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ONGOING MODIFICATION OF THE MEDITERRANEAN MARINE FAUNA AND FLORA BY THE ESTABLISHMENT OF EXOTIC SPECIES

Helmut ZIBROWIUS

Station Marine d'Endoume, rue Batterie-des-Lions, 13007 Marseille, France

Résumé : ***Modification en cours de la faune et flore marines méditerranéennes par l'établissement d'espèces exotiques.***

Même si des espèces exotiques ont probablement été introduites, accidentellement, en Méditerranée au cours des siècles passés, le nombre d'invasions réussies a considérablement augmenté avec l'âge technique et continue encore à augmenter. La migration lessepsienne (par le canal de Suez), la navigation et les transferts intentionnels de coquillages (les derniers entraînant habituellement des introductions non-intentionnelles) expliquent la présence de la plupart des organismes dont l'invasion a réussi. Mais on a aussi des exemples de quelques voies d'arrivée mineures. Dans tout le bassin méditerranéen divers groupes incluent maintenant des espèces d'origine étrangère qui ont pu établir des populations se reproduisant. Divers nouveaux arrivés ont même acquis une importance économique, certains comme nuisances (organismes causant des salissures biologiques), d'autres en devenant localement essentiels pour la pêche commerciale. Cette contribution a l'intention d'attirer l'attention sur le fait que la faune et la flore marine méditerranéennes sont des entités qui changent en relation avec des activités humaines. Mais elle ne prétend pas dresser un inventaire exhaustif des espèces exotiques et de la littérature s'y rapportant.

Mots-clés : Méditerranée, espèces exotiques, migration par le canal de Suez, navigation, transferts de coquillages, *Crassostrea gigas.*

Summary. Although alien species have probably been introduced, accidentally, into the Mediterranean over the past centuries, the number of successful invasions increased considerably with the technical age and is still increasing. Lessepsian migration (through the Suez Canal), navigation and intentional shellfish transfers (the latter commonly causing non intentional introductions) explain the presence of most of the successful invaders, but some minor ways of arrival are also illustrated by examples. Throughout the Mediterranean basin diverse groups now include alien species that have been able to establish reproducing populations. Various newcomers have even acquired economic importance, some as nuisances (fouling organisms), others by becoming locally essential for commercial fisheries. This contribution intends to attract attention to the Mediterranean marine fauna and flora as being changing entities in relation to human activies, but it does not pretend to provide an exhaustive inventory of aliens and the corresponding literature.

Key-words : Mediterranean, exotic species, Suez Canal migration, navigation, shellfish transfers, *Crassostrea gigas.*

The term biological invasion is currently used for the arrival, establishment and diffusion of species of exotic origin. In the Mediterranean colonizing alien species are recognized among diverse groups. Their arrival is due to migration and various types of transportation. Best studied is the lessepsian migration, i.e. the arrival of species of Red Sea origin passing through the Suez Canal (opened in 1869) and the changes in ecosystems following their establisment and diffusion in the southeastern part of the Mediterranean sea. The first representative synthesis by Por (1978) recognized 128 species as high-probability, and 76 species as low-probality lessepsian migrants. The list has been updated by Por (1989, 1990) and the ever increasing literature continuously adds further species of lessepsian migrants. These are not necessarily recent newcomers that just passed the Suez Canal. As in the case of shipborne aliens or species accompanying shellfish movements, the arrival and establishment may considerably precede actual detection.

Lessepsian migration is best documented for benthic organisms and fishes, although various planktonic species (including Dinoflagellatae and Copepoda) are considered as invaders (Halim, 1990 ; Kimor, 1990 ; Lakkis, 1990a, 1990b). For other planktonic groups specialists are affirmative : no Red Sea species of Thecosoma, Euphausiacea, and Thaliacea have yet invaded the Mediterranean (Rampal, 1990 ; B. Casanova, 1990 ; Godeaux, 1990).

Alien species invading the Mediterranean other than lessepsian migrants and thereby potentially showing up in diverse parts of the Mediterranean, have not yet been the subject of a representative inventory comparable to Por's studies of lessepsian migrants. An exhaustive inventory cannot be given here either, since it would require the teamwork of many specialists. In spite of a long tradition of biological investigations, reliable inventories of the Mediterranean fauna and flora not available for all groups. It is also very difficult to keep informed of all forthcoming publications on alien species new to the Mediterranean. Significant contributions may be published in journals and records with limited distribution. Furthermore, titles and abstracts of articles do not always provide an indication that aliens are mentioned in the text. And the ever open questions are : are the identifications reliable and the previously known geographical range representative ? (see remarks in Por, 1978, on rejected cases of lessepsian migration). The recognition of early introductions into the Mediterranean has frequently been obscured by taxonomic difficulties that led to confusion with native species.

It has to be remembered that species originally described from other areas and now discovered in the Mediterranean, are not necessarily newcomers that extend their range or

have their arrival related to human activities. In fact, their range of natural distribution may have been incompletely know. On the other hand, occurrences of markedly exotic species may be without consequences, not all isolated accidental introductions resulting in reproducing populations. Accordingly, the discovery of each species new to the inventory of the Mediterranean fauna and flora should be interpreted with caution and the circumstances be carefully analyzed.

This contribution intends to emphasize the fact in diverse groups alien species are continuously added to the Mediterranean marine fauna and flora, which are fluctuating entities. The considerable enrichment in number of alien species of the Black Sea, a very particular annex basin in the Mediterranean, is not especially taken into account here ; an updated inventory of the aliens in the Black Sea should be prepared by specialists from the adjacent countries.

For exotic species, means of access to the Mediterranean are diversified :

- migration through the manmade Suez canal supported by a predominant south to north current ;
- transport of sessile (fouling) and vagile (clinging) species on ship hulls, drilling platforms and possibly other towed manmade structures, with vagile species able to shelter in empty barnacle shells ;
- transport with ballast water and, in former times, transport with solid ballast such as sand and stones ;
- intentional introductions of species in view of commercial use, i. e., essentially shellfish movements ;
- accidental introductions of species accompanying intentionally introduced species ;
- discarding from the market and back to the sea, for whatever reasons, of intentionally imported live specimens, eventually together with an accompanying fauna ; this may include species used as bait and the fauna of algae used as packing material ;
- escape from aquaria, especially through an open circuit without treatment.

Migration through the Suez canal has been thoroughly analyzed by Por (1978, 1989, 1990), who also coined the term "lessepsian migration". Spanier and Galil (1991) provided a synthesis of major impact data. The other means of arrival in a new area have also been widely discussed in the literature (Catta, 1876 ; Man, 1913, 1914 ; Hanna, 1966 ; Relini and Montanari, 1973 ; Carlton, 1975, 1979, 1981, 1985, 1989 ; Forster and Willan, 1979 ; Andrews, 1980 ; Williams et al., 1988).

In the following, the lessepsian migration that in fact represents the strongest and best documented inflow of newcomers, is summarized, whereas species that have entered the Mediterranean by other ways are given preferential attention and a more detailed presentation. Exceptionally, some species that had mistakenly or hypothetically been considered as aliens, but that are now revealed to be naturally present in the Mediterranean, are also discussed.

To reiterate, this elaboration is not exhaustive, either in number of species discussed or in number of publications cited. Like any other selection, emphasis given to one aspect rather than to another is subjectively biased. For convenience, the alien species are grouped under various higher category headings (phylum, class, order, etc.).

BENTHIC ALGAE

Por (1978) listed various species of benthic algae from the Levantine basin as lessepsian migrants.

Some other algae, now widely distributed and abundant on the Atlantic coasts of Europe and the Mediterranean, are rather recent and very successful colonizers that most likely have been brought by ship a few decades ago (Farnham, 1980 ; ICES, 1982 ; Hartog and Velde, 1987), e. g. the cholorophycean ***Codium fragile*** (Suringar) Hariot, native of the northwestern Pacific, and the rhodophycean ***Asparagopsis armata*** Harvey, native of the southwestern Pacific. Even modern antifouling treatments do not always stop algal settlement on ship hulls (Callow, 1986).

First noticed in the Mediterranean in the Livorno area before being found on the coast of France, the rhodophycean ***Acrothamnion preissii*** (Sonder) Wollaston, has been interpreted as an alien introduced by navigation from the Pacific (?) to Italy and subsequently dispersed to the west by the Ligurian current (Boillot et al., 1982 ; Cinelli and Sartoni, 1969, 1970 ; Thélin, 1985).

Other species arrived with carelessly imported oysters and invaded the coasts of Europe, Mediterranean included. *Crassostrea gigas* has thus been the vector of several Japanese algae brought to Etang de Thau, from where some already have spread along the open coast of Languedoc (Pérez et al., 1981, 1984 ; ISTPM, 1982 ; Boudouresque et al., 1985a, 1985b ; Belsher et al., 1985, 1988 ; Knoepffler-Peguy et al., 1985 ; Gerbal, 1986 ; Ben Maïz et al., 1987 ; Verlaque and Riouall, 1989 ; Knoepffler et al. 1990 ; Floc'h et al., 1991). At least six species, the phaeophyceans (Fucophyceae) ***Laminaria japonica*** Areschoug, ***Sargassum muticum*** (Yendo) Fensholt, ***Sphaerotrichia divaricata*** (C. Agardh) Kylin, and ***Undaria pinnatifida*** (Harvey) Suringar ; and the rhodophyceans ***Anthithamnion nipponicum*** Yamada and Inagaki and ***Chrysymenia wrightii*** (Harvey) Yamada have thus been imported by negligence.

Undaria pinnatifida had been found in Etang de Thau as early as 1971. In order to minimize the significance of the accidental arrival, it has been suggested that the new alga be considered as a benefit : it is cultivated and eaten in the Far East. When *U. pinnatifida* appeared at Port Vendres, far to the southwest of Etang de Thau and near the Spanish border, it has also been hypothesized that it may have arrived independently, together with bait imported from Korea or Japan. But it has been shown elsewhere that the alga can be dispersed travelling on ship hulls (Hay, 1990). In the case of ***Sargassum muticum*** it has not yet been suggested that it should enrich French gastronomy. The species that most successfully has invaded the Atlantic coasts of Europe (Rueness,1989), has also had much attention in the Mediterranean. Knoepffler-Peguy et al. (1986) were able to report it from 17 localities along ca. 100 km of the coast of Languedoc, to the east and to the west of Etang de Thau. Knoepffler et al. (1990) reported further spreading, including to the Banyuls area near the Spanish border and to Costa Brava, northern Spain.

The rhodophycean ***Grateloupia doryphora*** (Montagne) Howe, first noticed in Etang de Thau in 1982, appears to illustrate a different situation (Riouall et al., 1985 ; Ben Maïz et al., 1986). Although introduction together with oysters may have occured there, this does not mean penetration into an entirely new area, the species having been

recorded from the northeastern Atlantic and from the Mediterranean since the turn of this century. But human activities may have contributed to its present, admittedly world-wide, distribution.

