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Fulvia fragilis (Bivalvia: Cardiidae): a lessepsian mollusc species from Izmir Bay (Aegean Sea)

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During studies performed on the ecological conditions of Izmir Bay and its biota, a population of *Fulvia fragilis* was observed to have recently colonized the bay. In this study, some comments are provided on the anatomical, ecological, taxonomical and distributional aspects of the species, which was first encountered during late 2001 in Izmir Bay.

INTRODUCTION

The Mediterranean Sea includes roughly a total of 8500 species of macroscopic organisms, which indicates a rich biodiversity if it is considered that the Mediterranean comprises less than 1% in surface area and volume as compared with the world oceans (Bianchi & Morri, 2000). This high biodiversity of the Mediterranean may be first explained by its geological history (Maldonado, 1985; Ruffel, 1997), and the conspicuous ecological and hydrological differences in various localities (Sarà, 1985). On the other hand, lessepsian (Red Sea immigrant) species that enter the Mediterranean Sea via the Suez Canal is another important factor contributing to local species composition, especially within the second half of the last century. According to Zibrowius (1991), causes for arrival of an alien species into a new habitat are diverse. The most prominent causes include natural range expansion (step by step); intentional introduction of species in view of commercial use [for example, introduction of *Ruditapes philippinarum* (Adams & Reeve, 1850) to the Venice Lagoon (northern Adriatic Sea) for aquaculture purposes] and transport of sessile and vagile species on ship hulls or with ballast water of ships. According to Eno et al. (1997), another important source of non-indigenous forms is provided by unintentional introductions associated with imported commercial species [for example, the introduction of the asiatic mytilid *Musculista senhousia* (Benson in Cantor, 1842) with the cupped-oyster *Crassostrea gigas* (Thunberg, 1793) in widely scattered areas of the world (Poutiers, 1998), including coastal lagoons of the north-western Mediterranean (Hoenselaar & Hoenselaar, 1989)]. The impact of a non-indigenous species introduced to an ecosystem for any reason includes restructuring established food webs, importing new diseases and competing with native organisms for food and space. In addition, they may cause variations in the gene pools of native forms via reproduction (Por, 1978; Galil & Lützen, 1998).

The low biodiversity of an ecosystem positively affects the establishment success of an introduced species (Boudouresque, 1994; Ribera, 1994). The oligotrophic nature of the eastern Mediterranean Sea, which is due primarily to various reasons that occurred during ancient geological times, and its low biological diversity motivates the establishment of non-indigenous organisms to the region and further extension of their distribution ranges (Boudouresque & Ribera, 1994). The Red Sea immigrant species constitute 5% of the Mediterranean fauna (Fredj & Meinardi, 1989; Zibrowius, 1991), with molluscs comprising the largest proportion. According to a recent study (Öztürk et al., 2002), lessepsian mollusc fauna of the Mediterranean includes 117 species, which belong to classes of Gastropoda (73 sp.), Bivalvia (41 sp.), Cephalopoda (2 sp.) and Polyplacophora (1 sp.). These species comprise approximately 8% of the total Mediterranean mollusc fauna. However, it should be noted that some species are considered questionable lessepsian species, since Mediterranean records of those molluscs are based on a few empty shells or since their occurrence in the Mediterranean is doubtfully related to an inclusion via the Suez Canal.

Although the majority of the lessepsian molluscs inhabit only their core distribution area, the Levant Basin, some have expanded their distribution range after a successful adaptation in the Levant. For example, *Cerithium scabridum* Philippi, 1848; *Pyrunculus fourierii* (Audouin, 1826); *Brachidontes pharaonis* (Fischer, P., 1870) and *Pinctada radiata* (Leach, 1814) are some of the species that adapted to different ecological conditions of the Aegean Sea (see Öztürk et al., 2002). Most recently, *Fulvia fragilis* (Forsskål, 1775) can be added to them.

