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Research article

Seeing Red: Alien species along the Mediterranean coast of Israel

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Abstract

An overview is presented of the metazoan alien biota recorded from the Mediterranean coast of Israel. Of the 296 alien species, 284 have been introduced from the Red Sea/Indo West-Pacific through the Suez Canal. A brief history of the research on introduced species along the Israeli coast is presented along with the list of species, and their ecological and economic impacts are discussed.

Key words: invasion, Israel, Mediterranean, Suez Canal, economic impact

A brief history of the research on marine alien species off the Mediterranean coast of Israel

The first marine alien species from the coast of Israel was found on the beach of Jaffa (Figure 1) and described in 1891 as *Cerithium levantinum* by E. A. Smith (in Hart, 1891). That species was later identified as *C. scabridum* Philippi, 1848 (Mienis, 1992b), a species known from the Red Sea and the Indian Ocean, that had already been described from the newly excavated Suez Canal and its Mediterranean terminal at Port Said (Fuchs 1878, Keller, 1883). The first alien species identified as such was the pearl oyster *Pinctada radiata* (Leach, 1814) (as *Meleagrina savignyi* Monterosato, 1878), mentioned from Jaffa " .. c'est là une espèce de la mer Rouge, immigrée dans la Méditerranée depuis le percement de l'Isthme de Suez" (Monterosato, 1899: 392). These early findings set a pattern that holds true to this day – 127 of the 297 alien

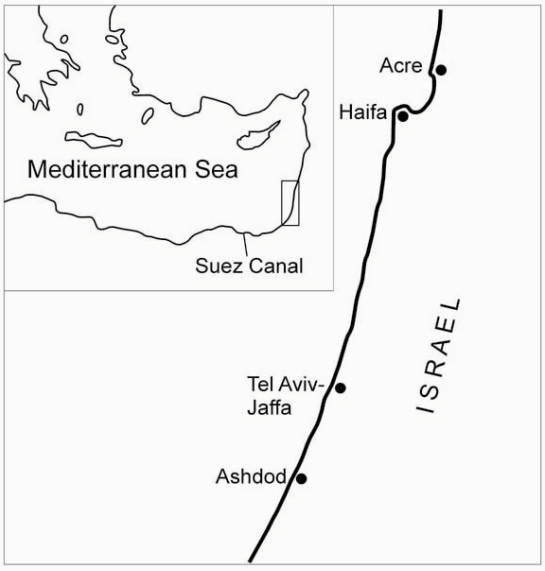

Figure 1. Map of the Levantine basin of the Mediterranean and the Israeli coast

species recorded off the Israeli coast are molluscs that had entered the Mediterranean through the Canal.

Dr. med. et phil. Walter Steinitz from Breslau was among the first to recognized the scientific significance of the movement of biota through the Canal. Dr. Steinitz, published a pamphlet at his own expense, where he pointed out that the Suez Canal "…is the only place on earth where two quite different zoological provinces have come into direct touch with one another", and that the Canal "…connects two oceans having each a very different fauna from the other, which throws up a number of new problems: Does an exchange of fauna take place between the two oceans by means of this canal? Do the immigrants from the other side flourish on this or die? Has such an immigration caused important changes in the fauna of the eastern basin of the Mediterranean?" (W. Steinitz 1919: 8). Steinitz deplored the lack of faunistic research in the Levantine Basin "… at this highly important point of juncture there is no place of observation!", and forsook his flourishing medical practice to study the marine biota of Palestine in 1924 and 1925. Noting 15 species of Indo-Pacific origin, he urged the creation of a Marine Station in the Levant dedicated to the study of the transformation of the Levantine biota (W. Steinitz 1929, 1936). In 1933 Dr. Steinitz immigrated to Israel and resumed his research in a space allotted him by the Zevulun Seafaring Society, Tel Aviv, but the need to provide for his family compelled him to join a communal village and breed poultry. However, he passed his scientific interest to his son, Heinz Steinitz, who studied with the pioneer ecologist Bodenheimer and received the first Ph.D. in zoology awarded by the Hebrew University of Jerusalem.

Munro Fox, who would later head the 'The Cambridge Expedition to the Suez Canal', outlined in 1923 "the dates of the various stages in the migration northward through the Canal of the Red Sea crab (*Neptunus pelagicus*) [= *Portunus pelagicus* (Linnaeus, 1758)], and … the apparent limits of its present distribution along the Mediterranean coast" including the fish market of Haifa (Fox, 1924). Indeed, Bodenheimer in his seminal "Animal life in Palestine" when discussing the "Indo-Pacific influx through the Suez Canal" mentioned that "Quite a number of [alien] fishes have not only reached our shores, but some of them have even increased in such numbers, that they appear regularly on the fish market" (Bodenheimer 1935: 457). He then presciently added "It is almost certain that the Indo-Pacific influx is still under way and it will be most interesting to study this process. The local increase will take considerable time, even for those organisms which thrive successfully in the new area" (Bodenheimer 1935: 460). The progress of Erythrean biota in the Levant in the early 20th century was noted in the inventories of molluscs (Monterosato 1899, Pallary 1912, 1938, Gruvel and Moazzo 1931, Haas 1937, 1948, Steuer 1939); decapod crustaceans (Gruvel 1928, 1929, 1930a,b, 1931, Monod 1930, 1931, 1932, Steuer 1938) and fish (Gruvel 1929, 1931, Liebman 1934), some of which report findings from the Israeli coast.

The intensive investigations of the biota of the continental shelf of Israel by the Sea Fisheries Research Station (SFRS) in 1946-1956 resulted in a series of publications that highlighted the extent the Erythrean taxa have been established along the coast (Carmin 1946, Haas and H. Steinitz 1947, Haas 1948, 1951, Gottlieb 1953, 1960, Holthuis and Gottlieb 1958, Pérès 1958, Tebble 1959, Oren and H. Steinitz 1959, Lewinsohn and Holthuis, 1964). The earlier community studies of the continental shelf of Israel were mainly fishery research (Wirszubski 1953, Gilat-Gottlieb 1959), and it was only in the 1960s that an extensive program was undertaken by Gilat (1964) to describe the macrobenthic communities off the Israeli coast. The SFRS fisheries biologist, Ben Tuvia, a former student of H. Steinitz, published the first list of fishes from the Mediterranean coast of Israel, focusing on the Erythrean alien species (Ben-Tuvia 1953a). He observed the development of the Erythrean invasion in "a, appearance of new Erythrean species in the eastern part of the Mediterranean; b, the spreading of Erythrean species, already established in the eastern Mediterranean close to the Suez Canal, to new areas (a movement following the coast of Israel, Syria, Turkey and Rhodes); c, the increased abundance of the invading species in areas where they were formerly scarce." (Ben-Tuvia 1953b: 464). Ben Tuvia continued to update the list of Erythrean alien fish off the Israeli coast: 21 species (Ben-Tuvia 1958), 30 species (Ben-Tuvia 1971), 41 species (Ben-Tuvia 1985). The steadily increasing number of alien fish moved him to write that "[v]ery little is known about how the influx of Red Sea species has influenced the

ecology of the eastern Mediterranean. Certainly these fish must play an important role in the food chain and the general biological balance of this area." (Ben-Tuvia 1971: 3). Ben Tuvia estimated, based on the catch statistics collated by the Department of Fisheries, that between 1965 and 1969 Erythrean fish made up 8% of the total landing (in weight) (Ben-Tuvia 1973), and the amount doubled to 16% between 1980 and 1982 (Ben-Tuvia 1985).

In 1967, a joint program by the Smithsonian Institution, the Hebrew University of Jerusalem, and the Sea Fisheries Research Station, Haifa, was established to investigate the spread of the Erythrean biota in the Levant (Israel, Cyprus, Rhodes) and its impact on the native biota. The scope of the program was expanded following the 'Six Day War' to include the Sinai coasts and the Suez Canal itself. H. Steinitz headed that program with W. Aron, Director of the Oceanography and Limnology Program, Smithsonian Institution. On the untimely death of Steinitz, his deputy, Por, assumed the position. At the end of the 3rd year of the program, with some 5300 samples collected and partially sorted and identified, Steinitz published "A critical list of immigrants via the Suez Canal" of 140 Erythrean and Indo-Pacific species known to have crossed the Suez Canal into the Mediterranean (H. Steinitz 1970). By now, it was widely perceived that the littoral and infralittoral biota of the Levantine basin has been undergoing a rapid and profound change (Por 1978). Galil and Lewinsohn (1981) noted that the shallow benthic communities along the Mediterranean coast of Israel had no known parallel outside the Levant because of the great number of Erythrean aliens.