A recent spectacular case of an alien alga colonizing the Mediterranean on a large scale is that reported by Meinesz and Hesse (1991) of the large chlorophycean ***Caulerpa taxifolia*** (Vahl) C. Agardh. Already wide spread in tropical seas, this alga in all likelihood escaped from the Oceanographic Museum of Monaco where it had been on display for many years in the tropical aquarium. In 1985 it was first seen settled in the natural environment next to the museum. Resisting winter temperatures as low 11-13° C, it gradually spread over all types of substrate, including rock, sand, and mud, at depths of 3-35 m. Areas supporting stands of the indigenous phanerogams *Cymodocea nodosa* (Ucria) Ascherson and *Posidonia oceanica* (L.) Delile are now covered by fronds of *C. taxifolia*, which measure up to 45 cm in length. Originally, Meinesz and Hess reported the exotic *Caulerpa* from the Monaco area and from Toulon, far to the west, but when their paper was finally printed, additional localities were known (A. Meinesz, pers. com. 1991) : to the Italian border in the east, and in the west closing the gap between the Monaco and Toulon areas. This is not one of the lessepsian migrants in the genus *Caulerpa* listed by Por (1978).

PHANEROGAMS

A marine phanerogam of Red Sea origin also invaded the Mediterranean : ***Halophila stipulacea*** (Forsskål) Ascherson is a very successful colonizer of the southeast that reached Cyprus, various Greek islands, the Greek mainland, Malta, and recently was recognized on the eastern coast of Sicily (Biliotti and Abdelahad, 1990). In spite of its evident spreading in the last decades, Por (1978) did not entirely exclude a prelessepsian arrival in the Mediterranean (prior to the opening of the Suez canal). Beyond the range indicated by Lipkin (1975a, 1975b,), it was found in 1977 in the Gulf of Corinth near Aspra Spitia (Zibrowius, 1992). According to Haritonidis and Diapoulis (1990) it is now very abundant in the Gulf.

PORIFERA

Presumedly alien sponges are reported only from the Levantine area. Por (1978) listed 5 species as high-probability and 2 species as low-probability lessepsian migrants. The difficulties of distinguishing species of the genera in question, together with the proportionally high number (5) of presumedly antilessepsian migrants listed by Por, suggest that a critical reevaluation is needed for this group.

HYDROIDEA

Various species of hydroids are part the Mediterranean harbour and ship fouling communities (see Chimenz Gusso and Rivosecchi Taramelli, 1975 ; Morri and Boero, 1986). Some are said to have a cosmopolitan distribution, and this may in part be due to navigation (see Carlton, 1975, 1979, for examples from the Californian fauna).

Human activities (navigation, introduction of oysters) may have caused the arrival on the Atlantic coasts of Europe of the brackish water ***Garveia franciscana*** (Torrey, 1902), a species that became abundant in the Zuiderzee (Vervoort, 1964) before being replaced by the freshwater ***Cordylophora caspia*** (Pallas, 1771). *G. franciscana*, the type locality of which is San Francisco Bay (but where it may also have been introduced ; Carlton, 1975, 1979) has lately been found established in the Mediterranean, the lagoon of Venice being its first recognized locality (Morri et al., 1982 ; Morri, 1982 ; Sacchi et al., 1983, 1989).

Edwards (1976) explained the wide distribution (northern hemisphere) of the genus *Gonionemus,* possibly comprising only one species (***Gonionemus vertens*** Agassiz, 1865 ; the medusa is better known than the polyp) as resulting mainly from oyster transfers. According to Edwards' review of the abundant literature, *Gonionemus* seems to have arrived first on the Atlantic coasts of Europe and subsequently in the Mediterranean.

Por (1978) listed 3 species of hydroids as low-probability lessepsian migrants. The difficult taxonomy and the proportionally high number (8) of presumedly antilessepsian migrants suggest that a critical reevaluation is needed for this group.

Eucheilota paradoxica is a small Leptomedusa widely distributed in tropical and substropical seas (type locality : Florida). In the Mediterranean it was discovered in 1967 in the Southern Adriatic Trough (Schmidt and Benović, 1977), in 1977 in the Bay of Villefranche, France (Carré and Carré, 1990), and in 1981 (abundant) in the Alboran Sea and (rare) between the Balearic Islands and Sardinia (Dallot et al., 1988). In the Bay of Villefranche, well-known for its thoroughly investigated plancton, *E. paradoxica* has occurred, since then, in great abundance every year, always during the same season. Its sudden appearence followed by regular mass occurrences suggests a recent introduction (Carré and Carré, 1990 ; Goy, 1991). Most likely its ability to reproduce asexually, including the formation of resting frustules, favoured both its accidental arrival by transportation and its successful establishment in an area where sexual maturity is not reached because of too low water temperatures.

SCYPHOZOA

Alien species reported from the southeastern Mediterranean (Goy et al., 1990 ; Lakkis et al., 1990 ; Galil and Spanier, 1990 ; Galil et al. ; 1990 ; Spanier and Galil, 1991) are likely to be lessepsian migrants : ***Phyllorhiza punctata*** Lendenfeld, 1884 ; ***Rhopilema nomadica*** Galil and Spanier, 1990 ; and ***Cassiopeia andromeda*** (Forsskål, 1775). The former are pelagic species, whereas the latter is a benthic medusa possessing zooxanthellae and living "upside down" on shallow soft bottoms. *C. andromeda* is said to be recorded from Cyprus as early as 1903, near Thira (Aegan Sea) in 1955, and from Lebanon in 1988. *R. nomadica* appeared on the coast of Israel in the mid-1970s and, being fairly common, is now well known for the severity of its sting (Spanier and Galil, 1991). Its life cycle has been elucidated (Lotan et al., 1892).

ACTINIARIA

The present distribution of certain actinian species undoubtedly results from navigation and oyster transfers (see Carlton, 1975, 1979, for examples from the Californian fauna). One of these, ***Haliplanella lineata*** (Verrill,

1869) [= *H. luciae* (Verrill, 1898)], has been considered as an alien in western Europe and the Mediterranean (Stephenson, 1935 ; Manuel 1981). It frequently occurs in harbour fouling communities and has been presumed to be of northwestern Pacific origin. Kiener (1971) reported it as particulary eurybiont from lagoons in Corsica and on the Mediterranean coast of France.

The abundance of a small actinian species (not identified because of poor preservation, D. Doumenc, pers. com. 1978) in the fouling community sampled at Toulon harbour (14.12.1977) from a ship arriving from the Indian Ocean via the Suez canal (see Zibrowius, 1979) shows that in this group navigation may be a factor of faunal transfer.

There is no observation of actinians being introduced into the Mediterranean together with oysters. But it should be remembered that *Crassostrea gigas* had been imported straight from Japan to Etang de Thau (France) under conditions similar to those of importation to the Atlantic coast of France (Gruet et al., 1976). On its arrival on the Atlantic coast the Japanese oyster carried an actinian species that was found still thriving in the Atlantic oyster parks one year after introduction. In Gruet et al. (1976) it is mentioned as ***Aiptasia pulchella*** Carlgren, 1943 (identified by D. Doumenc), but the illustrated specimen is another species, almost certainly *Haliplanella lineata* (Verrill, 1869) (R.L. Manuel, pers. com. 1983, 1991 ; J.C. den Hartog, pers. com. 1991). D. Doumenc (pers. com. 1991) confirms that the illustration in Gruet et al. (1976) does not conform to the species submitted to him for identification.

SCLERACTINIA

Typically, scleractinian corals are not part of fouling communities that ships may contact in harbour areas. Bertelsen and Ussing (1936) reported on reef corals as ship fouling. In fact, several species of scleractinians and one species of hydrocoral *(Millepora)* were found on the hull of an old ship that had been towed to Copenhagen from Bermuda where it had served for many years as a coaling station near a reef rather than in a typical harbour environment. For obvious reasons, tropical reef corals had not the slightest chance to colonize the Danish coasts.

The first, and up to now unique, case of a scleractinian species accidentally introduced to a distant area where it successfully established reproducing populations, is that reported from the Mediterranean by Zibrowius (1974, 1980) and Zibrowius and Ramos (1983) as ***Oculina patagonica*** De Angelis, 1908. The hypothesis of the species being an alien, and its identification do not appear to have been questioned or contradicted. The colonial shallow water coral in question possesses zooxanthellae and thrives in a variety of environments that are otherwise unusual for Mediterranean scleractinians : harbours and nearby polluted areas, the coast of a mining area with heavy metals pollution discharge, rock substrate exposed to heavy silting and, elsewhere, to abrasion effect by sand. Being successful under such variable and generally unfavorable conditions, as well as in natural infralittoral rock communities of photophilous algae, suggests that it is a strong opportunistic colonizer, a feature that generally characterizes invaders.

The species was first dicovered (in 1966 and 1978) in two localities of the Savona area (Ligurian coast, Italy) and subsequently found in many localities (including Alicante harbour) along ca. 300 km of coast in southeastern Spain, between Cabo de Gata and Cabo de la Nao. In Alicante harbour it was first noticed in the late 1960s and more formally recognized in 1973. The late discovery of the coral, although it is very obvious in shallow water because of its frequently large encrusting colonies, suggests a relatively recent addition to the Mediterranean fauna. In Liguria, the arrival of the coral has tentatively been explained (Zibrowius, 1974) by the release of larvae from a mature colony on the hull of an old ship imported for the local steel industry. The subsequent discovery of the coral as wide-spread and abundant in southeastern Spain (including Alicante harbour), suggests an earlier arrival, possibly as early as the Spanish colonial period in South America.

As for the origin of the coral, the temperate Atlantic coast of South America has been suggested, where *O. patagonica* was described from Pleistocene samples from the coastal area and is presumed to be part of the present fauna. Significant coincidence : the South American gastropod *Crepidula calytraeiformis* also occurs in Alicante harbour.

Colonies obtained by transplanting fragments from the Savona area and from Portman, southeastern Spain, are experimentally grown in the Marseille area, respectively, since 1972 and 1987. They easily invade the surrounding algae covered rock and may attain a linear growth of 2 cm per year. The species appears well adapted to a wide range of climatic conditions in the Mediterranean and is likely to be increasingly successful in that sea.

MOLLUSCA (GENERAL INFORMATION)

Although alien molluscs showed up in various parts of the Mediterranean, lessepsian migrants are by far the most numerous ; in fact, molluscs are one of the "leading" groups of the lessepsian migration, together with decapod crustaceans and fishes (Por, 1989).