The genus *Fulvia* is represented by two species in the Mediterranean Sea. *Fulvia australis* (Sowerby, G.B. II, 1834) is a rare species, hitherto reported only by Haas (1948: 142) and Barash & Danin (1972: 338) from the Israeli coasts. *Fulvia fragilis* is a relatively more abundant species in the Mediterranean.

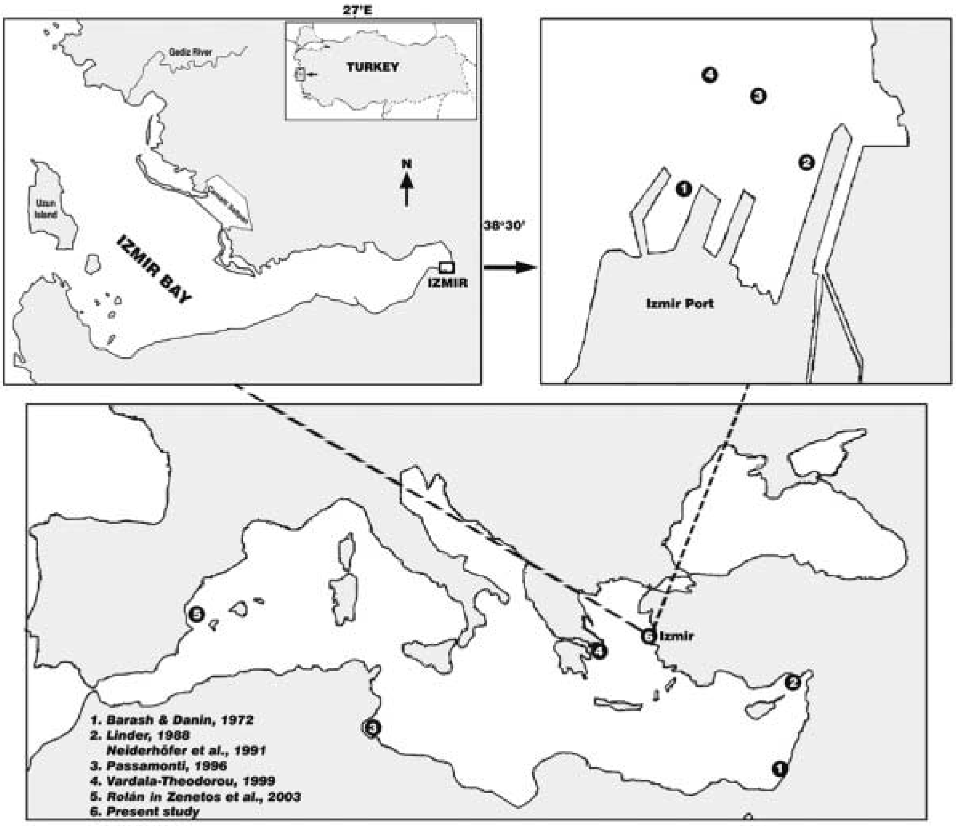

Figure 1. Map of the study area with location of sampling sites and distribution of the species in Mediterranean Sea.

The present study provides a new locality for *F. fragilis* and additional information on the species.

MATERIALS AND METHODS

Fulvia fragilis specimens were sampled for the first time in Izmir Bay on board the RV 'K. Piri Reis' at Station 4a in December 2001, within the framework of the project DBTE-134 (Figure 1). Several additional specimens of the species were then collected by the RV 'Hippocampus' in September 2002 and May 2003, during field works with different purposes. The muddy bottom was sampled by a Van Veen Grab, capturing a volume of almost 10 dm^3, and beam trawl. Some physical and chemical characteristics such as temperature, pH, dissolved oxygen and salinity were also measured at Stations 1 and 3. Material collected was washed through a sieve with 0.5-mm mesh size and fixed in 4% formalin. The samples were sorted under a stereomicroscope in the laboratory. Morphological characters such as length, height and inflation of the shell were measured using callipers. The specimens are deposited in the Department of Hydrobiology (Ege University, Turkey).