Over the past three decades Galil (a former student of Lewinsohn), D. Golani (a former student of Ben Tuvia), M. Goren and H. Mienis (among others) have continued to record the spread, biology and impact of alien species along the Israeli coast and the Levantine Basin (Galil 1986, 1993, 1997, 1999, 2000, 2004, 2005, 2006, 2007, Galil and Golani 1990, Galil and Lützen 1995. Galil et al. 1990; Golani 1987, 1992, 1993 a-c, 1996, 1998, 2000a,b, 2002, 2004, 2006, Golani and Ben Tuvia 1982, 1990, Golani and Fine 2002, Golani and Sonin 1992, 2006; Goren and Aronov 2002, Goren and Galil 1989, 1998, 2001, 2005, 2006, Mienis 1976 a,b, 1977a,b, 1979, 1980a,b, 1984, 1985 a,b, 1987, 1990, 1992a,b, 1995, 1999, 2000a,b, 2002a-c, 2003 a-e, 2004a-d, 2006a-c, Mienis and Singer 1983, Mienis and Gat 1987, Mienis et al. 1993a,b). Yet, no concerted effort had been undertaken to survey the entire coast since the early 1970s, and most of the records stem from fortuitous finds. A national targeted effort to survey the presence and abundance of the Erythrean species and study their biology and ecology is wanting.

Aliens, vectors, trends

Research papers, conference abstracts, the local Fishermen's Bulletin, unpublished M.Sc. and Ph.D. theses, and the author's own databases resulting from two decades of monitoring the benthic communities off the Israeli coast, were assembled and critically examined in order to construct an authoritative dataset tracing the origin, date and mode of introduction, current distribution, and impact of the 296 metazoan alien species recorded along the Mediterranean coast of Israel. Earlier records were reassessed and some were deleted, such as the seven sponge species and three species of hydroids listed by Por (1978) that, as tactfully suggested by Zibrowius (1992), were in need of "critical reevaluation". Por (1978) also included in his list seven species of ascidiaceans, that are either widely distributed, or of "problematic identification. The list thus provides an inexact impression of lessepsian migration among ascidians" (Zibrowius 1992: 96).

The dataset includes the date of collection (if unavailable, date of publication) of the first recorded specimens, the native range of the alien, its means of introduction, whether through the Suez Canal, vessels, or mariculture, and the current population status. The date of collection of the first specimen(s) is significant for the study of the patterns and processes of invasion, though we accept that the date of collection (or, when missing, the date of publication) may be years behind the actual entry dates, and that identification and publication may lag behind collection: the gastropod *Cerithium scabridum* (Philippi, 1848) collected on Jaffa beach before 1891, was misidentified as *C. levantinum* (see above), and only when collected again in Jaffa in 1928-9 it was correctly identified as a "forme de la mer Rouge" (Gruvel and Moazzo 1931). The pyramidellid gastropods *Chrysallida maiae* (Hornung and Mermod 1924) and *Syrnola fasciata* (Jickeli 1882) were collected off the Israeli coast in 1935 and 1949 and identified only in 1992 (van der Linden and Eikenboom

1992), and 1995 (Mienis 1995) respectively; the tube worm *Hydroides brachyacantha* Rijoa, 1941, was collected in Jaffa, Israel, in 1933, but identified only nearly 60 years later (Ben-Eliahu 1991).

The 296 metazoan species identified in the present work as alien off the Israeli coast are listed in the Annex. This particular list is limited to multicellular organisms because the identity of many unicellular organisms is still in doubt, as well as their native range and distribution. A taxonomic classification of the alien species (Figure 2) shows that the alien phyla most frequently recorded are Mollusca (43%), Chordata (22%), Arthropoda (16%), and Annelida (7%). Phyla not represented in the list include the little studied Porifera, Nemertea, Priapula, Nematoda, Entoprocta, Pogonophora, Sipuncula, Echiura, Brachiopoda and Phoronida. The data are presumably most accurate for large and conspicuous species, which are easily distinguished from the native biota.

A geographic classification (Figure 3) shows that the native range of the alien taxa recorded in Israel is most commonly the Indo-Pacific Ocean (48%), the Indian Ocean (24%), the Red Sea (17%), and pantropical (6%). Caution should be exercised when using these data: the true origin of the Israeli populations of a species widely distributed in the Indo-Pacific Ocean may be either its populations in the Red Sea or further in the Indian Ocean, or secondarily from other established Levantine populations. The source populations or means of introduction of alien species in Israel have not yet been successfully ascertained by molecular means (Terranova et al. 2006). But even taking into account these caveats, it is quite clear that most of the alien species off the Israeli coast are thermophilic, originating in tropical seas.

A classification according to the means of introduction shows that the great majority of aliens off the Israeli coast entered through the Suez Canal, whereas vessels and mariculture contributed only a small number of aliens. Here too, caution should be exercised when using these data: only rarely are the means and route of introduction known from direct evidence. Mostly they are deduced from the biology and ecology (if known) of the species, the habitats and locales it occupies in both the native and introduced range, and its pattern of dispersal (if known), i.e., for a fouling species frequently recorded from ports, shipping is assumed to be the most probable vector. It is has been assumed

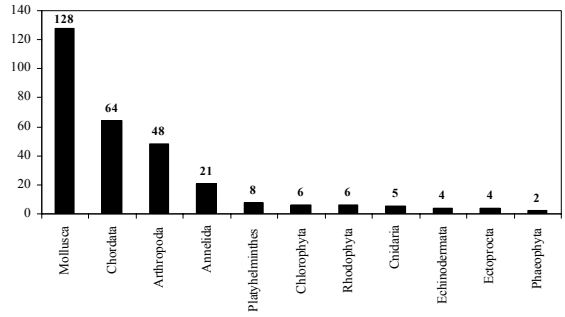

Figure 2. Taxonomic classification of marine alien species along the Mediterranean coast of Israel

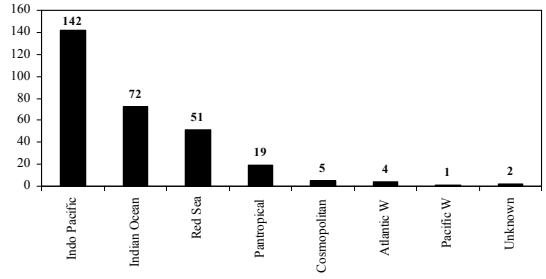

Figure 3. Native range of marine alien taxa recorded along the Mediterranean coast of Israel

that Erythrean aliens progress through the Suez Canal and along the coasts of the Levant as a result of "natural" dispersal, by autochthonous active or passive larval or adult movements, unaided further either directly or indirectly by human activity. Indeed, a temporal succession of directional ("stepping stones") records from the Red Sea, the Suez Canal, and along the coasts of the Levant confirms a species status as a naturally dispersing Erythrean alien. However, vessel-transported dispersal is feasible as well: "It is, of course, well known that ships have in more than one instance dispersed marine organisms from one part of the world to another. This must apply equally to transport through the Suez Canal. …. Possibly tugs and barges permanently employed in the Canal may take a larger share than other vessels in this transport from one end of the Canal to the other. There are coal barges, for instance, which remain for some months at one end of the Canal and then are towed through to stay for some months more at the other end. The time spent at either end would permit on the one hand of the settling of larvae on the bottom of the barges, and on the other

hand of the liberation of eggs or larvae from mature individuals" (Fox 1926:20). Even where records are consistent with long-shore dispersal, there might be a degree of uncertainty where fouling organisms (such as serpulid polychaetes or mussels) are concerned, as they are more susceptible to shipping-mediated transfer. In some cases we suspect simultaneous mechanisms of transport.

Though the date of collection (or publication, see above) may lag years behind the date of introduction, the numbers of alien species recorded off the Israeli coast each decade over the past century are given in Figure 4. With the exception of few scattered early records (see above), the records begin in the 1920s with the works of W. Steinitz and the results of 'The Cambridge Expedition to the Suez Canal', whereas the 1930s saw the publication of several regional lists (see above). The smaller number of records in the 1940s probably reflects the devastation of the Second World War and the struggle for the independence of Israel. A surge in the records in the 1950s through the 1970s probably represents both an increase in introductions and an interest in their study, culminating in the publications resulting from the joint program by the Smithsonian Institution, the Hebrew University of Jerusalem, and the Sea Fisheries Research Station, Haifa. Though no concerted effort was undertaken since, the number of records in the 1980s and 1990s were 35 and 36 respectively. More introductions were recorded in the first years of the 21th century than in the 1980s and 1990s.

Since the 1950s major political, economical and societal changes have occurred in the Levant. Their impact on the rate and means of introduction is apparent (Figure 5): though the Suez Canal remained the main access route for alien species, the rate of introductions by vessels has been higher. Of the 56 alien species known in 1950, 93% entered the Mediterranean through the Suez Canal, 7% were possibly canal/vessel-transported; of the 240 alien species recorded since 1950, 80% were Erythrean aliens, 9% were canal/vessel-transported, 10% and 1 % respectively were vessel-transported and mariculture introductions. The increase in vessel-transported aliens may be attributed to the increase in shipping volume throughout the region.

Since the probability of collecting a vagrant incursion in the sea is diminishingly small, most recorded alien species are considered as 'established' species that have self-maintaining

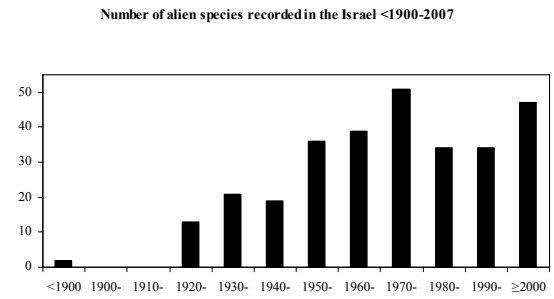

Figure 4. Number of marine alien species recorded per decade along the Mediterranean coast of Israel <1900-2007.

