorded since 1869 from the Mediterranean Sea to 156. Two months after the publication of the CIESM Atlas we can add already 34 additional species, which are based on new (23) or overlooked (11) records.

Origin of additional migrants

The 34 additional migrants originated from at least four or five different areas, although in some cases more options are possible (for instance in species with a wide distribution throughout the Indo-Pacific including the Red Sea).

-The following 18 species arrived most probably from the Red Sea: *Spondylus nicobaricus*, *Chama aspersa*, *Angulus flacca*, *Redicirce sulcata*, *Ethminolia hemprichi*, *Rissoina ambigua*, *Cerithium columna*, *Rhinoclavis sinensis*, *Tricornis tricornis*, *Engina mendicaria*, *Vexillum cadaverosum*, *Lienardi mighelsi*, *Retusa desgenettii*, *Atys cylindrica*, *Sepia pharaonis*, *Sepiotheutis lessoniana*, *Octopus cf. aegina* and *Octopus cyaneus*.

-Two species originated from either the eastern part of the Arabian Peninsula or India: *Cantharus tranquebaricus* and *Acteocina crithodes*.

-*Trochus niloticus* was shipped to the coasts of today's Israel from somewhere in the Indo-Pacific.

-Two species arrived from the Far East or elsewhere in the Western Pacific: *Theora lubrica* and

Patelloida saccharina.

-Finely 11 new species arrived from Australia: *Barbatia trapezina*, *Leiosolenus hanleyanus*, *Septifer bilocularis*, *Malvufundus decurtatus*, *Isognomon ehippium*, *Hytissa hyotis*, *Parahytissa imbricata*, *Planostrea pestigris*, *Plicatula chinensis*, *Chama asperella* and *Chama brassica*.

How did they arrive?

Not all the new species reached the Mediterranean in the same way. Although the majority of the Erythrean species moved into the Mediterranean most probably in a natural way either in the form of floating or free swimming larvae and the Cephalopods as free swimming adults, some species might have reached the Levantine coast as hitchhikers on the hull of a boat (for example *Ethminolia hemprichi* found at the shipyards in Haifa). Most probably the large Strombid species *Tricornis tricornis* has to be interpreted as a discarded souvenir.

The two species (*Cantharus tranquebaricus* and *Acteocina crithodes*), which arrived from the region of the Persian Gulf and Arabian Sea, reached the Eastern Mediterranean most probably also by means of inter-oceanic travel either as epibionts on the hull of a boat or as larvae in ballast water. To the same category belonged already such species as: *Conomurex persicus*, *Palmadusta lentiginosa*, *Thais lacera* and *Diodora funiculata*. The latter is now also known to occur in the Suez Canal (Hoffman et al., submitted) and it would be interesting to know whether this Limpet settled first along the Mediterranean coast of Israel and moved afterwards into the Suez Canal, which has already happened before with *Thais lacera* (Mienis, 1994), or the other way around.

Trochus niloticus dropped most probably in the Mediterranean Sea off the coast of Tel Aviv when commercial shipments of these large Top shells, destined for the former local button industry, were off loaded manually (Mienis, 2003g).

The arrival in the Mediterranean Sea of two species from the Far East or Western Pacific: *Theora lubrica* and *Patelloida saccharina*, is without doubt also closely connected with international sea traffic. Most interesting is however the discovery of at least 12 new species in the Mediterranean which arrived from Australia. They were found attached to a gas production platform, which had been towed from Australia to its present location: 25 km west off Ashqelon. In addition to the new species still three other species, which were known already from the Mediterranean Sea, were found to live as epibionts on the pillars of the platform: *Pinctada margaritifera*, *Malvufundus regulus* and *Chama pacifica*. The list of these Australian hitchhikers is not yet final because only about 50%

of the available study material has been identified so far. Besides these 15 bivalve species still several species of barnacles and polychaetes were attached to this platform and sooner or later we may expect at least part of them to turn up elsewhere along the coasts of the Eastern Mediterranean.

Changes in the habitat selection of migrant species

When exotic species manage to find a suitable habitat and start to reproduce, then they often form immediately very dense populations. However, this does not serve as a warranty that such a species has settled there forever. A good example for such an event is *Rhinoclavis kochi* Philippi, 1848. When it arrived along the coast of Israel (1963) it started to form soon dense populations at depths of 20-60 m. With every haul of a dredge thousands and thousands of live specimens were caught. This continued until about 20-25 years ago (Galil & Lewinsohn, 1981). Today hardly a single living specimen turns up from such depths. This does not mean that this *Rhinoclavis* species has disappeared altogether. It is still present along the coast but in much shallower water.