Por (1978) listed 27 species as high-probability and 13 species as low-probability lessepsian migrants. Various species subsequently got promotion to the former rank, e. g. when well established populations were found instead of isolated empty shells of the original record. Gastropods (including various opisthobranchs and one marine pulmonate) outnumber bivalves, a tendency confirmed by later investigations ; the ever increasing list still includes a single polyplacophoran species. Barash and Danin (1986) listed 92 species of molluscs of Indo-Pacific origin, including species of *Scapharca* and *Rapana* that are not strictly speaking lessepsian migrants. The last census by Aartsen et al. (1989), again of Indo-Pacific immigrants, increased the number to 104 identified species and included the following remark : "some 30 odd species also found in the eastern Mediterranean and in all likelihood immigrants from the Indo-Pacific province, still wait for definite identification" ; at least one of these has been identified now (Aartsen et al., 1990). The local impact of some lessepsian migrants on species associations has been pointed out by Tom and Galil (1991).

Lessepsian migrants that rapidly spread to the west (southern Italy) may have been helped by ship transport in addition to their natural spreading capacities.

POLYPLACOPHORA

An alien species, ***Chiton platei*** Thiele, 1910, has been reported from the coast of Israel as a lessepsian migrant (Barash and Danin, 1977 ; Por, 1978).

GASTROPODA PROSOBRANCHIA

Gibbula cineria (Linnaeus) is a common NE Atlantic trochid (Norway to the Straits of Gibraltar) that also penetrates into the Alboran Sea. Live specimens have been collected from the floating cages containing oysters of an experimental shellfish culture at Mistra Bay, Malta (Schembri, 1979). Spat of *Ostrea edulis* and *Crassostrea gigas* had been imported from Britain (Anglesey, Wales) where *C. cineria* is common, and this may well be the origin of the Maltese specimens. Even though no reproducing population was likely to result from the isolated accidental introduction, this well illustrates oysters being the vector of other species.

The lessepsian migrant ***Cerithium scabridum*** (Philippi, 1849) rapidly invaded the southeastern Mediterranean (Por, 1978 ; Bogi and Khairallah, 1987 ; Tringali and Villa, 1990) and attained the coasts of Sicily where it became locally abundant, especially in the highly polluted bay of Augusta (Piani, 1979 ; Di Natale, 1982).

Crepidula fornicata Linnaeus, 1758, is native of the Atlantic coast of North America from where it accidentally arrived, with the oyster *Crassostrea virginica* (Gmelin, 1791), on the Pacific coast of North America (Hanna, 1966 ; Carlton, 1975, 1979) as well as in southern England. From this starting point, where it was first noticed in 1872, it invaded (oyster transfers helping) the coasts of western Europe as far as southern Sweden and southwestern France. The literature is abundant on its nuisances to oyster and mussel cultures because of the competition for space and food (filter feeder).

C. fornicata has repeatedly been found in the Mediterranean. A specimen in the Marseille museum may represent the oldest record (previously unpublished) : it was found in ca. 1957 on the cultivated mussels at La Seyne-sur-Mer, near Toulon, France, where shipments from the Atlantic were currently received (J. Devidts, com. pers. 1991). Di Natale (1982) mentioned a population from the lagoon of Faro, near Messina, Sicily, where Atlantic mussels were commonly imported. According to Clanzig (1989), *C. fornicata* has appeared (in 1989) in the lagoon of Salses-Leucate, southern France, one of the Languedoc lagoons with extensive aquaculture that implies species transfers from the Atlantic coast. Especially in the Languedoc lagoons *C. fornicata* may have a chance to become established permanently.

Cachia (1981) reported *C. fornicata* from Marsamxett Harbour of Malta (collected alive in 1975, on rock together with oyesters) and from Marsaxlokk Bay (fresh dead shell found in 1973 on beach), and presumed its accidental introduction by foreign vessels. This occurrence, in southern Mediterranean harbour situations, reminds the occurrence of another *Crepidula* species in the harbour of Alicante (below), but the identification of the material from Malta has been verified by comparison with typical Atlantic specimens from England (C. Cachia, pers. com. 1991).

A very dense population of *Crepidula* was discovered in the harbour of Alicante, southeastern Spain, by A.A. Ramos, first noticed in the late 1960s, more formally recognized in 1973, and revisited by him and H.Z. in 1981 when studying the population of the alien scleractinian *Oculina patagonica* (see Zibrowius and Ramos, 1983). It has been recognized by P.M. Arnaud (pers. com. 1981) as not being *C. fornicata*, and has now been identified by S. Gofas (pers. com. 1991) as ***Crepidula calyptraeiformis*** Deshayes, 1830. Additional information provided by S. Gofas : Type material of *C. calyptraeiformis* is in the Paris museum. Deshayes (1830) did not know where the shell came from but presumed a Peruvian origin (purchased together with shells from Peru). Hoagland (1977) first listed *C. calyptraeiformis* among the nomina dubia and nuda (as from Peru, an unjustified assertion), then (1983) as poorly preserved specimens of *C. aculeata* (Gmelin, 1791), a species said to have a very wide distribution. S. Gofas now considers *C. calyptraeiformis* as a distinct species whose occurrence on the coast of Uruguay is confirmed by material of well known origin at the Paris museum (including collectings by A. Teissière in 1931, French consul in Uruguay). Since in Alicante harbour *C. calyptraeiformis* co-occurs with a thriving population of the scleractinian *Oculina patagonica*, of similar South American origin, the snail and the coral may have arrived together by navigation.

The presence of the alien *C. calyptraeiformis* in the harbour of Alicante is similar to the case of ***Crepidula onyx*** Sowerby, 1824, native of the Pacific coast of America (California to Costa Rica) that settled in Hong Kong harbour (Huang et al., 1893 ; Morton, 1987).

Littorina littorea Linnaeus, 1758, is native of the Atlantic coasts of Europe, from Scandinavia to southern Portugal. Its presence in northeastern North America has been explained by natural transatlantic colonization during the Holocene post-glacial climatic optimum or secondary climatic optimum ; by introduction via Iceland by early Norse settlers (ca. 1 000 years ago) ; and by more recent accidental arrivals (see Kraeuter, 1976 ; Carlton et al. 1982). It has also been brought to the Pacific coast of North America, probably together with oysters (Hanna, 1966 ; Carlton, 1975, 1979). Di Natale (1982) reported *L. littorea* from the lagoon of Faro, near Messina, Sicily, undoubtedly imported together with Atlantic mussels (*Mytilus* from the Netherlands and Portugal). Another population was found by Barsotti and Campani (1982) in rock pools at Punta Righini, Castiglioncello Promontory ca. 20 km south of Livorno in the northern Tyrrhenian Sea. No morphometric differences were found between North Atlantic populations and this one from the Tyrrhenian Sea, the origin of which is not evident.

Littorina saxatilis (Olivi,1792) is another species typical of the tidal zone on the Atlantic coasts of Europe. But it also exists in the lagoons of the northern Adriatic and in the Gulf of Gabès, the two areas of the Mediterranean with notable tides (Sacchi et al., 1989). *L. saxatilis* has occasionally been considered as illustrating the "subatlantic" characters of these areas, or as being a faunal relect, but Sacchi and Torelli (1974), Smith (1982), and Janson (1985) admitted, or at least did not exclude, a relatively recent introduction of *L. saxatilis* to the northern Adriatic (via Venice) where it settles, essentially, on hard artificial substrates. Olivi (1792) had the impression that this species was not abundant in the lagoon of Venice. It should be noted that the species had been described from Venice

(*saxatilis* Olivi, 1792) slightly earlier than from England (*rudis* Maton, 1797).

It is difficult to believe that ***Quoyula madreporarum*** (Sowerby, 1832), well-known in the Indo-Pacific and the Red Sea as a symbiont of scleractinian reef corals of the genus *Pocillopora* (see Schumacher, 1976), should have been able to colonize the Mediterranean where its usual host species do not exist. Whatsoever, Ghisotti (1968, 1974b) referred to *Q. madreporarum* three gastropods found in the Bari area, southern Adriatic, in a colony of *Cladocora caespitosa* (Linnaeus, 1767), a typical Mediterranean shallow water scleractinian (Zibrowius, 1980) ; but Ghisotti also made some remarks on differences observed between these shells and typical Indo-Pacific individuals. An empty shell from the harbour of Aci Trezza, eastern coast of Sicily, has also been referred to *Q. madreporarum* by Di Natale (1979, 1982).

The large muricid ***Rapana venosa*** (Valenciennes, 1847) [= *R. thomasiana* Gosse, 1861a ; = *R. pontica* Nordsieck, 1969 ; Nordsieck, 1982, mistakenly ascribed the authorship of *R. pontica* to Milachewitch, 1916, author of species named *pontifica* in various other genera ; for synonymy see Ghisotti, 1971 ; Mienis, 1976] is native of the northwestern Pacific and is also known from the Pacific coast of North America, where it accidentally arrived with the Japanese oyster *Crassostrea gigas* (see Hanna, 1966). Probably brought to the new area on ship hulls or with oysters (the latter means of transport suggested by Kinzelbach, 1986) it was first noticed in the Black Sea in 1947 and originally ascribed, by mistake, to the similar but more southern, Pacific *R. bezoar* (Linnaeus, 1767). *R. venosa* soon spread throughout the Black Sea and became a considerable nuisance in the oyster and mussel beds, as frequently stated in the literature. It passed the Bosphorus (Kinzelbach, 1986) and now is currently fished in the Marmara Sea (B. Öztürk, pers. com. 1990). Grossu and Lupu (1964) predicted its penetration into the Mediterranean where it first appeared in the northern Adriatic : Ravenna (Ghisotti, 1974a), lagoon of Venice where it is now well established (Mel, 1976 ; Cesari and Pelizzato, 1985a, 1985b, Sacchi et al., 1989), Rimini (Rinaldi, 1985b), Gulf of Trieste (Cucaz, 1983). First records in the northern Tyrrhenian Sea were from Elba (Terreni, 1980, 1981) and Fortullino, ca. 15 km south of Livorno (Paolini, 1987). Another representative of the genus, ***Rapana rapiformis*** (Born, 1778), is a lessepsian migrant and has been found as far north as Rhodes (Barash and Danin, 1988).