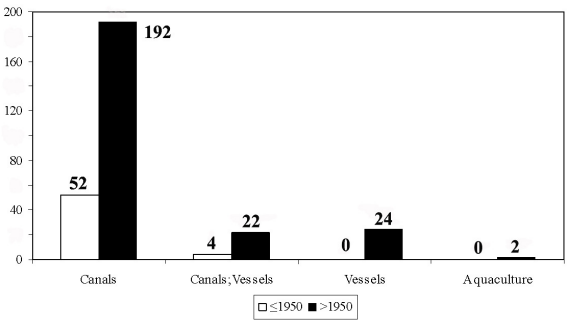

Figure 5. Number of species introduced by each pathway before and after 1950 along the Mediterranean coast of Israel

populations of some duration. It is recognized that some alien species may fail to maintain populations over time and thus a single record dating back several decades may be considered an ephemeral entry. We list 36 species known from single records, most of them recorded in the last decade. The distinction between the 'established' and 'ephemeral' aliens is sometimes difficult to discern and circumscribed in large part by our ignorance of the marine environment. Even once established in the Mediterranean, the alien species differ markedly in their histories.

The parasitofauna of the alien species off the Mediterranean coast of Israel

Absence of natural enemies, be it competitors, predators, pathogens, or parasites, is one of the explanations given for the success of alien biota (Wolfe 2002, Torchin et al. 2003). Diminished parasitization of alien species may be attributed to reduced probability of infestation due to the small numbers of the founding population, its

being composed of uninfected larval stages, or, in the case of heteroxenous parasites, the absence of intermediate hosts in the new locale, and on the other hand, the host-specificity of some native parasites forestalling infection of alien hosts.

The parasitofauna of the two Erythrean alien siganids were examined in the 1970s and 1980s and 11 parasite species were identified – all monoxenous parasites with direct life cycles requiring no intermediate host, including the monogenoids *Glyphidohaptor plectocirra* (Paperna, 1972), *Tetrancistrum polymorphus* (Paperna, 1972), *T. suezicus* (Paperna, 1972), *T. strophosolenum* Kritsky, Galli and Yang, 2007 (Paperna 1972, Diamant 1989, Galli et al., 2007). A study of *S. rivulatus* collected at the port of Ashdod, next to fish farming facilities, in the mid 1990s, revealed 7 Erythrean species of monoxenous parasites (Diamant et al. 1999). However, Fischthal (1980) identified in *Siganus rivulatus* (Forsskål, 1775) specimens from the Mediterranean two species of heteroxenous digenetic trematodes with complex life cycles requiring more than one host. Paperna (1972:3) suggested that endoparasitic helminthes spread into a new area only if they are not highly host-specific or if the suitable intermediate host has arrived as well, though "in most cases the migration of the fish host does not coincide with similar migration by the intermediate invertebrate hosts". It is of interest that a recent study of *S. rivulatus* has shown that the prevalence of its Erythrean monogenean ecto-parasite *Polylabris* cf. *mamaevi* off the Mediterranean coast is three times as high as that found in the Red Sea populations (Pasternak et al. 2007). These authors ascribe the heavier infection to "Changes in the natural environment and impact of anthropogenic factors encountered by the rabbitfish in their new Mediterranean habitats" (Pasternak et al. 724). However, the siganids are immensely successful colonizers, and it may be that the parasite high infestation levels stem from their access to much denser host populations.

Fischthal (1980) examined parasite loads of 500 fish of 59 species collected by gill-netting in 1977 off the Mediterranean coast of Israel. He found that 29 of the 43 (67%) native Mediterranean species were infected with digenetic trematodes, but only 5 of the 12 (42%) Erythrean alien species. Interestingly, many of the trematodes infecting the Erythrean hosts were of Atlanto-Mediterranean origin and were probably acquired in the Mediterranean from native hosts. These results support the 'enemy release hypothesis' – alien species generally import only a subset of their parasitofauna, thus releasing themselves from the parasites of their native habitat during introduction, and though subsequently accumulating parasites native to their new environment, they harbor fewer parasites in their new locale than in their native range (Torchin et al. 2001).

The Levantine populations of the Erythrean swimming crab *Charybdis longicollis* Leene, 1938 have been parasitized recently by the sacculinid rhizocephalan, *Heterosaccus dollfusi* Boschma, 1960 (Galil and Lützen 1995). The swimming crab, can form as much as 70% of the benthic biomass on sandy-silt bottoms off the Israeli coast (Galil 1986). Release from parasites may have contributed to its success - of the thousands of *C. longicollis* collected off the Israeli coast in over three decades, none was parasitized until 1992, when a few specimens were discovered carrying the externae (reproductive part of the parasite) of the castrating sacculinid, itself an Erythrean alien. Along the Israeli coast infection rates of up to 77% were recorded, with up to 57.6% of the infected hosts bearing more than one externa (Galil and Innocenti 1999). The rapid spread and the high prevalence of *H. dollfusi* infestation may be related to the dense population of the host and the year-round reproduction of the parasite, causing recurrent infection. In its second decade in the Mediterranean, the population of *H. dollfusi* seems stable: despite the high prevalence of the parasite and its injurious impact on the host reproduction, there is no noticeable reduction in the host population. It is suggested that the high fecundity of the host females, the "size refuge" formed by parasite-free larger males, and the "open" recruitment dynamics of *C. longicollis*, keep its population density high enough for *H. dollfusi*, with its "closed" recruitment dynamics, to maintain its pandemic infection rates (Innocenti and Galil 2007). The Erythrean sacculinid had not been detected in any of the other portunid crabs, alien or native, inhabiting the Levantine sublittoral, including the congeneric *C. helleri*.

The ecological impact of alien species off the Mediterranean coast of Israel

A single local extirpation of a native species is known and several cases of sudden decline in

abundance concurrent with proliferation of aliens had been recorded off the Israeli coast. But even when populations of native Mediterranean species appear to have been wholly outcompeted or partially displaced from their habitat space by an alien, the causes cannot be disentangled from potential confounding factors such as the profound anthropogenic alteration of the marine ecosystem through habitat destruction, pollution, and rising Mediterranean seawater temperature.

The Erythrean alien killifish, *Aphanius dispar* (Rüppell, 1829), is markedly euryhaline, occurring in freshwater, and in salinities up to 4 times as high as seawater, whereas its peri-Mediterranean endemic congener, *A. fasciatus* (Nardo, 1827), occurs mostly in brackish lagoons. The first Erythrean killifish was collected off Tel Aviv, Israel, in the winter of 1943/44 (Mendelssohn 1947). The last specimens of the native killifish, *A. fasciatus*, along the Israeli Mediterranean coast were collected on August 13, 1976 (M. Goren, pers. comm.; preserved in the National Collections, Tel Aviv University, access number 6319). Naturally occurring hybrids of the two killifish species were described as " ... common, and in some localities (Ashdod Harbour [southern coast of Israel], parts of Bardawill Lagune etc.), these populations comprise mostly hybrids" (Goren and Rychwalski, 1978: 261). Within a generation an endemic genotype appears to be locally lost through hybridization, and *A. dispar* and its hybrids replaced *A. fasciatus* along the Mediterranean coast of Israel (Goren and Galil 2005).

The two species of siganid fish, *Siganus rivulatus* and *S. luridus* (Rüppell, 1828), that entered the Mediterranean from the Red Sea through the Suez Canal, were first recorded off the coast of Israel in 1924 (Steinitz 1927) and 1955 (Ben Tuvia 1964), respectively. The schooling, herbivorous fishes, able to settle in a range of habitats, comprise one third of the fish biomass in rocky habitats along the Israeli coast (Goren and Galil 2001). The multitudinous siganids have altered the community structure and the native food web along the Levantine rocky infralittoral. They replaced native herbivorous fish, such as *Sarpa salpa* (Linnaeus, 1758), that had been abundant in trawl catches early in the 20th century (Gruvel 1931, George and Athanassiou 1967, Bariche et al. 2004). Prior to the invasion of the siganids, there were few native herbivorous fish and invertebrates and their role in the food web off the Levantine rocky habitats had been negligible. The siganids increased the rate by which large amounts of algal material were recycled, these fish apparently accelerated the transfer of energy from the producer to the consumer levels (in hours through the fish gastrointestinal system rather than weeks or months of decomposition), and by serving as major item of prey (up to 70 %) for larger infralittoral predators such as groupers (Aronov 2002, Goren and Galil 2005). Their grazing pressure on the intertidal rocky algae may have benefited the proliferation of an alien Erytrean mussel by providing suitable substrate for its settlement (see below). A comprehensive study of the algal vegetation and the ecology of the fish community off a vermetid reef, south of Haifa Bay, Israel, provided an opportunity to compare the diets of *S. rivulatus* and *S. luridus* collected at the site with the composition of the local algal community, and examine the importance of algal spatial variability and seasonality in the dietary choices of both siganid fishes. An analysis of the siganids' gut contents, in conjunction with the spatial and seasonal composition of the local algal community, showed that their diet has a significant impact on the structure of the local algal community: it seems that by feeding selectively they have nearly eradicated some of their preferred algae locally (Lundberg et al. 2004).