An exceptional development: a *Spondylus*-reef

Mienis et al. (1993a-b) reported for the first time the presence of *Spondylus spinosus* Schreibers, 1793 (and *Chama pacifica* Broderip, 1834) on a submarine sandstone ridge at depths ranging from 15 to 25 m, especially off the northern coast of Israel. Today (2004) it has completely covered that ridge and has created a *Spondylus*-reef with adult specimens sitting six high one on the other. This reef, unique in Mediterranean waters, forms an excellent habitat for numerous other epibionts and boring mussels. Probably due to overcrowding *Spondylus spinosus* is now moving also into shallower waters.

Competition between local and migrant species

So far little attention has been paid to competition between local and exotic species. Some interesting observations have become available recently concerning the displacement of autochthonous species by allochthonous ones along the coast of Israel (Fishelson, 2000; Mienis, 2002c & 2003a).

The introduced mussel *Brachidontes pharaonis* (P. Fischer, 1870) has replaced the much smaller local species *Mytilaster minimus* (Poli, 1795) almost completely in the intertidal zone. The large Erythrean Spiny oyster *Spondylus spinosus* has completely out-competed the much smaller local species *Spondylus gaederopus*, especially when the former started to move from the 15-40 m depth zone into much shallower water. The same is true for *Chama pacifica* and its much smaller autochthonous congener *Chama gryphoides* (Linnaeus, 1758).

The Erythrean limpet *Cellana rota* (Gmelin, 1791) is rapidly replacing the Mediterranean limpet *Patella caerulea* Linnaeus, 1758 in a south-north gradient along the Mediterranean coast of Israel.

Not always the size of a particular species warrants success in cases of competition. Among the Cerithiidae the opposite is true for what we have seen among the bivalves i.e. the larger species displacing smaller ones. The relatively tiny snails *Cerithium scabridum* Philippi, 1848 and *Rhinoclavis kochi* have taken the place of much larger local species like *Cerithium vulgatum* Bruguière, 1792, *Cerithium lividulum* Risso, 1826 and *Cerithium rupestre* Risso, 1826.

The Strombid species *Conomurex persicus* (Swainson, 1821) occurs in very dense numbers in sandy habitats at depths of 5-25 m, where it forms a major competitor of any herbivorous species. In the same area occurs also the Erythrean Spiny Murex or Forsskål's Venus comb *Murex forskoehlii* Röding, 1798, a major predator of all sand dwelling bivalves. To the regret of local shrimp-fishers it is being caught sometimes in large numbers. The spiny shells not only cause considerable damage to their fishing gear but also to the commercial catch by puncturing the shrimps with their spines (Mienis, 2003e).

Towards an up-dated list of Lessepsian migrants and other Indo-Pacific molluscs in the Mediterranean Sea

Not all the records of Erythrean and other Indo-Pacific molluscs from the Mediterranean Sea are of a same level. Some species have established themselves firmly in their new environment, they are enlarging their distribution constantly and records of new finds appear regularly in the malacological literature. Other species are known from one or a few recent records only but there

are reasons to believe that these species might get a foothold in the Mediterranean. Sometimes it turns out that we only lack the necessary information hidden in collections of local amateur collectors. This is especially a problem in Israel, because the current law protects the whole phylum Mollusca, without any exception. If you like to collect molluscs then you have to apply for a one time permit at the Israel Nature Reserves and National Parks Authority, which is usually a time-consuming event. Most amateur collectors carry out their hobby without a permit as a direct result of this bureaucracy. Much information remains in this way hidden in such private collections, because their owners are afraid that their names will appear in publications when they share their knowledge with people at scientific institutes (Mienis, 2002a).

A third group of species consists of odd finds like a single valve of *Hippopus hippopus*, two specimens of *Trochus niloticus*, a single fragment of *Tricornis tricornis* and other unique specimens, which have never been confirmed in the last 4-5 decades.

Three separate lists have therefore been drawn up: species, which seem to live in the Mediterranean Sea (109); species, which are known from a single living find or from a few empty shells (60), and species, which fall in the category of "odd" records (21). From these lists we have omitted already misidentifications as reported by Zenetos et al., 2004. Note that these lists are not final and that a certain species may shift from one category to another.