The invasion of the eastern Mediterranean by ***Strombus decorus*** (Röding, 1978), a large-sized gastropod occasionally exceeding 6 cm, does not appear to conform to lessepsian migration : unknown in the Red Sea, its nearest occurrence is in the northwestern Indian Ocean (Gulf of Aden, Arabian Sea, Persian Gulf), while the first localities to be known in the Mediterranean (late 1970s, early 1980s) are on the south coast of Turkey, far away from the Suez canal (Nicolay and Romagna Manoja, 1983). It has been hypothesized that its arrival could have been due to navigation. Subsequent records are from Lebanon (Bogi and Khairallah, 1987), Cyprus (Bazzocchi, 1985 ; Bogi et al., 1989), Rhodes (Verhecken, 1984 ; Barash and Danin, 1899), and from additional localities in Turkey (Tringali and Villa, 1990). Prior to this recent invasion, the genus *Strombus* had been extinct in the Mediterranean since the Pleistocene, the formerly represented *Strombus bubonius* Lamarck, 1802, surviving only on the west coast of Africa.

GASTROPODA OPISTHOBRANCHIA

The large aplysiid ***Bursatella leachi*** Blainville, 1817, is the most successful of the immigrant Indo-Pacific opisthobranchs and accordingly is mentioned in many publications, most records being referred to the subspecies *savigniana* Audouin, 1826 (Bebbington, 1972 ; Ghisotti, 1974b ; Barash and Danin, 1973, 1977, 1986 ; Por, 1978 ; Tortorici and Panetta, 1977 ; Parrinello and Catalano, 1978 ; Catalano et al., 1978 ; Piani, 1980 ; Bello, 1982 ; Cattaneo and Barletta, 1984 ; Vaccarella and Postorelli, 1984 ; Vaccarella, 1986 ; Jaklin and Vio, 1989). It is common in the Levantine basin where it appears to have no native competitor. It has progressed to Greece (Rhodes and Aegean Sea) and has attained the Ionian Islands, Malta, Sicily, southern Italy (Bari and Taranto areas), and the northern Adriatic. Locally (Sicily, northern Adriatic), the subspecies *B. leachi savigniana* was said to encounter the nominate subspecies *B. leachi leachi*, but Jaklin and Vio (1989) consider that distinction of subspecies is not justified and the colonization of the Mediterranean is entirely lessepsian (opinion shared by Ph. Bouchet, pers. com. 1990).

Originally described from the Red Sea, ***Chromodoris quadricolor*** (Rüppell and Leuckart,1872) also exists in the Indian Ocean (Tanzania) but had been confused elsewhere in the Indo-Pacific with several similar species (see Rudmann, 1982). Cattaneo Vietti (1986) referred to it a nudibranch from Capo Mortola (Imperia) on the Ligurian coast, northwestern Mediterranean, and suggested that it could be an immigrant species previously not recorded from the Mediterranean. It appears that the Ligurian opisthobranch was correctly identified (Ph. Bouchet, pers. com. 1990).

When first described from northwestern Corsica, ***Fryeria bayi*** Bouchet, 1983, was the first representative of this Indo-Pacific nudibranch genus to be known from the Mediterranean. Although Bouchet did not entirely exclude that it could be a lessepsian migrant, he considered it to be likely an autochthonous Mediterranean species in a genus naturally more widely distributed and possibly to be found also in the Atlantic. New records from the Straits of Gibraltar have subsequently confirmed this interpretation (Ph. Bouchet, pers. com. 1990).

The large-sized tethyid ***Melibe fimbriata*** Alder and Hancock, 1864, previously known from the Indian Ocean, has been reported (countless specimens, up to 14 cm in lenght) from Astakos Inlet on the Ionian coast of Greece and been considered as a lessepsian migrant (Thompson and Crampton, 1984 ; Barash and Danin, 1986).

GASTROPODA PULMONATA

An alien species, ***Siphonaria kurrachaensis*** Reeve, 1856, has been reported from the coast of Israel as a lessepsian migrant (Barash and Danin, 1977 ; Por, 1978). *Siphonaria* from the Athens area, Greece, has been referred to ***Siphonaria pectinata*** Linnaeus, 1758, by Nicolay (1980), a species known from the eastern Atlantic (Portugal to Angola). If correctly identified, its isolated (?) occurrence in Greece would suggest a recent introduction.

BIVALVIA OSTREIDAE

Oysters are by far the most transferred commercial bivalves. For various purposes they often have been transferred over great distances, from one continent or ocean to another : for live storage prior to sale ; in order to be grown from introduced spat ; or to be introduced into new areas for sustaining an oyster industry. These large scale oyster movements were started in the 19th century. Transportation by ship and rail was replaced by air freight in the 1960s. Various alien species of oysters have thus been brought to the Mediterranean (frequently together with the accompanying fauna). There appears to exist no precise inventory of these introductions, or whether they proved "successful" or not. Data are widely dispersed, including in technical reports, and it is probable that many introductions (not only among the early ones) did not leave traces in official records. Accordingly one can have only a vague idea which species of oysters have been (tentatively) introduced and where they came from (not necessarily straight from their native area). The remarks below should be considered as merely indicative. Additional species may have been brought to the Mediterranean.

It appears that originally ***Crassostrea angulata*** (Lamarck, 1819) was limited to the southwest of the Iberian peninsula before transfers to other areas in Europe were started in the 19th century. Given the affinities between that "Portuguese" oyster and *Crassostrea gigas* from eastern Asia (morphological resemblances, easy hybridization), some authors even hypothesized that Portuguese sailors might have introduced the oyster from Japan to Portugal as early as in the 16th century. In the late 19th century *C. angulata* started to be imported to oysterparks on the Atlantic coast of France where it finally became established (Pérez, 1906 ; ICES, 1972 ; Marteil, 1977 ; Andrews, 1980). It is said that a whole shipment thrown overboard for sanitary reason in the Gironde estuary in 1868 largely contributed to the successful settling in that area. *C. angulata* was then transferred to the Mediterranean coast of France, from both the Atlantic coast of France and straight from Portugal. Especially in Etang de Thau it had thus become a main resource (Raimbault, 1964 ; Pollio, 1981).

Tentative introductions to Italy (lagoon of Fusano) date back to 1905 and have been reconducted at a larger scale from 1966 on, on the Tyrrhenian coast (La Spezia, Fiumicino, lagoons of Fusano and Paola, etc.), in the Ionian Sea (Taranto) and in the northern Adriatic (Venice). These introductions implied multiple transfers : oysters from the Gironde estuary even transited by Etang de Thau and the Arcachon basin (i. e. back to the Atlantic) before arriving in Italy (Matta, 1969). *C. angulata* of uncertain origin has been discovered in the Po delta, and populations have been reported from the lagoon of Venice (Matta, 1970 ; Ghisotti, 1971b, 1971c ; Renzoni, 1974 ; Costa et al.,1976 ; Poluzzi et al. 1981 ; Cesari and Pelizzato, 1985b). Probably, *C. angulata* has been dispersed more widely throughout the Mediterranean.

Native of northeastern Asia (Sibirian coast of the Japan Sea, Korea, Japan), ***Crassostrea gigas*** (Thunberg, 1793) is now the most widely distributed oyster, introduced world-wide in temperate to tropical seas (Hawaii, Pacific coast of North America, South Pacific Islands, New Zealand, Australia, Mascarene Islands, northern Red Sea, South Africa, Brazil ; Atlantic coasts of France, Europe and Morocco ; Mediterranean, etc.). Partial inventories of earlier transfers can be found in Walford and Wicklund (1973), Mann (1979), Andrews (1980), ICES (1972, 1982), Coleman (1986), Hutchings et al. (1987). Introduction to Europe started in France in the late 1960s, first on the Atlantic coast, then in the Mediterranean (Maurin and Le Dantec, 1979). The official version is that "the first specimens of *C. gigas* were probably imported about 1966 by French oystermen in response to the declining production of *Crassostrea angulata*" (Grizel, 1983 ; see also Grizel and Heral, 1991). Oysters were imported on large scale by air freight from Japan and later also from the Pacific coast of North America. Particular aspects of the introductions (nonconformity to quarantine conditions leading to the joint introduction of accompanying fauna, parasites and oyster diseases) have been commented elsewhere (Gruet et al., 1976 ; Zibrowius, 1978, 1983b ; Ben Maïz et al., 1987). The Japanese oyster has also been the vector for the arrival in European waters (Atlantic and Mediterranean) of various alien seaweeds, probably including *Sargassum muticum* as the most conspicuous one.

Early uncontrolled introductions of *C. gigas* perfectly illustrate what could have been a main action conforming to a black humour proposal (Sinderman, 1991) : the "International Decade of Indiscriminate Ocean Transfers (Project IDIOT)". The core of project being "a decade of deliberate unrestricted movements of animals and plants from one place to another, whether for aquaculture, ornamental purposes, or for any other reason (or no reason at all). Then, after the expected great ecosystem disruptions and epizootics subsided (which might take half a century or longer), there would be no need for concern about future introductions, no oppressive regulations, no inspections at any border for diseases or pests".

As soon as it was implanted in France, including the lagoons of the Mediterranean coast, *C. gigas* was also introduced elsewhere in the Mediterranean (Italy, Algeria, Tunisia, Malta, Cyprus,...). In Italy the Adriatic lagoons (Venice, Grado, Varano, Foggia, etc.) were specially targeted (Blundo et al., 1972 ; Valli et al., 1979 ; Rinaldi, 1985 ; Cesari and Pelizzato, 1985b). Hrs-Benko (1982) reported larvae of *C. gigas* from the plankton of the Limski Kanal in northerm Yugoslavia ; this showed that the oyster was colonizing new areas from its starting points on the Italian coast. Agius et al. (1977, 1978) reported the first introductions to Malta. Information on early introduction in Tunisia is found in Madhioub and Zaouali (1988).

Saccostrea commercialis (Iredale and Roughley, 1933) is native of the southwest of Australia (New South Wales) and has occasionally been transferred to Tasmania (Hutchings et al., 1987). Cesari and Pelizzato (1985b) reported its recent introduction (details unknown) in the lagoon of Venice (also mentioned by Sacchi et al., 1989).

BIVALVIA OTHER THAN OSTREIDAE

Arcidae of Indo-Pacific origin of the genus ***Scapharca*** have been reported from the Mediterranean under six different names, but there are fewer species involved. In the southeast (Sinai and Israel) ***S. natalensis*** (Krauss, 1848) is considered as a lessepsian migrant ; ***S. rufescens*** (Reeve, 1844), previously reported from the same area, may be the same species (Barash and Danin, 1973, 1977 ; Por, 1978).

On the coasts of Italy the names ***S. inaequivalvis*** (Bruguière, 1789) and ***S. cornea*** (Reeve, 1844), have been used, the former having priority (also over *S. rufescens* and *S. natalensis*), according to Ghisotti and Rinaldi (1976). First noticed near Ravenna in the northern Adriatic, where an accidental introduction by ship transport is most likely, *S. inaequivalvis* rapidly invaded the Adriatic to the north and to the south (Ghisotti, 1973, 1974b ; Ghisotti and Rinaldi, 1976 ; Rinaldi, 1977, 1985b ; D'Introno, 1980 ; Lazzari and Rinaldi, 1981 ; Poluzzi et al., 1981 ; Cesari and Pellizzato, 1985b ; Taviani et al., 1985 ; Sacchi et al. 1989 ; etc.). Its capacity to survive in extreme conditions has also been noted and the literature record has become abundant. The species has further been reported from the coasts of Calabria and Sicily (Di Natale,1982) and even earlier from Naples and Genova (Ghisotti and Rinaldi, 1976). It has also settled in the Black Sea, where it was first reported from Romania (Gomoiu, 1984 ; Tiganus, 1988).