A small Erythrean mytilid mussel, *Brachidontes pharaonis* (Fischer P., 1870), was considered in the early 1970s "c. 250 times rarer" than the native mytilid *Mytilaster minimus* (Poli, 1795), that formed dense '*Mytilaster* beds' on intertidal rocky ledges along the Israeli coastline, with up to 26 specimens per cm² (at Palmahim, Safriel et al. 1980, tab. 4). Studies conducted in the late 1970s along the Israeli coastline, while *B. pharaonis* was still relatively rare, predicted it would neither establish dense populations nor outcompete the native *Mytilaster minimus*: "*B. variabilis* [*pharaonis*] never forms 'beds' in the eastern Mediterranean, and is singly or in small groups dispersed within *M. minimus*", and "… it did not displace *M. minimus*" (Safriel et al. 1980: 39, 59). The relative rarity of *B. pharaonis* was attributed to the invader's low intrinsic rate of increase in comparison to that of the native species, and to strong density-independent mortality generated by exposure to either high wave action or sedimentation. By the end of the 1980s, following a series of experiments, it was determined

that *Brachidontes* interferes with recruitment of *Mytilaster*, and detrimentally affects its survival and growth, yet the researchers maintained that the Erythrean mytilid was not likely to outcompete the native species: "The two species can coexist, both locally and regionally" (Safriel and Sasson-Frostig 1988: 225). In the late 1990s a survey conducted in some of the same sites have shown a rapid shift in dominance, with some dense populations of up to 300 specimens per 100 cm² on rocky platforms "where mussel beds were absent in the past" (Rilov et al. 2004: 347). More recently "the same rocks are …. completely covered with the Erythrean *B. pharaonis*, while *M. minimus* is only rarely encountered." (Mienis 2003d: 15). The establishment of massive beds of *Brachidontes* has had significant effects on the biota of the rocky intertidal. As the presence of algae is negatively correlated with the presence of the Erythrean mytilid, and is considered to impede the settlement of its postlarvae (Safriel and Sasson-Frostig 1988), a shift in habitat conditions that reduces algal cover might have benefited *Brachidontes*. As it happens, few herbivores occurred in the rocky shores of the southeastern Levant prior to the arrival of the Erythrean siganid fish (see above). During high tide schools of (mostly young) siganids feed on the intertidal platforms (Lundberg et al. 2004). It is suggested that the multitudinous siganids may have triggered the population increase by clearing the intertidal platform of algae. The displacement of the native mussel by the larger, thicker-shelled Erythrean mytilid may have changed predation patterns so that the population of the native whelk, *Stramonita haemastoma* (Linnaeus, 1758), that were found to preferentially prey on *Brachidontes*, increased greatly (Rilov et al. 2002).

An Erythrean limpet, *Cellana rota* (Gmelin, 1791), first collected in the Mediterranean in 1961 (Christiaens 1967), spread by 2000 along the Israeli coast, occupying the less wave-exposed intertidal sites, whereas the native Mediterranean limpet, *Patella caerulea* Linnaeus, 1758, inhabited rocks exposed to the surf. A recent survey along the Mediterranean coast of Israel found that the alien limpet dominates the upper rocky littoral and has been replacing the native limpet when "a few years ago *Patella caerulea* was the only limpet inhabiting the same rocks at that locality [Ashdod]" (Mienis 2002b: 275). Along the southern coast of Israel it has already completely replaced the native limpet, along the central coast it "has taken possession of 40-50% of the available space." (Mienis 2003d: 15). Similarly, the Erythrean jewel box oyster *Chama pacifica* Broderip, 1834, outnumbered its native congener, *C. gryphoides* Linnaeus, 1758: "The local *S. gaederopus* and *C. gryphoides* are hardly even encountered as epibionts on the new immigrant species." (Mienis 2003d: 15). The native Mediterranean cerithiid gastropods, *Cerithium vulgatum* Bruguière, 1792 and *C. lividulum* Risso, 1826, respectively common and abundant in shallow water along the coast of Israel until the 1970s, were supplanted by the Erythrean cerithiids *Cerithium scabridum* Philippi, 1848 and *Rhinoclavis kochi* (Philippi, 1848) (Mienis 2003d: 15). The population of the Erythrean narrow-barred mackerel, *Scomberomorus comerson* Lacepède, 1800, has greatly increased in the 1980s, coincidently with the decline of the one-time common native meager, *Argyrosomus regius* (Asso, 1801), to the point where the latter is rarely encountered along the Israeli coast; the Erythrean dragonet, *Callionymus filamentosus* Valenciennes, 1837, replaced the native callionymids *C. pusillus* Delaroche, 1809, and *C. risso* LeSueur, 1814, along the Levantine upper shelf (Golani 1998). The Erythrean snapping shrimps *Alpheus inopinatus* Holthuis & Gottlieb, 1958, and *A. audouini* Coutière, 1905, are more common in the south-eastern Levantine rocky littoral than the native *A. dentipes* Guérin-Méneville, 1832, and on the muddy bottoms *A. rapacida* de Man, 1908, is much more common than the native *A. glaber* (Olivi, 1792) (Lewinsohn and Galil 1982, Galil 1986). The native penaeid prawn, *Melicertus kerathurus* (Forskål, 1775) was commonly caught by trawlers along the Israeli coastal shelf on sandy or sandy mud bottoms, and supported a commercial fishery throughout the 1950s (Holthuis and Gottlieb 1958). It has since nearly disappeared, and its habitat overrun by the Erythrean penaeid prawns.

Competitive displacement may also modify bathymetric ranges in populations of Erythrean and native species: the native red mullet, *Mullus barbatus* (Linnaeus, 1758) and the native hake, *Merluccius merluccius* (Linnaeus, 1758) were both displaced into deeper, cooler waters by their respective Erythrean competitors, *Upeneus moluccensis* (Bleeker, 1855) and *Saurida undosquamis* (Richardson, 1848). The goldband goatfish, *U. moluccensis*, made up 10-15% of the total mullid catches off the Israeli coast by the

late 1940s (Wirszubski 1953). Following the exceptionally warm winter of 1954-55, its percentages increased to 83% of the catch, replacing the native red mullet in the commercial fisheries (Perlmutter, 1956). Both mullid species have a similar diet, and occupy muddy bottoms shallower than 75 m, but whereas the red mullet spawns from April to June with a peak in May, the goldband goatfish spawns from June to September (Wirszubski 1953). The considerably higher water temperatures may have resulted in poor survival of the red mullet spawn whereas an unusually large year class of the goldband goatfish survived. In previous years, the young red mullets would settle to the bottom during July through September, where they have had a distinct size advantage over the later-spawned goldband goatfish. The failure of the 1955 red mullet year class may have left their niche only partly occupied, to the advantage of the Erythrean species, and the unusually warm waters enhanced the latter species' survival rate (Oren 1957a, b). The native mullet has ever since been displaced into deeper, cooler waters: 87% of the mullid catch off the Israeli coast consisted of alien mullids at depth of 20 m, 50% at 55 m, but only 20% in waters deeper than 70 m (Golani and Ben Tuvia 1995). The Erythrean lizardfish, *S. undosquamis*, was first recorded from the Mediterranean coast of Israel in 1952 (Ben Tuvia 1953a). The "abrupt rise in catch of the lizard fish *Saurida undosquamis*, taken by otter trawlers with the usual gear on the regular fishing grounds" (Oren 1957b: 1) was attributed to the warm winter of 1954-55 (Ben Yami 1955, Chervinsky 1959). In 1955-56 the lizardfish became commercially important, constituting up to one fifth of the total annual trawl catch along the Mediterranean coast of Israel. This sudden increase came at the expense of the native hake, it too was displaced into deeper waters (Ben Yami and Glaser, 1974). Since the mid 1980s the lizardfish's share in catches has declined, and that of the hake augmented. Similarly, The Erythrean mantis shrimp, *Erugosquilla massavensis*, (Kossmann, 1880) is abundant off the Israeli coast at depths of 20-60 m. Though on occasion it is taken together with the native Spottail mantis shrimp, *Squilla mantis* (Linnaeus, 1758), generally the latter occurs in deeper waters than Erythrean alien. The Spottail mantis shrimp is fished commercially in shallow waters elsewhere in the Mediterranean (Lewinsohn and Manning 1980), but off the Israeli coast it is found mostly between 70 and 90 m. Lewinsohn and Manning (1980) questioned "whether temperature, bottom type, or pressure from *O. massavensis*, or a combination of these is responsible for its depth distribution".