List 1: Lessepsian migrants and other Indo-Pacific molluscs, which seem to have established themselves in the Mediterranean Sea (109 species)

BIVALVIA

Anadara demiri (Piani, 1981)
Anadara inaequalis (Bruguère, 1789)
Scapharca natalensis (Krauss, 1848)
Brachidontes pharaonis (P. Fischer, 1870)
Musculista perfragilis (Dunker, 1857)
Musculista senhousia (Benson in Cantor, 1842)
Modiolus auriculatus (Krauss, 1848)
Septifer forskali Dunker, 1855
Xenostrobus securis (Lamarck, 1819)
Crassostrea gigas (Thunberg, 1793)
Dendostrea frons (Linnaeus, 1758)
Saccostrea cucullata (von Born, 1778)
Saccostrea commercialis (Iredale & Roughley, 1933)
Pinctada radiata (Leach, 1814)
Malvifundus regulus (Forsskål, 1775)
Dendostrea frons (Linnaeus, 1758)
Spondylus groschi Lamprell & Kilburn, 1995
Spondylus spinosus Schreibers, 1793
Diplodonta aff. *subrotundata* (Issel, 1869)
Chama pacifica Broderip, 1834
Chama aspersa Reeve, 1846
Pseudochama corbieri (Jonas, 1846)
Afrocardium richardi (Audouin, 1826)
Fulvia australis (Sowerby, 1834)
Fulvia fragilis (Forsskål, 1775)
Mactra lilacea Lamarck, 1818
Mactra olorina Philippi, 1846
Angulus valtonis (Hanley, 1844)
Theora (*Endopleura*) *lubrica* Gould, 1861
Clementia papyracea (Gmelin, 1791)
Gafrarium pectinatum (Linnaeus, 1758)
Paphia textile (Gmelin, 1791)
Ruditapes philippinarum (Adams & Reeve, 1850)
Timoclea marica (Linnaeus, 1758)
Gastrochaena cymbium (Spengler, 1783)
Laternula anatina (Linnaeus, 1758)

GASTROPODA

Cellana rota (Gmelin, 1791)
Haliotis pustulata cruenta Reeve, 1846
Diodora funiculata (Reeve, 1850)
Diodora ruppellii (Sowerby, 1834)
Smaragdia souverbiana (Montrouzier, 1863)
Pseudominolia nedyma (Melvill, 1897)
Trochus erithreus Brocchi, 1821
Cerithium egenum Gould, 1849
Cerithium scabridum Philippi, 1848
Rhinoclavis kochi (Philippi, 1848)
Gibborissoa virgata (Philippi, 1849)
Clathrofenella ferruginea (A. Adams, 1860)
Finella pupoides A. Adams, 1860
Diala varia A. Adams, 1860
Rissoina bertholletii Issel, 1869
Voorwindia tiberiana (Issel, 1869)
Conomurex persicus (Swainson, 1821)
Erosaria turdus (Lamarck, 1810)
Palmadusta lentiginosa lentiginosa (Gray, 1825)
Purpuradusta gracilis (Gaskoin, 1849)
Metaxia bacilla (Issel, 1869)
Cerithiopsis pulvis (Issel, 1869)
Cerithiopsis tenthrenois (Melvill, 1896)
Cycloscala hyalina (Sowerby, 1844)
Sticteulima lentiginosa (A. Adams, 1861)
Ergalatax obscura Houart, 1996
Murex forskoehlii Röding, 1798
Rapana venosa (Valenciennes, 1846)
Thais lacera (von Born, 1778)
Thais sacellum (Gmelin, 1791)
Engina mendicaria (Linnaeus, 1758)
Zafra savignyi (Moazzo, 1939)
Zafra selasphora (Melvill & Standen, 1901) [? = *trogloodytes* (Souverbie, 1866)]
Fusinus verrucosus (Gmelin, 1791)
Lienardi mighelsi Iredale & Tomlin, 1917
Murchisonella columna (Hedley, 1907)
Adelactaeon amoenus (A. Adams, 1851)
Adelactaeon fulvus (A. Adams, 1851)
Chrysallida fischeri (Hornung & Mermod, 1925)
Chrysallida maiae (Hornung & Mermod, 1924)
Chrysallida pirintella (Melvill, 1910)
Cingulina isseli (Tryon, 1886)
Hinemoa cylindrica (de Folin, 1879)
Iolaea neofelizoides (Nomura, 1936)
Odostomia (Megastomia) lorioli (Hornung & Mermod, 1924)
Oscilla jocosus Melvill, 1904
Styloptygma beatrix Melvill, 1911
Syrnola cinctella A. Adams, 1860
Syrnola fasciata (Jickeli, 1882)
Turbonilla edgarii (Melvill, 1896)
Acteocina mucronata (Philippi, 1849)
Ventomnestia girardi (Audouin, 1826)
Retusa desgenettii (Audouin, 1826)
Pyrunculus fourierii (Audouin, 1826)
Bulla ampulla Linnaeus, 1758
Haminoea cyanomarginata Heller & Thompson, 1983
Chelidonura fulvipunctata Baba, 1938
Elysia ornata (Swainson, 1840)