SYSTEMATICS

Fulvia (*Fulvia*) *fragilis* (Forsskål, 1775)
(Figure 2A,B)

Cardium fragile Forsskål, 1775: XXXI.
Cardium papyraceum Gmelin, 1791: 3254.
Papyridea papyracea, Barash & Danin, 1972: 338–339, 362, figure 20; 1992: 275, figure 304.
Fulvia fragilis, Vidal, 1994: 102–103, plate 1 figure 6, plate 3 figure 1a–b.

Material examined

Station 1, project 03 SÜF 005, 01 July 2003, Van Veen Grab, 3 replicate, 27°C, dissolved oxygen 6 mg/l, salinity 35.39 psu, pH 8.38, 8 m, mud, 2 specimens. Largest specimen length 10.8 mm, height 10.7 mm, inflation 5.8 mm.

Station 2, project on pollution, 18 September 2002, Van Veen Grab, 6 m, mud, 2 specimens. Largest specimen: length 47.9 mm, height 47.4 mm, inflation 31.9 mm.

Station 3, project 03 SÜF 005, 01 July 2003, Van Veen Grab, 3 replicate, 27.5°C, dissolved oxygen 4.8 mg/l, salinity 37.73 psu, pH 8.41, 5 m, mud, 8 specimens. Mean dimensions of specimen 38.8 ±17.5 mm length, 38.3 ± 17.8 mm height, 25.2 ±11.3 mm inflation. Largest specimen

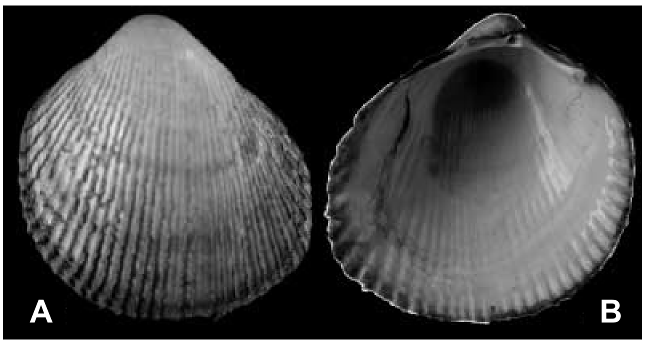

Figure 2. *Fulvia fragilis* (Forsskål, 1775), 54.9 mm length, 54.0 mm height and 34.8 mm inflation. (A) Left valve from the outside; (B) left valve from the inside.

observed in this study was sampled in this station: length 54.9 mm, height 54.0 mm, inflation 34.8 mm.

Station 4a, project DBTE-134, 22 December 2001, Van Veen Grab, 8 m, mud, 6 specimens. Mean dimensions of specimen 12.3 ±3.0 mm length, 10.9 ±2.9 mm height, 6.7 ±2.0 mm inflation.

Station 4b, project 03 SÜF 005, 02 July 2003, beam trawl (swept for a distance of 500 m), 6–10 m, mud, 812 specimens. Mean dimensions of 50 randomly selected specimens 17.2 ±10.4 mm length, 16.5 ±10.7 mm height, 10.5 ±7.0 mm inflation.

Description

Remark. In the following description, shell characters rely only on the sampled Izmir population.

Shell equivalve, variable in outline, almost subcircular in young specimens, ovate with posterior part more or less transversally or obliquely expanded in the adult (Figures 2 & 3). Umbones prosogyrate, prominent and closely approximate. Anterior and ventral margins rounded, posterior margin slightly truncate, particularly in adults. Lunular sector large and smooth, lunular heart variable but never large. External sculpture of 32–38 smooth and not prominent radial ribs with periostracal insertions arising from the rib crests in anterior and posterior parts of the shell and from the posterior margin of the ribs in middle part of the shell.