The economic impact of marine alien species off the Mediterranean coast of Israel

Some Erythrean aliens have been exploited commercially almost as soon as they entered the Levant and their economic importance had been acknowledged early : "... les passages définitifs de ces espèces à travers la totalité du Canal présentent un résultat économique [sic] également très important..... pour les marchés palestiniens et syriens, un appoint non négligeable et particulièrement intéressant, par consequent, pour l'ensemble des populations de ces deux Pays" (Gruvel 1936: 228, 229).

An early Erythrean invader, the swimming crab *Portunus pelagicus* was on sale already by the early 1900s in the fish market of Haifa (Fox 1924, Calman 1927), and during the British Mandate the fishermen of Haifa and Acre sold 20 tons of the crab annually (Perlmutter 1956). By mid-century the Erythrean fishes were an important part of the Levantine fisheries. Insofar as the Israeli fishing grounds were concerned, the bulk of the trawler catch from 1950 to 1955, was comprised of three species – the native red bream, *Pagellus erythrinus* (Linnaeus, 1758), and hake, *Merluccius merluccius*, and the Erythrean yellow striped mullet, *Upeneus moluccensis*. The latter were fished commercially in the early 1940s only along the southern coast of Israel, but by 1946-1947 were found all along the coast (Gottlieb 1957), and by the late 1940s constituted an estimated 10-15% of the total mullid catch (Wirszubski 1953). In 1955 Israeli fishermen noticed greater numbers of the yellow striped mullet, and data assembled by the Sea Fisheries Research Station, Haifa, indicated that their percentage in the mullid catch rose to 20%, and to over 83% in early 1956 (Oren 1957a,b), and was considered "the most important commercial fish in the Israel trawl catches" (Gottlieb 1957:20). Since the total mullid catch had remained constant, the yellow striped mullet had in the early 1950s "almost completely replaced the Mediterranean species, the red mullet, *Mullus barbatus* in the trawl catch" (Perlmutter 1956:4). In 1955, another Erythrean alien, the lizardfish, *Saurida undosquamis* became an important part of the trawl catch

(Oren 1957b). In 1953 it was first recorded from the Mediterranean coast of Israel (Ben Tuvia 1953a,b) as much rarer than the native Mediterranean lizardfish, *Synodus saurus* (Linnaeus, 1758). Within two years commercial catches increased steadily, in November and December 1955, 22 and 27.5 tons respectively were taken, swelling to 40 and 46.8 tons in January and February 1956 respectively, to a total of 266.5 tons for 1956 – 20% of the total annual trawl catch (Oren 1957a, b). The sudden increase in the populations of the lizardfish, the yellow striped mullet, the red soldierfish, and Erythrean penaeids was attributed to a rise of 1-1.5ºC in sea temperature during the winter months of 1955 (Ben Yami 1955, Chervinsky 1959).

Examination of the Israeli fisheries statistics since the mid 1980s underscores the growing prominence of the Erythrean aliens. The Erythrean conch, *Conomurex persicus* Swainson, 1821, and on occasion the Erythrean spiny oyster, are served in seafood restaurants in Israel. Erythrean penaeid prawns make up most of the shrimp catches along the SE Levantine coasts. The Erythrean prawns, in particular *Marsupenaeus japonicus* (Bate, 1888), *Metapenaeus monoceros* (Fabricius, 1798) and *Penaeus semisulcatus* de Haan, 1844, are highly prized and beginning in the 1970s a shrimp fishery developed off the Sinai coast, and since the mid 1980s off the Israeli coast where a small fleet of coastal "mini" trawlers has specialized in shrimping, bringing in a quarter of the total trawl catch volume and a third of the trawl gross income (Pisanty and Grofit 1991, Snovsky and Shapiro 1999). Nearly half of the trawl catches along the Israeli coast consist of Erythrean fish (Golani and Ben Tuvia 1995). The dominant fishes in the inshore fisheries (trammel-netting and hook-and-lining) are the siganids *S. rivulatus* and *S. luridus*, the obtuse barracuda *Sphyraena chrysotaenia* Klunzinger, 1884, and the Erythrean jack, *Alepes djedaba* (Forsskål, 1775). The above species, together with *Sillago sihama* (Forsskål, 1775) and *S. commerson*, two species that underwent population explosion in the early 1980s, are common in purse-seine landings. The annual catch of the Erythrean lizardfish which reached 400 tons in 1960 soon after its arrival (see above), declined to 100 tons in the mid 1960s, but has since increased, and catch fluctuations are correlated with CPUE. Catch statistics for mullids do not distinguish between the natives, *M. barbatus* and *M. surmuletus* Linnaeus, 1758, and the Erythrean aliens *Upeneus moluccensis* and *U. pori*, but a study of the frequency of the latter in trawl catches conducted in the mid 1980s showed they formed 87% of the mullid catch off the coast of Israel at depths of 20 m, and 50% at 55 m, whereas the native mullids are more abundant in deeper waters (Golani and Ben Tuvia 1995). The percentage of the Erythrean mullids in the total mullid catch has been increasing steadily, from 30% in 1980, 42% in 1984, to 47% in 1989 (Golani and Ben Tuvia 1995). Similarly, catch statistics of sphyraenids do not separate the Red Sea obtuse barracuda from the native Mediterranean species *S. sphyraena* (Linnaeus, 1758) and *S. viridensis* Cuvier, 1829. However, examination of the landed catch showed that the Erythrean barracuda had outnumbered the native sphyraenids in inshore trawl and purse-seine catches (Grofit 1987). In addition, two of the four species of Erythrean clupeids that established populations in the Levant – *Dussumieria elopsoides* Bleeker, 1849, and *Herklotsichthys punctatus* (Rüppell, 1837) – are of importance in the inshore-pelagic fishery. The increasing exploitation of Erythrean aliens meant the shifting of the trawling grounds nearshore since their densest populations occur at depths up to 50 m. Between 1980 and 1986 the Israeli trawlers doubled their activity (measured as fishing hours) in shallow waters (Pisanty and Grofit 1991). The shoreward displacement of the fishing grounds coupled with the inexorable gain of Erythrean aliens raise the ratio of alien to native taxa in the Levantine trawl landings.

But together with the commercially exploitable species, the Erythrean invasion swept ashore the scyphozoan jellyfish, *Rhopilema nomadica* Galil, 1990. Each summer since the mid 1980s huge swarms of the Erythrean jellyfish have appeared along the Levantine coast. These planktotrophic swarms, some stretching 100 km long, must play havoc with the limited resources of this oligotrophic sea, and when the shoals draw nearer shore, they adversely affect tourism, fisheries and coastal installations. Local municipalities report a decrease in holiday makers frequenting the beaches because of the public's concern over the painful stings inflicted by the jellyfish. The local newspapers and TV news report during the summer months the presence of jellyfish along the beaches. Coastal trawling and purse-seine fishing are disrupted for the duration of the swarming due to net clogging and inability to sort yield "It is not uncommon that fishermen,

especially purse seines, discard entire hauls due to the overwhelming presence of poisonous medusae in their nets" (Golani and Ben Tuvia 1995: 287). Jellyfish-blocked water intake pipes pose a threat to cooling systems of port-bound vessels and coastal power plants: in the summer of 2001 Israel Electric removed tons of jellyfish from its seawater intake pipes at its two largest power plants, at estimated costs of 50,000 US$ (M. Cohen, pers. comm.). Yet, the jellyfish shelters among its nematocyst-laden tentacles the juveniles of the Red Sea carangid fish, *Alepes djedaba* (Galil et al. 1990), and may have precipitated the sudden population increase of this commercially important species (Grofit 1987).

The recent spread of the silver stripe blaasop, *Lagocephalus sceleratus* (Gmelin, 1789), and the striped catfish, *Plotosus lineatus* (Thunberg, 1787), pose severe health hazards. The blaasop's internal organs, and in particular the gonads during the spawning season, contain a strong paralytic neurotoxin. In the Suez City, on the Red Sea, eight fatalities from tetrodoxin poisoning associated with eating the fish have been described recently (Zaki 2004). Several cases of poisoning were reported from Israel, but none proved fatal. Injuries caused by the barbed and venomous first dorsal spine and pectoral spines of the striped catfish may produce pain levels requiring hospitalization – injuries have been reported by local professional and amateur fishermen.

The miners' canary

Evidence is accumulating that changes in biodiversity patterns in the Mediterranean are linked to direct drivers such as climate change and invasive species, in addition to the well-established drivers of habitat change, over-exploitation and pollution. By the middle of the century, climate change and invasive species may be the dominant direct drivers of biodiversity loss and increased risk of extinction for many species, especially those already at risk due to low population numbers, restricted or patchy habitats, and limited climatic ranges.

The Erythrean aliens are thermophilic, originating in tropical waters. It stands to reason that rising seawater temperature enhances the reproduction, growth, and survival of the Erythrean aliens, and provides them with a distinct advantage over the native Mediterranean biota (Galil 2007). The location of the Israeli coast "downstream" of the prevailing current from the opening of the Suez Canal means that it is the first haven for the Erythrean propagules. Most of the Erythrean aliens known from the Mediterranean Sea have been first recorded from Israeli coast.