Demir (1977) reported an Arcidae abundant in the harbour of Izmir, Aegean coast of Turkey, well known for its heavy pollution ; it was then referred to *S. amygdalum* (Philippi, 1847), a preoccupied name that was replaced by ***S. demiri*** Piani, 1982. Pending a detailed comparison of the forms reported as different species (*S. natalensis/rufescens, S. inaequivalsis/cornea, S. demiri/amygdalum*) from different parts of the Mediterranean, its remains uncertain whether more than one invading species is involved.

The mytilid ***Brachidontes semistriatus*** (Krauss, 1848) [= *B. variabilis* (Krauss, 1848] is a very successful lessepsian migrant that rapidly colonized the southeastern Mediterranean (Barash and Danin, 1973, 1977, 1989 ; Felsenburg and Safriel, 1974 ; Por 1978 ; Kinzelbach, 1984 ; Tringali and Villa, 1990) and to the west attained the coasts of Calabria and Sicily (Di Geronimo, 1971 ; Arcidiacono and Di Geronimo, 1976 ; Zanca, 1976 ; Berdar et al., 1977 ; Di Natale, 1979, 1982).

The mytilid ***Musculista senhousia*** (Benson in Cantor, 1842) is native of East Asia, from the Sibirian coast of the Sea of Japan to Singapore. Its arrival on the Pacific coast of North America was probably due to accidental transfer with the Japanese oyster *Crassostrea gigas* and lead to definite establishment (Carlton, 1975, 1979). Starting in 1980 and 1982 respectively, *M. senhousia* also proved to be a successful colonizer in New Zealand and Australia (Willan, 1987 ; Hutchings et al., 1987) where it probably arrived among fouling on ship hulls or as larvae in ballast water. *M. senhousia* is opportunistic in its ecology, able to adapt to a variety of habitats, both on soft and on hard bottoms. By establishing dense colonies (mat building), it may radically alter the biota and stabilize fine sediments ; colonies may be so thick as to exclude infaunal species. Accordingly, its arrival in New Zealand and Australia was greeted with much concern.

M. senhousia was part of the alien fauna imported to the Atlantic coast of France together with the Japanese oyster *Crassostrea gigas* (See Gruet et al., 1976). Hoenselaar and Hoenselaar (1989) then reported this species from two lagoons of the Mediterranean coast of France (discovered in 1982 in Etang de Thau ; more recent records in Etang de Leucate). According to Hoenselaar and Hoenselaar, this is identical with ***Modiola (Arcuatula) arcuatula*** Hanley, 1844, considered of wide Indo-Pacific distribution. Under the latter name a bivalve had been reported by Barash and Danin (1971) from the Mediterranean coast of Israel. Independently, the alien bivalve has summarily been reported by Clanzig (1989) as *Arcuatula* cf. *senhousia* from three lagoons on the Mediterranean cast of France (Etang de Salses-Leucate since 1985, Etang d'Or and Etang de Thau since 1988), information that confirms that by Hoenselaar and Hoenselaar (1989). Given the extensive shellfish culture in the Languedoc lagoons and the related invasions by many aliens, *M. senhousia* undoubtedly was brought in together with shipments of *Crassostrea gigas*.

The pearl oyster ***Pinctada radiata*** (Leach, 1814) was considered a low-probability lessepsian migrant by Por (1978), who admitted that it may have entered the Mediterranean previous to the construction of the Suez canal, or that its presence in the Mediterranean might be part of a wide circumtropical distribution (presence in the Gulf of Gabès, Tunisia, was noticed as early as 1890). Whatever, *P. radiata* is present in the Red Sea and the Suez Canal and is now abundant throughout the Levantine basin (Barash and Danin, 1973, 1977, 1989a, 1989b, Por, 1978 ; Zibrowius and Bitar, 1981 ; Kinzelbach, 1984 ; Tringali and Villa, 1990) and shows a tendency of dynamic expansion away from this area : in the north it has attained Cyprus, Rhodes, Turkey and Greece, in the west Malta, Sicily and the Aeolian Islands (Barash and Danin, 19873, 1988 ; Ghisotti, 1974b ; Di Natale, 1982). The rapid spreading of *P. radiata* may have benefited from dispersal by ship-borne individuals, as it is suggested by an observation made in 1977 in Toulon harbour, France : several specimens were present in the fouling community sampled on a ship that arrived via the Suez Canal after a cruise of 7 months in the western Indian Ocean (Zibrowius, 1979).

Serbetis (1963) referred to another Indo-Pacific pearl oyster, ***Pinctada margaritifera*** (Linnaeus, 1758), populations discovered in 1961 in the Athens area. He even transplanted the pearl oysters to other areas in Greece with the intention of creating a pearl industry. Most likely these pearl oysters were misidentifiel *P. radiata*, a species that Kalopissis (1982) reported from the same area near Athens (Saronikos Gulf).

Petricola pholadiformis Lamarck, 1819, native of the Atlantic coast of North America, is able to bore in rather soft substrates (clay, chalk, consolidated mud, etc.). In southern England it was first found in an area where the American oyster *Crassostrea virginica* had been imported. It then extended its range along the Atlantic coasts of Europe and also colonized the Mediterranean and the Black Sea (Duval, 1963 ; ICES, 1972 ; Tebble, 1966).

The venerid ***Ruditapes philippinarum*** (Adams and Reeve, 1850), with a rich synonymy [= *R. japonica* (Deshayes, 1853) ; = *R. semidecussata* (Reeve, 1864) ; occasionally referred to the genera *Paphia, Tapes, Venerupis*], is native of the western Pacific. Accidentally introduced, it became an important commercial species on the Pacific coast of North America ; probably it had arrived together with the Japanese oyster *Crassostrea gigas* (Hanna, 1966 ; Carlton, 1975). *R. philippinarum* has intentionally been introduced in France, first on the Atlantic coast (ISTM, 1977, 1979 ; Maurin 1980 ; ICES, 1982, 1983), then in the Mediterranean lagoons of Languedoc (Bodoy et al., 1981 ; Maître-Allain, 1983a, 1983b, 1985). In Italy, it was first established in the lagoon of Venice (Breber, 1985 ; Cesari and Pelizzato, 1985b ; Sacchi et al., 1989). Hybridization with indigenous species is unlikely to occur (Borsa and Thiriot-Quiévreux, 1990).

The venerid ***Mercenaria mercenaria*** (Linnaeus, 1758) from the Atlantic coast of North America became established in southern England and on the Atlantic coast of France by intentional and accidental introductions started in the 19th century. A first tentative introduction to the Mediterranean coast of France (no further details are reported) was contemporary with those on the Atlantic coast (Bretagne, 1863 ; Fischer, 1864, 1865). The introduction has been tried again, successfully, beginning in 1965, in the lagoons of Languedoc, especially in Etang de Thau, with specimens from Connecticut and the Atlantic coast of France (Bascheri, 1965, 1969, 1970). *M. mercenaria* is now well established there.

POLYCHAETA (GENERAL INFORMATION)

Based on literature that unfortunately comprised some particularly unreliable older publications, Por (1978) listed 9 species of polychaetes (including one species of Serpulidae) as high-probability, and 14 species (including one species of Serpulidae) as low-probability lessepsian migrants, and 20 species (including two species of Serpulidae) as antilessepsian migrants. A partial correction and updating was provided by Zibrowius (1983b) ; in particular, it was stated that considerably more serpulid species of Indo-Pacific origin had settled on the Levantine coast. Por (1989, 1990) was able to refer to new data obtained by Ben-Eliahu (1989, 1991b) on Nereidae (6 species) and Serpulidae (see below), whereas data for other polychaete families remain problematical.

POLYCHAETA SERPULIDAE AND SPIRORBIDAE

The serpulids of Red Sea/Indo-Pacific origin presently known from the coasts of Israel and Lebanon are : ***Hydroides*** cf. ***brachyacantha*** Rioja, 1941 ; ***H. novaepommeraniae*** Augener, 1925 [= *H. grubei* Pillai, 1965] ; ***H. heterocera*** (Grube, 1868) ; ***H. homocera*** Pixell, 1913 ; ***H. minax*** (Grube, 1878) ; ***H. operculata*** (Treadwell, 1929) ; ***Pomatoleios kraussii*** (Baird, 1865) ; ***Spirobranchus tetraceros*** (Schmarda, 1861) (see Laubier, 1966 ; Zibrowius and Bitar, 1981 ; Ben-Eliahu, 1988, 1989, 1991a ; Ben-Eliahu and Hove, 1990, 1992). In addition to active dispersal by planktonic larvae, passive dispersal as ship fouling may have contributed to their present range. In fact, most of these species, together with ***Hydroides albiceps*** (Grube, 1870), and ***H. steinitzi*** Ben-Eliahu, 1972 (both of Red Sea/Indo-Pacific origin), have also been found among the fouling sampled at Toulon harbour from a ship arriving from the Indian Ocean via the Suez canal (Zibrowius, 1979). As for *Pomatoleios kraussii*, it is wide-spread in the Indo-Pacific (from Japan to South Africa) and also occurs in the Gulf of Guinea. This disjunct distribution may well be due to early dispersal by navigation (Zibrowius, 1983b).

Comprising world-wide > 80 species and particularly specious in tropical seas, the genus *Hydroides* is predominant not only among lessepsian migrants, but also includes the three earliest alien serpulids in the Mediterranean (Zibrowius, 1971, 1973, 1978, 1983b ; Zibrowius and Thorp, 1990). ***Hydroides dianthus*** (Verrill, 1873), ***H. dirampha*** Mörch, 1863, and ***H. elegans*** Haswell, 1883, have been collected together at Naples from harbour fouling as early as 1888, *H. elegans* being quantitatively dominant (an association currently observed in present harbour fouling throughout the Mediterranean). But two species can be traced to an even earlier date : *H. dianthus* at Izmir (year of publication 1865) and at Trieste (year of collecting 1874) ; *H. dirampha* at Naples (year of publication 1870). All three species are now widely distributed in the Mediterranean in harbours and coastal lagoons. The distribution is disjunct leaving out "natural" habitats of full marine salinity, except in areas immediately adjacent to harbours. Within this pattern, *H. dirampha* appears to be absent from the northernmost parts of the Mediterranean and to be more frequent in the south ; its origin could be the tropical American Atlantic. *H. elegans* (frequently confused with the autochthonous northeastern Atlantic and Mediterranean *H. norvegica* Gunnerus,1768) also appears to be of tropical/subtropical origin, but its native area is even less evident ; being first described from Australia does not prove an Australian origin. *H. dianthus* appears native of the Atlantic coast of North America where it occurs in a variety of "natural" habitats. Possibly the arrival with ship fouling of the three *Hydroides* species in the Mediterranean considerably antedates their first records. Considerable fouling nuisances by *H. elegans* have been described by Parenzan (1965) and Paoletti and Sebastio (1973).