The periostracal insertions change into small tubercles or spines at the posterodorsal part near umbo. Ribs less marked in the earliest formed part of the shell. Shape of the ribs variable, rounded to sometimes triangular in the anterior part of valves, becoming progressively asymmetrically triangular and flatly rounded in the medial part, and more elevated and symmetrically triangular in the posterior part. Width of the ribs and interstices generally equal. Width of interstices of the first anterior ribs sometimes wider. Surface of the lunular area microscopically shagreened, giving a dull aspect somewhat obscured in larger specimens by densely set growth marks strengthened by periostracal folds. Posterodorsal margin of the outer surface smooth, larger on right valve and forming a low radial fold posteriorly overlapping the corresponding part of left valve. Microgranulations of the outer surface generally restricted to the anterior part of shell and mostly visible at juvenile stages. Granules rather sparsely set and easily rubbed off, only developed in a radial zone roughly covering the posterior part of lunular area and the two or three anteriormost rib interstices. Granulated zone generally extending ventrally to a distance of about 7 to 12 mm from the umbones, narrowing and disappearing ventralward. External ligament short and convexly swollen. Hinge characteristic of Cardiidae, with two cardinal teeth, and anterior and posterior lateral teeth in each valve. Hinge plate rather narrow and strongly bent (umbonal angle between cardinal and lateral teeth is lower than 130). Two subequal adductor muscle scars. Anterior pedal retractor scar well developed, extending rather high on the ventral surface of the lateral tooth, roughly elongate ovate in shape and distinctly narrowed close to the corresponding adductor scar. Posterior pedal retractor scar smaller, pointing toward the umbonal cavity and broadly connected with dorsal end of adductor muscle scar, often forming a branching expansion on the base of posterior lateral tooth. Pallial line rather broad, without a sinus. Internal margins with crenulations corresponding with the outer sculpture. Internal surface nearly smooth from umbones to midheight of valves, radially ribbed ventralward.

Figure 3. Colour variation in young specimens of *Fulvia fragilis*. Scale bar: 10 mm.

External colour of juvenile specimens beige to yellowish with darker and irregular zigzag concentric bands. Zigzag markings more or less prominent, depending on specimens (Figure 3). Ribs of some specimens sometimes yellow and light purple in rib interstices. Slim and long purple stains restricted to umbo or extending all over the dorsal part beginning from umbo. Interior yellowish in the young specimens, with outer colour markings also visible in the inner surface. Adults with a whitish to yellowish external colour, sometimes with a purple stain on the umbo. Interior of the adults white, except for posterior and dorsal parts of the shell which are purple in the umbonal cavity.

Anatomy

Animal markedly tinged in a brownish red wine colour, more strongly on foot and gills; coloration deepest on adductor muscles.

Foot strong, folded at right angle into a ventral, tapering anteriorward distal limb and a dorsal, subcylindrical limb (Figure 4). Distal limb elongate, laterally compressed, with more or less distinct lateral ridge near its anterior end. Ventral edge of distal limb rather sharp, bearing a fine ridge along its anterior half. Surface of the foot covered by a rather thick and strongly coloured cuticle, appearing somewhat paler and smoother anteriorly. An irregular pattern of darker transverse threads developed on the ventral half of the distal pedal limb. Posterior limit of the paler area forming on either side of the foot a V-shaped pattern pointing posteriorward and reaching a position below the front edge of dorsal pedal limb. Byssal apparatus with a narrow longitudinal slit on ventral ridge of foot, ending posteriorly in a trigonal hole bearing byssal thread (at least at young stage). Pedal elevator muscles well developed, inserting in each valve deep in the umbonal cavity.