As both processes – sea surface temperature rise and influx of aliens – continue unabated, it is imperative to expand research into those issues. The likely biotic change may impact the already teetering fisheries, mariculture, and tourism through proliferation of alien parasitic, noxious and poisonous species, displacement of commercially-important native species, or through alteration of the food web and by causing phase shift in coastal ecosystems and changing seascape patterns.

The profound changes in the biota off the Israeli Mediterranean coast caused by the intrusion of Erythrean aliens should serve as a miners' canary - if unheeded and unchecked they are likely to spread beyond the easternmost Mediterranean Sea.

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Annex

Aquatic alien species reported from the coastal waters of Israel

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Macrophytes						
Rhodophyceae						
Galaxaura rugosa (Ellis & Solander) Lamouroux, 1816	2003, Shikmona	alien	Pantropical	vessels	unknown	Hoffman *et al*. 2007
Hypnea cornuta (Kützing) J. Agardh, 1851	unknown	alien	Atlantic Ocean;Indian Ocean	Suez Canal	unknown	Nemlich and Danin, 1964
Hypnea esperi Bory de Saint-Vincent 1828	unknown	alien	Indian Ocean	Suez Canal	unknown	Lipkin 1972
Lophocladia lallemandii (Montagne) F. Schmitz, 1893	unknown	alien	Pantropical	Suez Canal	unknown	Gomez Garreta et al. 2001
Sarconema filiforme (Sonder) Kylin, 1932	1945, Tel Aviv	alien	Indo Pacific	Suez Canal	unknown	Rayss 1963
Solieria dura (Zanardini) F. Schmitz, 1895	1957, Bat Yam	alien	Indo Pacific	Suez Canal	unknown	Rayss 1963
Phaeophyceae						
Padina boergesenii Allender & Kraft, 1983	before 1965, Mikhmoret	alien	Pantropical	Suez Canal	unknown	Ramon and Friedman, 1965
Stypopodium schimperi (Buchinger ex Kützing) Verlaque & Boudouresque, 1991	1973, Mikhmoret	alien	Atlantic Ocean;Indian Ocean	Suez Canal	unknown	Lundberg 1980 fide Verlaque and Boudouresque 1991
Chlorophyceae						
Acetabularia calyculus Lamouroux in Quoy & Gaimard, 1824	1943, Haifa Bay	alien	Pantropical	Suez Canal	unknown	Rayss 1955
Caulerpa mexicana Sonder ex Kützing, 1849	1939, Tel Aviv	alien	Pantropical	Suez Canal	unknown	Rayss 1941
Caulerpa racemosa var lamourouxii f. requienii (Montagne) Weber-van Bosse	1955, Haifa Bay	alien	Red Sea	Suez Canal	unknown	Rayss and Edelstein 1960
Caulerpa scalpelliformis (Brown ex Turner) C. Agardh, 1817	1929, Tel Aviv	alien	Cosmopolitan	Suez Canal	unknown	Carmin 1934
Cladophoropsis javanica (Kützing) P.C. Silva, 1996	unknown	alien	Indo Pacific	Suez Canal	unknown	Rayss 1955
Codium taylorii P.C. Silva, 1960	1958, Bat Yam	alien	Atlantic Ocean;Indian Ocean	Suez Canal	unknown	Silva 1960
Cnidaria **Hydrozoa**						
Acabaria erythraea Ehrenberg, 1834	1999, Hadera	alien	Red Sea	Vessels	unknown	Fine *et al*. 2005
Oculina patagonica de Angelis, 1908	1993, Sdot Yam	alien	Atlantic coast of South America	Vessels	unknown	Fine and Loya 1995

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Anthozoa						
Cassiopeia andromeda (Forsskål, 1775)	1988, Neve Yam	alien	Indo Pacific	Suez Canal	unknown	Galil et al. 1990
Phyllorhiza punctata von Lendendfeld, 1884	1965, Beit Yanai	alien	Indo Pacific	Suez Canal	unknown	Galil et al. 1990
Rhopilema nomadica Galil, 1990	1976, Dor	alien	Indian Ocean	Suez Canal	Venomous, interferes with fisheries, coastal installations, seabathing	Galil et al. 1990
Platyhelminthes						
Glyphidohaptor plectocirra (Paperna, 1972)	1971, unknown	alien	Red Sea	Suez Canal	parasite	Paperna 1972
Hysterolecitha sigani Manter, 1969	1977, Haifa	alien	Indo Pacific	Suez Canal	parasite	Fischthal 1980
Lecithochirium magnicaudatum Fischthal & Kuntz, 1963	1977, Jaffa	alien	Red Sea	Suez Canal	parasite	Fischthal 1980
Monilicaecum ventricosum Yamaguti, 1942	1977, Jaffa	alien	Indo Pacific	Suez Canal	parasite	Fischthal 1980
Polylabris cf. mamaevi Ogawa & Egusa, 1980	1971, unknown	alien	Indo Pacific	Suez Canal	parasite	Diamant 1989
Tetrancistrum polymorphus (Paperna, 1972)	1971, unknown	alien	Red Sea	Suez Canal	parasite	Paperna 1972
Tetrancistrum strophosolenum Kritsky, Galli & Yang, 2007	1971, unknown	alien	Red Sea	Suez Canal	parasite	Paperna 1972
Tetrancistrum suezicus (Paperna, 1972)	1971, unknown	alien	Red Sea	Suez Canal	parasite	Paperna 1972
Annelida **Polychaeta**						
Branchiomma boholense Grube, 1878	1927, unknown	alien	Indo Pacific	Suez Canal	unknown	Knight-Jones and Ergen 1991
Ceratonereis mirabilis Kinberg, 1866	1974-5, Haifa Bay	alien	Pantropical	Suez Canal	unknown	Amoureux 1976
Eunice cf. *indica* Kinberg, 1865	1972, unknown	alien	Indo Pacific; Red Sea	Suez Canal	unknown	Ben Eliahu 1972b
Ficopomatus enigmaticus (Fauvel, 1923)	1954, swamp near Akko, Alexander river.	alien	southern Hemisphere	Vessels	fouling	Fauvel 1955
Hydroides brachyacantha Rioja, 1941	1933, Jaffa	alien	Red Sea	Suez Canal, Vessels	fouling	Ben Eliahu 1991
Hydroides elegans (Haswell, 1883)	1965-6, Haifa port	alien	Pantropical	Vessels	fouling	Queiroz, 1968
Hydroides heterocerus (Grube, 1868)	1990, Akhziv	alien	Indian Ocean	Suez Canal, Vessels	fouling	Ben Eliahu and ten Hove 1992
Hydroides homoceros Pixell, 1913	1955, Haifa	alien	Indian Ocean	Suez Canal, Vessels	fouling	Ben Eliahu 1991

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Hydroides minax (Grube, 1878)	1990, Rosh Hanikra	alien	Indo Pacific	Suez Canal, Vessels	fouling	Ben Eliahu 1991
Hydroides operculatus (Treadwell, 1929)	1959, Haifa	alien	Indian Ocean	Suez Canal, Vessels	fouling	Ben Eliahu 1991
Leonnates decipiens Fauvel, 1929	1980-9, Haifa	alien	Indian Ocean	Suez Canal	unknown	Ben Eliahu 1989
Leonnates indicus Kinberg, 1865	1991, off Haifa	alien	Indian Ocean	Suez Canal	unknown	Ilan et al. 1994
Leonnates persica Wesenberg-Lund, 1948	1937, Haifa	alien	Indian Ocean	Suez Canal	unknown	Ben Eliahu 1989
Lepidonotus tenuisetosus Gravier, 1901	1969, Ashkelon	alien	Indo Pacific	Suez Canal	unknown	Barnich and Fiege 2003
Linopherus incarunculata Peters, 1858	before 1976, unknown	alien	unknown	Suez Canal	unknown	Ben Eliahu 1976
Metasychis gotoi Izuka, 1902	before 1972, unknown	alien	Indo Pacific	Suez Canal	unknown	Ben Eliahu 1972b
Nereis persica Fauvel, 1911	1937, Haifa	alien	Pantropical	Suez Canal	unknown	Ben Eliahu 1989
Pista unibranchia Day, 1963	1974-5, Haifa Bay	alien	Arabian Gulf	Suez Canal	unknown	Amoureux 1977
Pomatoleios kraussii (Baird, 1865)	1958, Hadera	alien	Indo Pacific	Suez Canal, Vessels	unknown	Ben Eliahu 1992
Pseudonereis anomala Gravier, 1901	1937, Haifa	alien	Red Sea; Arabian Gulf	Suez Canal	unknown	Ben Eliahu 1989
Terebella ehrenbergi Grube, 1870	1976, unknown	alien	Indo Pacific	Suez Canal	unknown	Ben Eliahu 1977
Crustacea						
Cirripedia						
Balanus reticulatus Utinomi, 1967	2003, Hadera harbour	alien	tropical and warm-temperate seas	Vessels	fouling	F. Kerckhof pers. com.
Heterosaccus dollfusi Boschma, 1960	1990, Palmahim	alien	Red Sea	Suez Canal	parasite on *Ch. longicollis*	Galil and Lützen 1995
Copepoda						
Acartia centrura Giesbrecht, 1889	1968, Netanya	alien	Indo-Pacific	Suez Canal	unknown	Berdugo 1974
Calanopia media Gurney, 1927	1965, Haifa	alien	Indian Ocean	Suez Canal	unknown	Berdugo 1968
Amphipoda						
Elasmopus pectenicrus (Bate, 1862)	before 1959, unknown	alien	Circumtropical	Suez Canal, vessels	unknown	Ruffo 1959
Gammaropsis togoensis Schellenberg, 1925	before 1979, Ashdod harbour	alien	Cosmopolitan	vessels	unknown	krapp-Schickel and Myers 1979
Photis lamellifera Schellenberg, 1928	1951-2, Cesarea	alien	Indian Ocean	Suez Canal	unknown	Ruffo 1959
Cumacea						
Eocuma rosae Corbera & Galil, 2007	2005, Haifa Bay	single record	Red Sea	Suez Canal	unknown	Corbera and Galil, 2007
*Scherocumella gurneyi (*Calman, 1927)	2005, Haifa Bay	alien	Red Sea	Suez Canal	unknown	Corbera and Galil 2007