Ficopomatus enigmaticus (Fauvel, 1923) probably was brought to Europe with ship fouling during the first world war. Dense brackish water populations were first noticed at London harbour and in a canal of northern France (Zibrowius and Thorp, 1990). A few years after its description *F. enigmaticus* invaded suitable biota in the Mediterranean where it is now wide-spread in coastal lagoons and estuaries. Its apparition in San Francisco Bay at the close of the first world war, as evidenced by local newspaper accounts (Carlton, 1975), was about contemporary with its apparition in Europe. Fauvel's hypothesis of an Indian/Indonesian origin can be ruled out : other species of *Ficopomatus*, but not *F. enigmaticus*, exist in that area (Hove and Weerdenburg,1978). The origin from a subtropical to temperate area, eventually southern Australia, appears more likely (Zibrowius, 1978, 1983b).

The Spirorbidae ***Spirorbis marioni*** Caullery and Mesnil, 1897, and ***Pileolaria berkeleyana*** (Rioja, 1942) have originally been described from the eastern Pacific (Panama and Mexico). In 1979 both species were discovered on stones in a harbour at Marseille where they did not exist some years before. Investigations of harbours and adjacents areas motivated by this discovery and conducted for several years showed that the two alien species were differently distributed in the Mediterranean (Zibrowius and Bianchi, 1981 ; Zibrowius, 1983a, 1983b). *P. berkeleyana* was found limited to harbours in the Marseille area sensu lato (from the Gulf of Fos in the west to Les Lecques in the east) whereas *S. marioni* was already wide-spread, from Morocco through Spain and France to Italy (southern limit of explorations at Monte Argentario promontory), including Elba, Corsica and Sardinia. Both species frequently occur in dense populations. It was also found that *S. marioni* and *P. berkeleyana* had been present in the Marseille area, and *S. marioni* at Genova, as early as 1977. Both spirorbids are able to spread from harbour to harbour by ship navigation since many of the investigated harbours shelter mainly small sailing and motor boats that do not travel far. *S. marioni* appears to have better spreading

abilities, but the previously studied coasts should be checked again in order to see whether *P. berkeleyana* has extended its area.

In 1987 *S. marioni* has also been found in Izmir Bay and elsewhere on the Turkish coast of the Aegean Sea, always in harbour areas (Knight-Jones et al., 1991). It would be of interest to extend these investigations in view of alien spirorbids to other parts of the Mediterranean.

COPEPODA

In its native area, the Japanese oyster *Crassostrea gigas* is parasitized by ***Mytilicola orientalis*** Mori, 1935, and ***Myicola ostreae*** Hoshina and Sugiura, 1953. Both copepod species have negligently been introduced, together with their host, to the oyster parks of the Atlantic coast of France and of Etang de Thau, a Mediterranean coastal lagoon. In Etang de Thau they were observed for the first time in 1979 and 1980 (ISTPM, 1977 ; His, 1979 ; Pollio, 1981 ; ICES, 1982 ; Clanzig, 1989). Both species are able to settle on other host species.

Por (1978) listed 10 benthic and planktonic species as high-probability and 2 species as low-probability lessepsian migrants. Updating remarks taking into account more recent publications are found in Por (1989, 1990). Indo-Pacific immigrants among the planktonic copepods are also summarily mentioned by Lakkis (1990a, 1990b).

CIRRIPEDIA BALANOMORPHA

Balanomorph barnacles are usually well represented in fouling communities on ship hulls and harbour structures, both in marine and brackish waters (Southward and Crisp, 1963 ; Relini and Montanari, 1973). Species that are particularly resistent to low salinities and various aspects of pollution are more likely to settle from harbour to harbour. The literature on balanomorphs in harbour and fouling communities is abundant and contains many indications on wide to cosmopolitan or disjunct distribution (see Carlton, 1975b) and the recent spreading of various species. But as in other groups, the native area of these species often remains, at best, conjectural. *Balanus* species have also been found as fellow-travellers on imported exotic oysters, as reported by Gruet et al. (1976) for the Atlantic coast of France.

The presence of the exotic ***Balanus reticulatus*** Utinomi, 1967 (det. A.J. Southward) in the fouling community sampled at Toulon harbour (14.12.1977) from a ship arriving from the Indian Ocean via the Suez Canal (see Zibrowius, 1979), once more illustrates that navigation may be a factor of introduction.

It is noteworthy that ***Elminius modestus*** Darwin, 1854 (see Southward and Crisp,1963) did not yet colonize Mediterranean. This alien of temperate Australian and New Zealand origin proved most successful along the western European coasts (Denmark to Portugal), starting from England where it arrived during the second world war. As expressed repeatedly (e. g. Relini and Montanari, 1973), further spreading can be expected.

CIRRIPEDIA RHIZOCEPHALA

Boschma (1972) summarized information on introduction of this group of parasites together with their host crabs. From the record of a rhizocephalan on *Callinectes sapidus* Rathbun, 1896, in the Aegean Sea (Kinzelbach, 1965), he deduced that ***Loxothylacus texanus*** Boschma, 1933, had followed its host species from the Atlantic coast of North America into the Mediterranean (to be verified).

STOMATOPODA

Oratosquilla massavensis (Kossmann, 1880), a lessepsian migrant, is now abundant from Egypt to Turkey and has locally economic importance for fisheries (Por, 1978 ; Lewinsohn and Manning, 1980 ; Kokataş, 1981 ; Tom and Galil, 1991).

Contrary to erroneous old records, another Indo-Pacific stomatopod, ***Gonodactylus falcatus*** (Forsskål, 1775), is not established in the southeastern Mediterranean (Manning, 1977 ; Por, 1978 ; Lewinsohn and Manning, 1980 ; R.B. Manning, pers. com. 1991).

DECAPODA

Being a "popular" group, decapods arriving in new areas, especially when establishing reproducing populations, have always special attention. Crabs are quite often found on ship hulls ; e. g. Catta (1876), Bertelsen and Ussing (1936), Boschma (1972) and Holthuis and Gottlieb (1958) quoted various cases of exotic species accidentally transported to European waters, but unable to settle. Pesta (1918) listed a few exotic species of Decapoda previously reported from the Adriatic Sea. In his opinion these were likely to include two categories : erratic individuals that had been transported to the Adriatic on ship hulls, and specimens inverted and mislabelled in museum collections. Other means of transport discussed in the literature include ballast water tanks and oyster transfers (Carlton, 1975, 1979).

A more modern version of travelling is by drilling platform. Relini Orsi and Mori (1979) found an ovigerous female of the wide-spread Indo-Pacific portunid crab ***Thalamita gloriensis*** Crosnier, 1972, among the "rich tropical fauna" of a plateform towed to Genova harbour from the Indian Ocean via the Suez canal. They also reported an ovigerous female of *T. gloriensis* from a rock pool on the west coast of Sardinia, and predicted the further spread of the species that appears able to settle in new environments.

The native area of the portunid crab ***Callinectes sapidus*** Rathbun, 1896, is the western Atlantic where it is commercially fished (Blue Crab) along the coast of North America. Its first record from Europe was from Rochefort harbour in the Bay of Biscay (Bouvier,1901), but only much later additional records became known from various areas on the Atlantic coasts, the Mediterranean and the Black Sea. The main records are given here arranged in geographical order : Denmark (Wolff, 1954 : Copenhagen), Germany (Kühl, 1965 : Elbe estuary), the Netherlands (Hartog and Holthuis, 1951 ; Holthuis and Gottlieb, 1955 ; ICES, 1983), Bay of Biscay (Amanieu and Le Dantec, 1961 : Gironde estuary), Portugal (Gaudêncio and Guerra, 1979 : Tejo estuary), Ligurian Sea (Tortonese, 1965 : Genova, La Spezia), Sicily (Cavaliere and Berdar, 1977 ; previous

records by Ghisotti, 1966, and Torchio, 1967, were mistaken and referable to *Portunus pelagicus*, see Torchio, 1968, and Ariani and Serra, 1969), Malta (Schembri and Lanfranco, 1984), Adriatic (Giordani Soika, 1951, erroneously under *Neptunus pelagicus*; identification revised by Holthuis and Gottlieb, 1955; see also Froglia, 1972, and Stevčić, 1990), Aegean Sea (Kinzelbach, 1965; Georgiadis and Georgiadis 1974), south coast of Turkey (Kokataş, and Katagan, 1983), Cyprus (Lewinsohn and Holthuis, 1986), Lebanon (Shiber, 1981), Israel (Holthuis and Gottlieb, 1955; Snovsky and Galil, 1990), Egypt (Banoub, 1963; Ramadan and Dowidar, 1976; Abdel-Razek, 1987), Sea of Marmora (Georgiadis and Georgiadis, 1974; Müller, 1986: Istanbul fishmarket), Black Sea (Monin, 1984). It is noteworthy that *C. sapidus*, which proved to be a successful colonizer of the Mediterranean and locally of economic importance, also settled in Japan (Williams, 1984).

In the Aegean Sea, *C. sapidus* has been found infested with a rhizocephalan parasite (Kinzelbach, 1965). Without the opportunity of verifying, Boschma (1972) presumed that this was *Loxothylacus texanus* Boschma, 1933, known from the American Blue Crab populations.

The portunid crab ***Necora puber*** (Linnaeus,1767), formerly known as *Macropipus puber* and common on the Atlantic coasts of Europe, was said to be rare in the Mediterrranean since imprecisely reported from only a few localities (review by Holthuis, 1987). But Zariquiey Alvarez (1968) also stated that it was frequent in the mussel parks of Barcelona that received mussels from Galicia, northwestern Spain. In the Marseille area where the species had been rarely noticed before, it became abundant by the end of the 1970s, especially at the Fos oil terminal and on the jetty of the electric plant of Martigues-Ponteau, at the entrance of Gulf of Fos (the neotype selected by Holthuis, 1987, comes from that locality). The populations possibly originated from ship-borne specimens. The occasional (?) presence of *N. puber* near Athens (Holthuis and Gottlieb, 1958) may be due to the same type of introduction.