Bursatella leachi savignyana Audouin, 1826
Pleurobranchus forskalii Rüppell & Leuckart, 1828
Plocamopherus ocellatus Rüppell & Leuckart, 1828
Discodoris lilacina (Gould, 1852)
Hypselodoris infucata (Rüppell & Leuckart, 1830)
Dendrodoris fumata (Rüppell & Leuckart, 1830)
Melibe fimbriata (Alder & Hancock, 1864)
Caloria indica (Bergh, 1896)
Flabellina rubrolineata (O'Donoghue, 1929)
Aeolidiella indica (Bergh, 1888)
Siphonaria crenata Blainville, 1827

CEPHALOPODA

Sepia pharaonis Ehrenberg, 1831
Sepioteuthis lessoniana Lesson, 1830
Octopus cf. aegina Gray, 1849
Octopus cyaneus Gray, 1849

List 2: Lessepsian migrants and other Indo-Pacific molluscs of which the presence in the Mediterranean Sea has to be confirmed by additional finds (60 species)

POLYPLACOPHORA

Chiton hululensis (E.A. Smith in Gardiner, 1903)

BIVALVIA

Acar plicata (Dillwyn, 1817)
Barbatia trapezina (Lamarck, 1819)
Glycymeris arabica (H. Adams, 1870)
Limopsis multistriata (Forsskål, 1775)
Leiosolenus hanleyanus (Reeve, 1857)
Septifer bilocularis (Linnaeus, 1758)
Pinctada margaritifera (Linnaeus, 1758)
Malvufundus decurtatus (Lamarck, 1819)
Isognomon ephippium (Linnaeus, 1758)
Hytissa hyotis (Linnaeus, 1758)
Parahytissa imbricata (Lamarck, 1819)
Planostrea pestigris (Hanley, 1846)
Plicatula chinensis Mörch, 1853
Spondylus nicobaricus Schreibers, 1793
Divalinga arabica Dekker & Gould, 1994
Chama asperella Lamarck, 1819
Chama brassica Reeve, 1846
Mactrinula tryphera Melvill, 1899
Angulus flacca (Römer, 1871)
Psammotreta praerupta (Salisbury, 1934)
Trapezium oblongum (Linnaeus, 1758)
Hiatula ruppelliana (Reeve, 1857)
Atactodea striata (Gmelin, 1791) [= *glabrata* (Gmelin, 1791)]
Antigona lamellaris Schumacher, 1817
Circenita callipyga (von Born, 1778)
Dosinia erythraea Römer, 1860
Redicirce sulcata (Gray, 1838)
Sphenia rueppellii A. Adams, 1850

GASTROPODA

Patelloida saccharina (Linnaeus, 1758)
Nerita sanguinolenta Menke, 1829
Ethminolia hemprichi (Issel, 1869)

Stomatella impertusa (Burrow, 1815)
Cerithium nodulosum adansonii Bruguière, 1792
Cerithium caeruleum Sowerby, 1855
Cerithium columna Sowerby, 1834
Cerithium echinatum Lamarck, 1822
Cerithium nesioticum Pilsbry & Vanatta, 1906
Clypeomorus bifasciata (Sowerby, 1855)
Rhinoclavis sinensis (Gmelin, 1791)
Angiola punctostriata (E.A. Smith, 1872)
Planaxis griseus (Brocchi, 1821)
Rissoina ambigua (Gould, 1849)
Rissoina spirata Sowerby, 1825
Scaliola elata Issel, 1869
Hipponyx conicus (Schumacher, 1817)
Canarium mutabilis (Swainson, 1821)
Staphylaea nucleus sturanyi (Schilder & Schilder, 1938)
Notocochlis gualteriana (Récluz, 1844)
Ergalatax contracta (Reeve, 1846)
Rapana rapiformis (von Born, 1778)
Cantharus tranquebaricus (Gmelin, 1791)
Nassarius obvelatus (Deshayes, 1834)
Vexillum (Pusia) depexum (Deshayes, 1834)
Conus fumigatus Hwass, 1792
Amathina tricarinata (Linnaeus, 1758)
Leucotina cf. eva Thiele, 1925
Acteocina crithodes Melvill & Standen, 1907
Atys cylindrica (Helbling, 1779)
Chromodoris quadricolor (Rüppell & Leuckart, 1830)