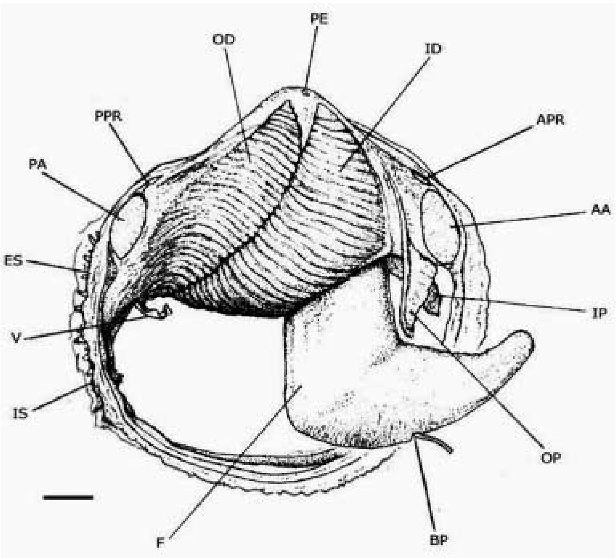

Figure 4. *Fulvia fragilis*, general anatomy of a specimen from the right side: AA, anterior adductor muscle; APR, anterior pedal retractor muscle; BP, byssal pore; ES, exhalent siphon; F, foot; ID, inner demibranch; IP, inner palp; IS, inhalent siphon; OD, outer demibranch; OP, outer palp; PA, posterior adductor muscle; PE, pedal elevator muscle; PPR, posterior pedal retractor muscle; V, valvule.

Strongly branching gonads visible on dorsal sides of visceral mass, between upper tip of outer demibranch and anterior adductor muscle. Gills of Cl type (Atkins, 1937), strongly plicate (outer demibranch with 37 folds and inner demibranch with 48 folds, on a 18.5 mm long specimen). Outer demibranch relatively large, dorsally diverging from inner demibranch. Food groove present on inner demibranch only. Anterior filaments of inner demibranch fused into a distal oral groove and forming a type II connection (Stasek, 1963) with labial palps. Anterior end of inner demibranch inserted between inner and outer palps. Outer surface of inner palp and inner surface of outer palp transversally ridged.

Mantle widely open in a large pedal gape, from just above dorsal tip of anterior adductor muscle to the base of inhalent siphon. Mantle lobes thin and translucent, moderately thickened at margins. Mantle margins slightly folded and expanded in accordance with radial grooves of inner shell surface, not papillate.

Siphons short, of A+ type (Yonge, 1982) with many tentacles of variable size (about 150 to 160 in number) on outer wall and surrounding pallial area; a small horizontal surface devoid of tentacles between the two siphons. Tentaculated area extending from lower half of adductor muscle height to a little beyond ventral margin of inhalent siphon. Tentacles tending to distribute in oblique radial sets around each siphon, and to reduce in size toward siphonal openings. Distal end of inhalent siphon with an additional ring of about 40 very small and delicate tentacles, alternatively larger and smaller; base of larger tentacles often with two dark spots near their base; two distinctly larger tentacles arise from both sides of the ventral end of siphon opening. Distal rim of exhalent siphon smooth. Internal siphonal valvule moderately large, extending on about half the length of posterior septum.

Comments

Since the 1970s, Izmir Bay has been influenced by pollution due to domestic and industrial wastes. Higher levels of pollution are encountered in the part called 'inner bay', and are connected with a seaport suitable for large-tonnaged ships and with a dense settlement in the vicinity. Especially from 1996 onward, several studies were carried out in order to determine effects of pollution on the local biota, mostly in seasonal field surveys within the frame work of the 'Izmir Bay Monitoring Project'. The waste-water treatment plant (WTP), which was constructed with the aim of refining domestic and industrial wastes, has started partial working during 2000 (now fully working) and constitutes a revolutionary enterprise in the history of Izmir Bay. Apparent positive changes in ecological conditions have started just after the construction of the WTP. The locality where *F. fragilis* was collected (Figure 1, shaded area) included, once only, pollution indicator species such as *Capitella capitata* and *Polydora ciliata* (Polychaeta); however, the ongoing positive modifications currently led to an increase in local biodiversity, and more than ten mollusc species re-settled the inner bay (e.g. *Cerastoderma glaucum*, *Corbula gibba*, *Abra alba* and *Scapharca demiri*).

Fulvia fragilis was first collected from Izmir Bay on 21 December 2001 at Station 4a. It seems highly probable that the species was transported to the bay and established during 2001. Recently, *F. fragilis* has both expanded its distribution area in the bay and has increased in density. For example, a total of 812 specimens of the species was collected at Station 4b, from a beam trawl hauled for a distance of 500 m.