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Decapoda						
Alpheus audouini Coutiere, 1905	1951, Herzeliya	alien	Indo West Pacific	Suez Canal	displaced native species	Forest and Guinot 1956
Alpheus inopinatus Holthuis & Gottlieb, 1958	1951, Herzeliya	alien	Indian Ocean	Suez Canal	displaced native species	Forest and Guinot 1958, Holthuis and Gottlieb 1958
Alpheus migrans Lewinsohn & Holthuis, 1978	1977, Palmahim	alien	Red Sea	Suez Canal	unknown	Lewinsohn and Holthuis 1978
Alpheus rapacida de Man, 1908	1960, Tel Aviv	alien	Indo West Pacific	Suez Canal	displaced native species	Lewinsohn and Holthuis 1964
Ashtoret lunaris (Forsskål, 1775)	1987, Haifa Bay	single record	Indo West Pacific	Suez Canal	unknown	Galil and Golani 1990
Atergatis roseus (Rüppell, 1830)	1961, Tel Aviv	alien	Indo Pacific	Suez Canal	unknown	Lewinsohn and Holthuis 1964
Callinectes sapidus Rathbun, 1896	before 1955, unknown	alien	Western Atlantic	vessels	unknown	Holthuis and Gottlieb 1955
Carupa tenuipes Dana, 1851	2002, Tel Aviv	alien	Indo Pacific	Suez Canal	unknown	Galil 2004
Charybdis helleri (A. Milne Edwards, 1867)	1925, Haifa Bay	alien	Indo West Pacific	Suez Canal	unknown	Steinitz 1929
Charybdis longicollis Leene, 1938	1961, Tel Aviv	alien	Indian Ocean;Persian Gulf	Suez Canal	nuisance to fisheries	Lewinsohn and Holthuis 1964
Coleusia signata (Paulson, 1875)	1953, Bat Yam	alien	Indo West Pacific	Suez Canal	unknown	Holthuis 1956
Dorippe quadridens Fabricius, 1793	2004, Ashdod	alien	Indo West Pacific	Suez Canal	unknown	Galil 2005
Eucrate crenata de Haan, 1835	1994, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Galil 1997
Halimede tyche (Herbst, 1801)	1998, Palmahim	single record	Indo West Pacific	Suez Canal	unknown	Galil 2000
Hyastenus hilgendorfi de Man, 1887	1960, Palmahim	alien	Indo West Pacific	Suez Canal	unknown	Lewinsohn and Holthuis 1964, Galil 2006
Ixa monodi Holthuis & Gottlieb, 1956	1977, Palmahim	alien	Red Sea	Suez Canal	unknown	Galil and Golani 1990
Leptochela pugnax de Man, 1916	1947, Tel Aviv	alien	Indo West Pacific	Suez Canal	unknown	Holthuis and Gottlieb 1958
Macrophthalmus graeffei A. Milne Edwards, 1873	2002, Tel Aviv, Ashquelon	alien	Indo West Pacific	Suez Canal	unknown	Ksiunin and Galil 2004
Marsupenaeus japonicus (Bate, 1888)	before 1951, unknown	alien	Indo Pacific	Suez Canal	commercially valuable; displaced native species	Gottlieb 1953
Melicertus hathor (Burkenroad, 1959)	1997, Haifa Bay	alien	Indian Ocean	Suez Canal	unknown	Galil 1999
Metapenaeopsis aegyptia Galil & Golani, 1990	1987, Palmahim	alien	Indo Pacific	Suez Canal	unknown	Galil and Golani 1990
Metapenaeopsis mogiensis consobrina (Nobili, 1904)	1996, Palmahim	alien	Indo West Pacific	Suez Canal	unknown	Galil 1997
Metapenaeus monoceros (Fabricius, 1798)	before 1951, unknown	alien	Indo West Pacific	Suez Canal	commercially valuable; displaced native species	Gottlieb 1953

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Metapenaeus stebbingi (Nobili, 1904)	1958, Haifa Bay	alien	Indian Ocean	Suez Canal	commercially valuable; displaced native species	Lewinsohn and Holthuis 1964
Myra subgranulata Kossmann, 1877	1929, Jaffa	alien	Western Indian Ocean	Suez Canal	unknown	Monod 1930
Notopus dorsipes (Linnaeus, 1758)	1962, Atlit	single record	Indo West Pacific	Suez Canal	unknown	Lewinsohn and Holthuis 1964
Ogyrides mjoebergi (Balss, 1921)	1947, Cesarea	alien	Indo West Pacific	Suez Canal	unknown	Holthuis and Gottlieb 1958
Palaemonella rotumana (Borradaile, 1898)	1948, Haifa Bay	alien	Indo West Pacific	Suez Canal	unknown	Holthuis and Gottlieb 1958
Panulirus ornatus (Fabricius, 1798)	1988, Haifa Bay	single record	Indo West Pacific	Suez Canal	unknown	Galil et al. 1989
Penaeus semisulcatus de Haan, 1844	before 1951, unknown	alien	Indo West Pacific	Suez Canal	commercially valuable; displaced native species	Gottlieb 1953
Pilumnopeus vauquelini (Audouin, 1826)	1951, Haifa Bay	alien	Western Indian Ocean	Suez Canal	unknown	Holthuis 1956
Portunus pelagicus (Linnaeus, 1758)	before 1924, unknown	alien	Indo Pacific	Suez Canal	commercially valuable	Fox 1924
Thalamita poissonii (Audouin, 1826)	1952, Bat yam	alien	Indo West Pacific	Suez Canal	unknown	Holthuis and Gottlieb 1958
Trachysalambria palaestinensis (Steinitz, 1932)	1924-1925, probably Haifa Bay	alien	Red Sea	Suez Canal	unknown	Steinitz 1929
Stomatopoda						
Clorida albolitura Ahyong & Naiyanetr, 2000	2006, Ashdod	alien	Indo West Pacific	Suez Canal	unknown	Ahyong and Galil 2006
Erugosquilla massavensis (Kossmann, 1880)	before 1938, Khan Yunes	alien	Red Sea; Persian Gulf	Suez Canal	displaced native species	Steuer 1938
Pycnogonida						
Anoplodactylus californicus Hall, 1912	1951, Cesarea	alien	Subcosmopolitan	Vessels	unknown	Stock 1958
Anoplodactylus digitatus (Buhm, 1879)	1951, Cesarea	alien	Indo West Pacific	Suez Canal	unknown	Stock 1958
Pigrogromitus timsanus Calman, 1927	1960, Mikhmoret	alien	Circumtropical	Vessels	unknown	Lipkin and Safriel 1971
Ectoprocta						
Celleporaria aperta Hincks, 1882	1968, Acre	alien	pantropical	Vessels	unknown	Powell 1969
Reteroporella jermanensis (Waters, 1909)	1974, Haifa Bay	alien	Red Sea	Suez Canal, Vessels	unknown	d'Hondt 1988
Scrupocellaria jolloisi (Audouin, 1826)	before 1988, unknown	alien	Red Sea	Suez Canal	unknown	d'Hondt 1988
Smittina malleolus (Hincks, 1884)	1985, Haifa	alien	circumtropical	Vessels	unknown	d'Hondt 1988