The freshwater grapsid crab ***Eriocheir sinensis*** H. Milne Edwards, 1854, migrates to the estuaries for reproduction. Native of China, it has been found in Europe for the first time in 1912 in a river of northern Germany. It probably had arrived with ballast water in a harbour of the North Sea. *E. sinensis* subsequently invaded northern Europe to the east (Finland) and to the west (France) and locally became very abundant (Peters, 1933; Peters and Panning, 1933; Hoestland, 1948; Elton, 1958). By following an artificial waterway (Canal du Midi) the crab appeared in southern France and invaded the Languedoc lagoons (first captured in 1959, many captures from 1967 and 1968; Petit, 1960; Petit and Mizoule, 1974).

A typical northeastern Atlantic species, the cancrid crab ***Cancer pagurus*** Linnaeus, 1758, has occasionally been reported from the Mediterranean, including in the older literature: Olivi's (1792: pl. 1) precise illustration of a large specimen from Venice (as *Cancer fimbriatus*; "found only once, erring in the Lido harbour") excludes any doubts on its identity. L. B. Holthuis (pers. com. 1990) also considers authentic a record from Livorno in 1828 (specimen in the Leiden museum, with the collector's detailed account of the locality).

Zariquiey Alvarez (1968) summarily referred to early records from Greece, Naples and Marseille. The record from Greece (Peloponnese) by Guérin-Méneville (1832; quoted by Holthuis and Gottlieb, 1955) may be confused since *C. pagurus* is said to occur "every where, but to be less common than on our [i.e. the French] coasts". As for Naples, Costa (1838) did not report it from there even though he included it in the Fauna del Regno di Napoli. Since the kingdom of Naples reached the [southern] Adriatic, Costa referred to Olivi's (1792) record from the [northern] Adriatic, stating that *C. pagurus* had not yet been seen on the "Mediterranean" [i.e. Tyrrhenian] coast. This contrasts with the precise record from Marseille by Gourret (1888): from the entrance to the harbour and from a locality close to the harbour (most likely accidental and isolated introductions, see below).

Pesta (1918) admitted that *C. pagurus* naturally occurs in the Adriatic as a very rare species. References compiled by Pesta include Heller (1863) and Graeffe (1900). Heller had no original data and vaguely referred to the literature for previous records (Venice, but also Genova, Naples, and Greece); his vague indication on the occurrence "in greater depth at the Venitian coast" may be a very liberal interpretation of Olivi's (1792) precise indication. Original information by Graeffe (1900) appears reliable: a specimen obtained at Trieste from local fishermen has been kept in the aquarium of the Zoological Station for more than one year. Stevčić (1985, 1990) also knew about old records of *C. pagurus* from the Adriatic but referred to Marchesetti (1882), who had expressed a doubt about its natural occurrence, presuming that specimens on the fish market had been imported from the North Sea. However, Stevčić (1985) was able to report the capture near Rovinj (in 1982) of a large male. This appeared to indicate that *C. pagurus* occurs, though very rarely, in the Adriatic, but a doubt subsisted, the species being again imported for the Italian market. And so it is elsewhere, e.g. on the Mediterranean coast of France. Zariquiey Alvarez (1968) indicated that he had never found *C. pagurus* in the Mediterranean ("very rare"), except for the fact that it was commonly imported to Barcelona from Galicia, northwestern Spain.

Being a sturdy species, *C. pagurus* is likely to survive in the Mediterranean when discarded from the market and returned to the sea. Should successful reproduction be possible on the basis of a small starting population, *C. pagurus* might be able to resettle in the Mediterranean where it was established in the Pleistocene (Berdar and Guglielmo, 1979).

The grapsid crab ***Pachygrapsus transversus*** (Gibbes, 1850), wide-spread in lower latitudes of the western and eastern Atlantic, also occurs along the coast of North Africa and in the southeastern Mediterranean (Manning and Holthuis, 1981). Previously, in the absence of records from North Africa, uncertainty existed as to whether its eastern Mediterranean range was connected with the West African, or found its origin in an accidental introduction (Holthuis and Gottlieb, 1958). Anyway, this species is known to tolerate accidental transportation. It was described by Catta (1876) as a new species, *Pachygrapsus advenus*, on the basis of a population found on the hull of a ship that arrived at Marseille from India (Pondichery) via the Cape of Good Hope. Catta's inventory of the fouling community also included additional species of crabs, isopods, amphipods, cirripedia and green algae.

The importance of the Suez canal as an artificial passageway for the immigration of Indo-Pacific decapods is

evident from the lists compiled by Holthuis and Gottlieb (1958) and Por (1978). Por listed 23 species as high-probability and 8 species as low-probability lessepsian migrants. About 10 more lessepsian migrants have been added subsequently (Ramadan and Dowidar, 1976 ; Abdel-Razek et al., 1981 ; Shiber, 1981 ; Almaça, 1985 ; Galil, 1986, 1989, 1990 ; Galil et al., 1989 ; Galil and Golani, 1990). Por (1989) considered decapods as one of the "leading" groups of lessepsian migration.

The portunid crab ***Portunus pelagicus*** (Linnaeus,1758) of the Red Sea and Indo-Pacific was the first lessepsian migrant to be noticed in the Mediterranean after the opening of the Suez canal (Por, 1978). This species is now widely distributed in the eastern basin (Holthuis and Gottlieb, 1955 ; Ramadan and Dowidar, 1976 ; Lewinsohn and Manning, 1980 ; Lewinsohn and Holthuis, 1986 ; Shiber, 1981 ; Galil, 1986, 1989 ; Abdel-Razak, 1987 ; Halim, 1990) and has locally become of economic importance (especially in Egypt), being the dominant crab in commercial catches all around the eastern Mediterranean. Progressing westward, it attained Sicily (abundant in the Siracusa area) where it is commercially fished (Ariani and Serra, 1969 ; Lewinsohn and Manning, 1980). First records from Sicily had mistakenly been referred, by Ghisotti (1966) and Torchio (1967), to *Callinectes sapidus,* another alien portunid (identification revised by Torchio, 1968, and Ariani and Serra, 1969).

Lessepsian migrants include penaeid shrimps like ***Penaeus japonicus*** Bate, 1888, that are commercially fished in the eastern Mediterranean (Dowidar and Ramadan, 1976 ; Galil, 1986, 1989 ; Spanier and Galil, 1991). As reported by Lumare and Casalino (1986) and listed by Stevčić (1990), *P. japonicus* has been caught on the Adriatic coast of Italy. It is uncertain whether this occurrence was due to a natural progressive extension of its area from the earlier colonized southeastern Mediterranean (including Cyprus ; Lewinsohn and Holthuis, 1986), or resulted from restocking trials in Adriatic lagoons and sowing in the open sea. In fact, *P. japonicus* is now widely farmed, and this artificial distribution may give rise locally to new populations in the sea. Larvae have been released, e.g. in the lagoons of Languedoc, France (ICES, 1983).

In the Gulf of Naples a shrimp had been identified (Caroli, 1947), by error, as ***Processa aequimana*** (Paulson, 1875) and considered as an immigrant from the Red Sea. *P. aequimana* has further been reported from the North Sea (larval stages) and considered as a recent importation with ballast water (Rees and Cattley, 1949 ; Rees, 1955). The presumed immigrant has later been referred to *Processa parva* Holthuis,1951, distinct from the Red Sea species (Nouvel and Holthuis, 1957 ; Zariquiey Alvarez, 1968). Finally, the use of the name *P. parva* was restricted to the west African region and the NE Atlantic-Mediterranean populations were described as a new species, *Processa modica* Williamson, 1979, with two subspecies, *P. modica modica* along the Atlantic coasts of Europe, and *P. modica carolii* in the Mediterranean. Por (1978) apparently did not know about this species mistakenly considered as a migrant of Red Sea origin.

CUMACEA

Por (1978) listed 2 species as low-probability lessepsian migrants.

TANAIDACEA

The wide distribution of ***Leptochelia dubia*** (Krøyer, 1842), subtropical-cosmopolitan according to Miller (1968) and also present in the Mediterranean, may be due to spreading by means of ship navigation.

Por (1978) listed one species as high-probability and one species as low-probability lessepsian migrants.

ISOPODA

For evident reasons, wood-boring species of the genus ***Limnoria*** have had early and more attention than other isopods candidates for transportation by human activities (Andrè and Lamy, 1933). But it is no longer possible to define the native area of subsequently wide-spread species, some of them present in the Mediterranean.

Sphaeroma walkeri Stebbing, 1905, appears to have its origin in the northern Indian Ocean from where navigation has taken it to harbour and fouling communities elsewhere in warm seas, including to California (Carlton and Iverson, 1981), Hong Kong (Mak et al., 1985) and the southeastern Mediterranean. Additional new records of *S. walkeri* (identified by D.M. Holdich, pers. com. 1986) are from a fouling community sampled at Toulon harbour (14.12.1977) from a ship arriving from the Indian Ocean via the Suez canal (see Zibrowius, 1979), from Alicante harbour (H.Z., 4.4.1981), and from Tanger harbour (H.Z., 13.6.1982), just west of the Straits of Gibraltar (the two latter records published by Jacobs, 1987). *S. walkeri* may now be more widely established in harbour communities of the Mediterranean.

Originally described from California, ***Paracerceis sculpta*** (Holmes, 1904) has been found elsewhere in the tropical Pacific and Atlantic, trans-oceanic shipping being the likely vector (Harison and Holdich, 1982a). It has also been recorded from the Lake of Tunis (Rezig, 1978) and the lagoon of Venice (Sacchi et al., 1983, 1985, 1989 ; Forniz and Sconfietti, 1985) and could be a recent addition to the Mediterranean fauna. Additional new records (identified by D.M. Holdich, pers. com. 1986 ; published by Jacobs, 1987) are from Alicante harbour (H.Z., 4.4.1981) and from Tanger harbour (H.Z., 13.6.1982). *P. sculpta* may now be more widely established in harbour communities of the Mediterranean.

The sphaeromatid ***Paradella dianae*** (Menzies, 1962), originally described from Baja California and subsequently reported from California, the Marshall Islands, Queensland, West Australia, the Arabian Sea, Brazil and Puerto Rico (Harrison and Holdich, 1982b), was recorded for the first time in the Mediterranean from Alexandria, Egypt, associated with superficial algae (Atta, 1991). It may have arrived with ship fouling. Harrison and Holdich (1982b : 105) found it "noteworthy that in Australia it has been found only near international ports, often amongst sessile organisms belonging to groups commonly found attached to ship's hulls".

Por (1978) listed one species of isopod as a low-probability lessepsian migrant.