Fulvia fragilis, as belonging to subgenus *Fulvia*, can be distinguished from the members of the subgenus *Laevifulvia*, by the presence of periostracal flanges on the ribs (Vidal, 1994). *Fulvia fragilis* was first described by Forsskål (1775: XXXI) as *Cardium fragile*. In later studies, the species was often misidentified and reported as *Cardium papyraceum*, *Papyridea papyracea* and *Laevicardium papyraceum* (Oliver, 1992: 123). Vidal (1994) contributed in solving this nomenclatural confusion and designated the shell figured by Yaron et al. (1986: 194, figure 42) as a neotype of *C. fragile*.

The only other member of the genus in the Mediterranean Sea is *Fulvia australis* (Sowerby, G.B. II, 1834), but its distribution is relatively limited, and it has been reported until now from the Israeli coasts only (Haas, 1948: 142; Barash & Danin, 1972: 338). We may consider that *F. fragilis* has more successfully adapted to different conditions of the Mediterranean than *F. australis*. The diagnostic differences between the two *Fulvia* species occurring in the Mediterranean was indicated in previous studies (Oliver, 1992; Vidal, 1994; Zenetos et al., 2003).

Although Vidal (1994) reported that the mean number of ribs in *F. fragilis* is 41 (range 34–52), the specimens we examined had a lower rib number, with a mean of 34 (range 31–38). This finding suggests that the number of ribs not only differs between specimens, but also according to geographical region where the species is distributed. The rib number of *F. fragilis* specimens in Izmir Bay is much more in accordance with the findings of Oliver (1992), who reported a range between 30–35 for Red Sea specimens, or with the rib counts (32–38) of the West African subspecies *F. fragilis congoensis* Cosel, 1995. Furthermore, in juvenile specimens of the Izmir population, no trace of periostracal fringe was found on the rounded posterodorsal margin of the right valve (the 'last fold' of Vidal, 1994), contrary to Vidal's claim that in this species, a periostracal insertion is present in the young stage in 50% of the specimens. This character shown by the Izmir population may represent only an ecophenotypical variation, or it may result from the development of a genetically isolated local population from a limited number of founder specimens.

Ecology

The species is known to inhabit fine soft substrates of sand, sandy mud, mud and sandy bottoms with *Zostera* sp. in the littoral region (Zenetos et al., 2003: 269), but additional detailed information on the ecology of *F. fragilis* in the Indian Ocean is scarce in previous literature. In tropical West Africa, it lives in muddy sand and fine sand, from just below low tide marks to about 10 m depths, mostly in calm bays and lagoons where it seems to tolerate somewhat reduced salinities (Cosel, 1995: 38). The substrate in which the species distributes in Izmir Bay is soft mud blackened by pollution [for example, at Station 3 *flammable substance* (%) and *carbon* (%) were 11.09 and 9.24 respectively (project 03 SÜF 005)], with shells or shell fragments of some molluscs such as *Cerastoderma glaucum* and *Corbula gibba*, which used to inhabit the locality before pollution. Because no mollusc species was encountered in recent studies conducted at the research area until the day *F. fragilis* was first determined, the species appears rather resistant to the effects of pollution. This is also a species with high ecological tolerance, since it can establish new populations at ecosystems with quite different ecological conditions than the Red Sea.

The principal factors that lead to the population increase of *F. fragilis* in the last two years seem to be the very low biodiversity and the plankton richness linked with nutrients richness of bay waters [for example, at Station 3: $\Sigma_{\mathrm{N\ inorganic}}=1.91\ \mu$g.at/l, $PO_4^{3-}-P=3.94\ \mu$g.at/l (project 03 SÜF 005)].