List 3: Rejected records of supposed Lessepsian migrants and other Indo-Pacific molluscs mentioned from the Mediterranean Sea (21 species)

BIVALVIA

Spondylus limbatus Sowerby, 1847
Spondylus spectrum Reeve, 1856
Hippopus hippopus (Linnaeus, 1758)
Saxidomus purpuratus (Sowerby, 1852)
Petricola hemprichii (Issel, 1869) [? = *divergens* (Gmelin, 1791)]

GASTROPODA

Trochus niloticus Linnaeus, 1767
Umbonium vestiarium (Link, 1807)
Dahlakia proteum (Jousseume, 1930)
Lentigo lentiginosus (Linnaeus, 1758)
Tricornis tricornis (Lightfoot, 1786)
Cypraea pantherina Lightfoot, 1786
Erronea caurica (Linnaeus, 1758)
Monetaria annulus (Linnaeus, 1758)
Monetaria moneta (Linnaeus, 1758)
Coralliophyla (Coralliobia) madreporarum (Sowerby, 1832)
Latirus polygonus (Gmelin, 1791)
Vasum turbinellus (Linnaeus, 1758)
Strigatella virgata (Reeve, 1844)
Vexillum (Costellaria) cadaverosum (Reeve, 1844)
Conus arenatus aequipunctatus Dautzenberg, 1937
Lophiotoma indica (Röding, 1798)

CONCLUSION

At the end of May 2004 at least 109 species of Erythrean and Indo-Pacific molluscs were known to have established themselves in the Mediterranean Sea (Table 1) with 60 additional species still remaining in the waiting room (Table 2). Does it mean that we have reached more-or-less the end of the road concerning an additional influx of such exotic molluscs into the Mediterranean Sea? And what about local expansions for example along the coast of Israel and Palestine?

There are strong indications that we are still at the beginning of a process, which will bring back a tropical mollusc fauna in the Mediterranean Sea. The temperature of the seawater is slowly rising, the salinity of the water is increasing and if the plans to widen and deepen the Suez Canal to a width of 400 m and a depth of 25 m, then we may expect still many additional species to reach the Eastern Mediterranean. Still quite a number of species are living in the Suez Canal, which have not been recorded so far from the Mediterranean (Barash & Danin, 1973; Hoenselaar & Dekker, 1998; Hoffman et al., submitted). A deepening of the Canal may allow also deepwater species to penetrate into the Mediterranean basin. One species: *Ergalates contracta*, a typical deepwater species in the Gulf of Aqaba, has been encountered already in Israel and Lebanon. Another similar species *Maetrinula tryphera* has been found so far only once. Do they form the first signs for a new chapter in the migration of molluscs towards the Mediterranean: the arrival of deepwater species?

If we look at the local mollusc fauna of Israel and Palestine then it is obvious that they will receive their fair part of such new developments. At the other hand a southward migration of species so far reported only from the coasts of Lebanon and Turkey, in particular from the Bay of Iskenderun, may increase the number of Indo-Pacific molluscs in the southeast corner of the Mediterranean Sea. A good example of such a southward migration forms *Conomurex persicus*, which is now the most common gastropod in sandy habitats along the coast of Israel.

The establishment and further development of so-called marina's: harbours for sea-going yachts, along the coast of Israel and the ever increasing use of the Suez Canal in order to sail from Mediterranean harbours to the Gulf of Aqaba in general and Elat in particular and vice versa has created additional opportunities for molluscs to hitch hike from one area to the other.

I do not think we will ever reach a level of saturation, however, without doubt the biodiversity among the molluscs of the Eastern Mediterranean will increase accordingly and the competition between autochthonous and allochthonous species will create interesting situations.

I am convinced that while I am writing these last lines we have to update already the list of Lessepsian migrants and other Indo-Pacific molluscs observed so far in the Mediterranean Sea.

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