AMPHIPODA

It is commonly admitted that navigation and oyster transports contributed to the present wide distribution of

various amphipod species. Carlton (1975, 1979) listed about 15 species as recent additions to the Californian fauna. Especially wood borers of the genus ***Chelura*** and tubicolous species of the genus ***Corophium*** (well represented in lagoon and harbour environments) appear to have spread world-wide thanks to human activities. The aspect of additions to the Mediterranean fauna has not yet been widely taken into account, although it is occasionally suggested (Taramelli and Scipione, 1977 ; Diviacco and Relini, 1981).

Elasmopus pectenicrus (Bate,1862), previously known in the Mediterranean only from near the Suez canal (coast of Israel and Egypt) and considered by Por (1978) as a low-probability lessepsian migrant, has subsequently been found established in the lagoon of Venice. Known from the Red Sea and the Indian Ocean, it is likely to have attained the northern Adriatic as a ship-borne species (Morri et al., 1982 ; Sconfietti, 1983 ; Sacchi et al., 1983, 1985, 1989).

Por (1978) listed 2 species (one being *Elasmopus pectenicrus)* as low-probability lessepsian migrants.

PANTOPODA

The Indo-Pacific ***Ammothea hilgendorfi*** (Böhm, 1879), found established in the lagoon of Venice, appears to be a recent addition to the Mediterranean fauna, probably introduced by ship transport (Morri et al., 1982 ; Krapp and Sconfietti, 1983 ; Sacchi et al., 1983, 1985, 1989). It has now also been found in the Solent area, southern England (Bamber, 1986).

Por (1978) considered ***Anoplodactylus digitatus*** (Böhm, 1879) [= *A. saxatilis* Calman, 1923] from the Mediterranean coast of Israel as a high-probability lessepsian migrant. According to Stock (1965, 1968) this wide-spread Indo-Pacific species also occurs in the Antilles.

BRYOZOA

Various species of bryozoans are part of the Mediterranean harbour fouling communities (see Powell, 1969 ; Agius et al., 1977 ; Occhipinti Ambrogi, 1981). Some are said to be of cosmopolitan distribution, and this may in part be due to navigation (Ryland, 1965, 1967). ***Tricellaria inopinata*** Hondt and Occhipinti Ambrogi, 1985, described from the previously well investigated lagoon of Venice where it is actively spreading (Occhipinti Ambrogi, 1991), may indeed be a recent newcomer from an unknown origin. Alien bryozoans imported together with exotic oysters have been reported from the Atlantic coast of France (Gruet et al., 1976 ; Hondt, 1984). No similar cases have yet been formally recognized in the Mediterranean, even though Agius et al. (1977) found two species of ***Celleporaria,*** apparently unrecorded from the Mediterranean, on oyster cultures in Maltese waters.

In the southeastern Mediterranean, Por (1978) considered 4 species as high probability and 3 species as low-probability lessepsian migrants (mainly after Powell, 1969). But it should be remembered that some of these are known from harbour and ship fouling communities throughout warm seas in general, and not specifically from the Red Sea and Indo-Pacific. Accordingly, species like ***Hippopodina feejeensis*** (Busk, 1884) could have arrived in the southeastern Mediterranean by navigation.

Surprisingly, Hondt's (1988) study of bryozoans from the coasts of Israel (Red Sea and Mediterranean) does not refer to lessepsian migration or other ways of arrival, although the presence of ***Watersipora subtorquata*** (Orbigny, 1852) is confirmed for the Mediterranean.

CHAETOGNATHA

In the Mediterranean this mainly planktonic group appeared to include an alien species, ***Sagitta neglecta*** Aida, 1897, reported from Alexandria, Egypt, on the basis of an unique specimen (Guerguess and Halim, 1973). While Por (1990) and Halim (1990) inclined to accept it as a lessepsian migrant, J.P. Casanova (1990) did not comment on the case in his study of Red Sea chaetognaths, but now indicated (pers. com. 1991) that the illustrations of the Alexandria specimen suggest an incorrect identification.

ECHINODERMATA

In general, human activities appear to have had comparatively litlle impact on the distribution of echinoderms. In the Mediterranean alien species have been reported only from the Levantine area. One asteroid and one ophiuroid were considered by Por (1978) as high-probability, and one ophiuroid as low-probability lessepsian migrants. In fact, the asteroid reported as ***Asterina wega*** Perrier,1875, or ***A. burtoni*** Gray, 1840 (see Tortonese, 1966 ; Achituv, 1969, 1973 ; Achituv and Sheer, 1991) appears to have spread rapidly and to have locally replaced the indigenous, ecologically similar *Asterina gibbosa* (Pennant, 1777). There are now at least two ophiuroids of Red Sea origin well established on the coast of Israel : ***Ophiactis savignyi*** Müller and Troschel, 1842, and ***Ophiactis parva*** Mortensen, 1926 (dense populations reported from Haifa Bay by Tom and Galil, 1991).

Tortonese (1947) reported the Red Sea holothurian ***Synaptula reciprocans*** (Forsskål, 1775) from Lake Timsah, Suez Canal (observed in 1944/45). Cherbonnier (1986) found it in the Mediterranean (Israel, Cyprus), but did not allude to lessepsian migration, although this would be the most likely explanation of the apparent distribution extension.

ENTEROPNEUSTA

Saccoglossus guernei Robinson 1927, described from the Suez Canal (type locality) and subsequently reported from the Mediterranean coast of Egypt near Alexandria (problematic identification), was considered by Por (1978) as a low-probability lessepsian migrant. In fact, this unconfirmed case in a rarely studied group needs to be carefully verified.

ASCIDIACEA

Navigation has efficiently contributed to the (world-) wide distribution, Mediterranean included, that now characterizes various species of ascidians that also, or mainly, are known from harbour and ship fouling communities (Millar, 1969 ; Monniot, 1981 ; Monniot and Monniot, 1983 ; Monniot et al., 1985). Generally, their spreading from an area of origin can no longer be traced.

Nevertheless some appear rather recent additions to the Mediterranean fauna. Ascidians have also been transferred together with oysters (examples of the arrival on the Atlantic coast of France in Gruet et al.,1976).

The circumtropical and Mediterranean distribution of ***Microcosmus exasperatus*** Heller, 1878, has been summarized by Monniot (1981). In the Mediterranean *M. exasperatus* is known since 1963 as a species related to navigation, present mainly in harbours and neighbouring areas. To the localities already listed by Monniot (Nice, Vado Ligure, Savona, Porto Vecchio bay in Corsica, Taranto, Bizerte) the following localities can be added : Le Lavandou, Saint-Raphaël, Cannes (new records in 1982, C. Monniot, pers. com. 1983) ; Porto Maurizio of Imperia (H.Z. 31.5.1981) ; Magra estuary near la Spezia (Covre et al., 1989) ; Nador on the Mediterranean coast of Morocco. The tug "Choroub" examined (H.Z. 13.6.1982) in Tanger harbour where it had been transferred to from Nador, was found heavily fouled by *M. exasperatus*, whereas elsewhere in Tanger harbour the species had not yet settled. It is also locally abundant on the Mediterranean coast of Spain (Turon, 1987, 1990 ; Ramos, 1988 ; Ramos et al., 1991).

Originally described from the eastern Pacific (Peru) and also reported from Brazil (Millar, 1958), ***Polyandrocarpa zorritensis*** (Van Name, 1931) was found in the Mediterranean for the first time in La Spezia harbour (Brunetti, 1981) where it appears to be a recent addition due to navigation.

There is no observation of ascidians being introduced into the Mediterranean together with oysters. But it should be remembered that originally *Crassostrea gigas* had been imported straight from Japan to Etang de Thau, France, under conditions similar to those of importations to the Atlantice coast. On its arrival on the Atlantic coast the Japanese oyster was found to carry several species of ascidians (Gruet el al., 1976).

Mainly referring to Pérès (1958), Por (1978) listed 4 species as high-probability and 3 species as low-probability lessepsian migrants. Included in the list are species of wide, essentially tropical distribution and others of problematic identification. The list thus provides an inexact impression of lessepsian migration among ascidians. ***Ascidia cannelata*** Oken, 1820, may be the only true lessepsian migrant in the list (C. Monniot, pers. com. 1990).

PISCES

Fishes among the lessepsian migrants have always received great attention (Kaspiris, 1976 ; Ben-Tuvia,1978, 1985 ; Ben-Tuvia and Golani, 1989 ; Golani and Ben-Tuvia, 1989, 1990 ; Golani, 1990 ; Por, 1878, 1989,1990 ; Goren and Galil, 1990 ; Papaconstantinou, 1990 ; Golani and Diamant, 1991 ; Tsimenides et al., 1991).

The arrival of many Red Sea species has had a great impact on the composition of the southeastern Mediterranean fish fauna. Ben-Tuvia (1978) listed 36 immigrant species and studied the decrease of number of species away from the most influenced coasts of Israel and Lebanon. Some species had already reached the Aegean Sea, the Gulf of Taranto, and Tunisia, whereas only two successful immigrant species have been found on the Cretan shelf during a survey of demersal fishes in 1988-1990 (Tsimenides et al., 1991). Ben-Tuvia (1985) recognized 41 immigrant species, out of a total of about 310 species known in the Levantine area. According to Por's (1990) census, 44 species have arrived, representing not less than 14 families previously unknown in the Mediterranean. Fredj (1989 ; see also Fredj and Meinardi, 1989) admited 45 species as lessepsian migrants [more recent publications slightly increased this number], i. e. 7 % of the 648 fish species known from the Mediterranean and about 10 % of the 469 species reported from the eastern basin. Some of these newcomers now form dense populations and are important in commercial catches (Spanier and Galil, 1991).

CONCLUSION

Man's impact on the composition of the Mediterranean marine fauna and flora is related to three main activities : navigation caused the arrival, probably over several centuries, of species of various origins ; opening the sealevel Suez canal in 1869 produced a passageway for progressive invasion by species from the Red Sea ; commercial shellfish movements and intentional introductions (especially of *Crassostrea gigas* since the late 1960s) contributed to accidental introductions, including that of oyster nuisances. Colonizing by alien species is proportianally more important in harbour, estuarine and other brackish environments throughout the Mediterranean, and in the near-shore environments of the southeastern basin. These types of environments diverge from more standard conditions in the western Mediterranean. Under the special abiotic and biotic conditions, including a less diversified fauna of North Atlantic affinities, potential invaders proved particularly successful in establishing reproducing populations. These newcomers are now integrated into Mediterranean ecosystems, the original state of which will be difficult to know in many cases. Various alien species acquired negative economic importance by fouling harbour structures, ship hulls, cooling systems, and oyster parks. Others are main commercially fished species in the southeastern Mediterranean (lessepsian migrants among fishes and shrimps). Being main commercial species also implies being main consumers in the food web and competing successfully with indigenous species.

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AVRIL 1992