Distribution

Fulvia fragilis forms two geographically isolated subspecies: the nominal Indo-Pacific subspecies, and the West African subspecies *congoensis*. The latter has probably developed independently after an invasion of the Atlantic realm during the Eemian interglacial period, from the Indian Ocean and via the Cape of Good Hope (Cosel, 1995). The wide Indian Ocean distribution of *Fulvia fragilis fragilis*, which passed to the Mediterranean via the Suez Canal, was summarized by Vidal (1994: 103). Its Mediterranean distribution is indicated in Figure 1. The species was first reported from the Mediterranean from Haifa Bay (Israel) on 17 May 1955 at a depth of 30 m (Barash & Danin, 1972), and it is noteworthy that this Indo-Pacific originated species has recently adapted to the different ecological conditions of Izmir Bay. On the other hand, it is the second lessepsian mollusc species, following *Brachidontes pharaonis* (Fischer, P., 1870), which established reproductive populations outside the southern Aegean Sea that is impacted by the warm and saline waters of the Levant Sea.

The pathway through which *F. fragilis* entered the Izmir Bay is controversial, but a transportation process via balast waters of ships seems probable. Considering that the species was previously known only from Saronikos Bay (Greece) in the Aegean Sea, and could not be collected until recently in other parts of the Aegean Sea and in any parts of Izmir Bay despite dense field surveys, a step by step inclusion pattern to the bay stands as a low probability.

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REFERENCES

Atkins, D., 1937. On the ciliary mechanisms and interrelationships of Lamellibranchs. Part 3: types of Lamellibranch gills and their food currents. *Quarterly Journal of Microscopical Science*, **79**, 375–421.

Barash, A. & Danin, Z., 1972. The Indo-Pacific species of Mollusca in the Mediterranean and notes on a collection from the Suez Canal. *Israel Journal of Zoology*, **21**, 301–374.

Bianchi, C.N. & Morri, C., 2000. Marine biodiversity of the Mediterranean Sea: situation, problems and prospects for future research. *Marine Pollution Bulletin*, **40**, 367–376.

Boudouresque, C.F., 1994. Les espèces introduites dans les eaux côtières d'Europe et de Méditerranée. In *Introduced species in European coastal waters* (ed. C.F. Boudouresque et al.), pp. 8–27. Luxembourg: European Commission Publication.

Boudouresque, C.F. & Ribera, M.A., 1994. Les introductions d'espèces végétales et animales en milieu marin—conséquenses écologiques et économiques et problèmes légistatifs. In *Proceedings of the First International Workshop on* Caulerpa taxifolia (ed. C.F. Boudouresque et al.), pp. 29–102. GIS Posidonie Publication.

Cosel, R. von, 1995. Fifty-one new species of marine bivalves from tropical West Africa. *Iberus*, **13**, 1–115.

Eno, N.C., Clark, R.A. & Sanderson, W.G., 1997. *Non-native marine species in British waters: a review and directory.* Peterborough: Joint Nature Conservation Committee.

Forsskål, P., 1775. *Descriptiones animalium avium, amphibiorum, piscium, insectorum, vermium quae in itinere orientali observavit Petrus Forsskål.* Prof. Haun. Post mortem auctoris edidit Carsten Niebuhr. Hauniae (Copenhagen).

Fredj, G. & Meinardi, M., 1989. Inventaire faunistique des ressources vivantes en Méditerranée: intérêt de la banque des données Medifaune. *Bulletin de la Société Zoologique de France*, **114**, 75–87.

Galil, B.S. & Lützen, J., 1998. Jeopardy: host and parasite lessepsian migrants from the Mediterranean coast of Israel. *Journal of Natural History*, **32**, 1549–1551.

Gmelin, J.F., 1791. Carli Linnaei systema Naturae per regna tria naturae. Editio decimatertia, aucta, reformata. *Vermes Testacea*, **1**, 3021–3910.

Haas, G., 1948. Sur l'immigration de Mollusques Indo-Pacifiques dans les eaux côtières de la Palestine. *Journal de Conchyliologie*, **88**, 141–144.

Hoenselaar, H.J. & Hoenselaar, J., 1989. *Musculista senhousia* (Benson in Cantor, 1842) in the western Mediterranean (Bivalvia, Mytilidae). *Basteria*, **53**, 76–79.

Lindner, G., 1988. *Laevicardium (Fulvia) papyraceum* (Bruguière, 1788) -von der südtürkischen Mittelmeerküste (Leg. der Familie Schmidt, Feldkirchen). *Club Conchylia Informationen*, **20**, 35–37.

Maldonado, A., 1985. Evolution of the Mediterranean basins and a detailed reconstruction of the Cenozoic paleoceanography. In *Key environments: western Mediterranean* (ed. R. Margalef), pp. 17–59. Oxford: Pergamon Press.

Niederhöfer, H.J., Enzeroß, L. & Enzeroß, R., 1991. Neue erkenntnisse über die ausbreitung von "Lesseps'schen Einwanderern" (Mollusca) an der türkischen Mittelmeerküste. *Club Conchylia Informationen*, **23**, 94–108.

Oliver, P.G., 1992. *Bivalved seashells of the Red Sea*. Oxford: Alden Press Osney Mead.

Öztürk, B., Önen, M., Dogan, A. & Ürkmez, D., 2002. The lessepsian molluscs of the Mediterranean and their distribution along the Turkish coasts. In *Workshop on lessepsian migration, Gokceada, 20–21 July 2002* (ed. B. Öztürk and N. Basusta), pp. 62–70. Istanbul: Turkish Marine Research Foundation Press.

Passamonti, M., 1996. Nuova segnalazione per le coste Tunisine di *Papyridea papyracea* (Gmelin, 1791) (Bivalvia: Cardiidae). *Bollettino Malacologico*, **32**, 153–156.

Por, F.D., 1978. *Lessepsian migration—the influx of Red Sea biota into the Mediterranean by way of the Suez Canal*. Berlin: Springer Verlag.

Poutiers, J.-M., 1998. Bivalves (Acephala, Lamellibranchia, Pelecypoda). In *FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific* (ed. K.E. Carpenter and V.H. Niem), pp. 1233–1262. Rome: FAO.

Ribera, M.A., 1994. Les macrophytes marins introduits en Méditerranée: biogéographie. In *Introduced species in European coastal waters* (ed. C.F. Boudouresque et al.), pp. 37–43. Luxembourg: European Commission Publication.

Ruffel, A., 1997. Geological evolution of the Mediterranean basin. In *The Mediterranean: environment and society* (ed. R. King et al.), pp. 12–29. London: Environment and Society.

Sarà, M., 1985. Ecological factors and their biogeographic consequences in the Mediterranean ecosystems. In *Mediterranean marine ecosystems* (ed. M. Moraitou-Apostolopoulou and V. Kiortsis), pp. 1–17. New York: Plenum Press.

Stasek, C.R., 1963. Synopsis and discussion of the association of Ctenidia and labial palps in the bivalved mollusa. *Veliger*, **6**, 91–97.

Vardala-Theodorou, G.E., 1999. The occurrence of the Indo-Pacific molluscan species *Fulvia fragilis* (Forsskal, 1775) and *Bulla ampulla* L., 1758 in Elefsis Bay. *Newsletter Hellenic Zoological Society*, **31**, 10–11.

Vidal, J., 1994. A review of the genus *Fulvia* Gray, 1853 (Mollusca, Cardiidae). *Apex*, **9**, 93–118.

Yaron, I., Schiotte, T. & Wium-Andersen, G., 1986. A review of molluscan taxa described by P. Forsskal and C. Niebuhr with citation of original descriptions, discussion of type-material available and selection of some lectotypes. *Steenstrupia*, **12**, 157–203.

Yonge, C.M., 1982. Mantle margins with a revision of siphonal types in the Bivalvia. *Journal of Molluscan Studies*, **48**, 102–103.

Zenetos, A., Gofas, S., Russo, G. & Templado, J., 2003. *CIESM atlas of exotic species in the Mediterranean*. Vol. 3. *Molluscs*. Monaco: CIESM Publishers.

Zibrowius, H., 1991. Ongoing modification of the Mediterranean marine fauna and flora by the establishment of exotic species. *Mésogée*, **51**, 83–107.

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