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Mollusca						
Polyplacophora						
Chiton hululensis (Smith E.A *in* Gardiner, 1903)	1934, unknown	alien	Indo West Pacific	Suez Canal	unknown	Barash 1974
Gastropoda						
Acteocina mucronata (Philippi, 1849)	1986, Haifa Bay	alien	Red Sea	Suez Canal	unknown	van Aartsen et al. 1990
Amathia tricarinata (Linnaeus, 1767)	2005, Shiqmona	alien	Indo Pacific	Suez Canal	unknown	Mienis 2006b
Angiola punctostriata (Smith E.A., 1872)	1950, Dor	single record	Red Sea	Suez Canal	unknown	Mienis 1980b
Atys angustatus Smith, 1872	1974, Haifa Bay	alien	Red Sea	Suez Canal	unknown	van Aartsen and Goud 2006a
Atys cylindricus Helbling, 1779	2002, Shikmona	single record	Indo Pacific	Suez Canal	unknown	Mienis 2004a
Bulla ampulla Linnaeus, 1758	1978, Ga'ash	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1982
Bursatella leachi De Blainville, 1817	before 1939, unknown	alien	circumtropical	Suez Canal	unknown	O'Donoghue and White 1940
Caloria indica (Bergh, 1896)	1986, Ashqelon	alien	Indo Pacific	Suez Canal	unknown	Gat 1993
Canarium mutabilis Swainson, 1821	1991, HaBonim	alien	Indo West Pacific	Suez Canal	unknown	Mienis 2001b
Cellana rota (Gmelin, 1791)	1961, Acre	alien	Indian Ocean	Suez Canal	displaced native species	Christiaens 1967
Cerithidium diplax (Watson, 1886)	1961, Bat Yam	alien	Indo Pacific	Suez Canal	unknown	van Aartsen 2006
Cerithidium perparvulum (Watson, 1886)	2004, Rosh HaNikra	alien	Indo Pacific	Suez Canal	unknown	Bogi and Galil 2006
Cerithiopsis pulvis (Issel, 1869)	1978, Dor	alien	Red Sea	Suez Canal	unknown	Mienis 1992
Cerithiopsis tenthrenois (Melvill, 1896)	1982, Haifa Bay	alien	Indian Ocean	Suez Canal	unknown	van Aartsen et al. 1989
Cerithium columna Soweby, 1834	1966, Cesarea	single record	Indo Pacific	Suez Canal	unknown	Mienis 2003a
Cerithium egenum Gould,1849	1971, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Mienis 2001a
Cerithium nesioticum Pilsbry &Vanatta, 1906	1971, Shikmona	alien	Indo West Pacific	Suez Canal	unknown	Mienis 1977
Cerithium scabridum (Philippi, 1848)	1891, Jaffa	alien	Red Sea, Arabian Sea	Suez Canal	displaced native species	Hart 1891
Chelidonura fulvipunctata Baba, 1938	1986, Ashkelon	alien	Indo Pacific	Suez Canal	unknown	Mienis and Gat 1987
Chrysallida fischeri (Hornung & Mermod, 1925)	1974, Haifa Bay	alien	Red Sea	Suez Canal	unknown	van Aartsen and Carroza 1979
Chrysallida maiae (Hornung & Mermod, 1924)	1935, Atlit	alien	Red Sea	Suez Canal	unknown	van der Linden and Eikenboom 1992

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Chrysallida pirintella (Melvill, 1910)	1984, Haifa Bay	alien	Red Sea	Suez Canal	unknown	van Aartsen et al. 1989
Cingulina isseli (Tryon, 1886)	1980, Haifa Bay	alien	Atlantic Ocean, Indian Ocean	Suez Canal	unknown	van Aartsen and Carroza 1983
Clypeomorus bifasciatus (Sowerby G.B II, 1855)	1983, Akhziv	alien	Indo West Pacific	Suez Canal	unknown	Mienis 1985a
Conomurex persicus Swainson, 1821	1983, Shikmona	alien	Persian Gulf, Arabian Gulf	Suez Canal	unknown	Barash and Danin 1986
Dendrodoris fumata (Rüppell & Leuckart, 1830)	1980, Dor	alien	Red Sea	Suez Canal	unknown	Barash and Danin 1986
Diala varia Adams A., 1860	1935, Jaffa	alien	Indo West Pacific	Suez Canal	unknown	Mienis 1984
Diodora funiculata Reeve, 1850	1998, Palmahim	alien	Indo Pacific	Suez Canal	unknown	Mienis 2002b
Diodora ruppellii (Sowerby, 1834)	before 1948, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Haas 1948
Diplodonta bogii van Aartsen, 2004	1982, Hadera	alien	Red Sea	Suez Canal	unknown	van Aartsen 2004
Discodoris lilacina Gould,1852	1974, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1977
Engina mendicaria Linnaeus, 1758	2001, Shikmona	alien	Indo Pacific	Suez Canal	unknown	Mienis 2004a
Ergalatax contracta Reeve, 1846	2001, Jaffa	single record	Red Sea	Suez Canal	unknown	Mienis 2004a
Ergalatax obscura Houart, 1996	2004, Akhziv-Rosh Hanikra	alien	Red Sea	Suez Canal	unknown	Mienis 2006
Erosaria turdus (Lamarck, 1810)	1980, Dor	alien	Indian Ocean	Suez Canal	unknown	Barash and Danin 1986
Finella pupoides Adams A., 1860	1958, unknown	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1977
Flabellina rubrolineata (O'Donoghue, 1929)	1988, Ashkelon	alien	Indo Pacific	Suez Canal	unknown	Gat 1993
Fusinus verrucosus (Gmelin, 1791)	1929, Haifa Bay	alien	Red Sea	Suez Canal	unknown	Gruvel and Moazzo 1929
Gibborissoa virgata (Philippi, 1849)	1970, HaBonim	alien	Indo Pacific	Suez Canal	unknown	van Aartsen et al. 1989
Haliotis pustulata cruenta Reeve, 1846	1961, Shikmona	alien	Red Sea	Suez Canal	unknown	Talmadge 1971
Hypselodoris infucata (Rüppell & Leuckart, 1830)	1965, Caesarea	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1977
Leucotina natalensis (Adams A., 1851)	1978, unknown	alien	Indo Pacific	Suez Canal	unknown	Mienis 1985b
Metaxia bacillum (Issel, 1869)	1978, Dor	alien	Red Sea	Suez Canal	unknown	Mienis 1985b
Monotigma lauta (Adams A., 1851)	1967, unknown	alien	Indo Pacific	Suez Canal	unknown	Lavaleye and Barash 1981
Murchisonella columna (Hedley, 1907)	1997, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Bogi and Galil 1999
Murex forskoehlii Roding, 1798	1932, Haifa	alien	Red Sea	Suez Canal	unknown	Settepassi 1967

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Nassarius obvelatus (Deshayes, 1834)	1968, Haifa Bay	single record	Indian Ocean	Suez Canal	unknown	Barash and Danin 1977
Notocochlis gualteriana (Recluz, 1844)	1966, Caesarea	alien	Indo West Pacific	Suez Canal	unknown	Mienis 2000b
Oscilla jocosa Melvill, 1904	1984, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	van Aartsen et al. 1989
Palmadusta lentiginosa (Gray, 1825)	1990, Tel Aviv	alien	Indian Ocean	Suez Canal	unknown	Mienis 1990
Planaxis griseus (Brocchi, 1821)	1997, unknown	alien	Red Sea	Suez Canal	unknown	Gianuzzi-Savelli et al. 1997
Pleurobranchus forskalii Rüppell & Leuckart, 1828	1975, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1977
Plocamopherus ocellatus Rüppell & Leuckart, 1828	1977, Nizzanim	alien	Red Sea	Suez Canal	unknown	Barash and Danin 1982
Pseudominolia nedyma (Melvill, 1897)	1966, Atlit	alien	Red Sea, Persian Gulf	Suez Canal	unknown	Barash and Danin 1973
Purpuradusta gracilis notata (Gill, 1858)	1981, Hadera	alien	Indian Ocean	Suez Canal	unknown	Mienis and Singer 1983
Pyrunculus fourierii (Audouin, 1826)	before 1989, Haifa Bay	alien	Indo West Pacific	Suez Canal	unknown	van Aartsen et al. 1989
Retusa desgenettii (Audouin, 1826)	1997, Haifa Bay; Ashkelon; Acre	alien	Red Sea	Suez Canal	unknown	Bogi and Galil 2002
Rhinoclavis kochi Philippi, 1848	1963, Haifa Bay	alien	Indo West Pacific	Suez Canal	displaced native species	Barash and Danin 1973
Rhinoclavis sinensis Gmelin, 1791	2003, Palmahim	single record	Indo Pacific	Suez Canal	unknown	Mienis 2004a
Rissoina bertholleti Issel, 1869	1958, Haifa	alien	Indian Ocean	Suez Canal	unknown	van Aartsen 1963
Rissoina spirata Sowerby, 1825	1997, Haifa	single record	Indo Pacific	Suez Canal	unknown	Gianuzzi-Savelli 1997
Sabia conica (Schumacher, 1817) [doubtful]	1980, Dor	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1986
Siphonaria crenata Blainville, 1827	1965, Shikmona	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1973
Sticteulima cf. Lentiginosa (Adams A., 1861)	2004, Rosh Hanikra	alien	Indo Pacific	Suez Canal	unknown	Bogi and Galil 2006
Stomega lorioli (Hornung & Mermod, 1924)	1974, Haifa Bay	alien	Red Sea	Suez Canal	unknown	van Aartsen 1987
Syrnola fasciata (Jickeli, 1882)	1949, Tantura & Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Mienis 1995
Syrnola lendix A. Adams, 1863	1994, Palmahim	alien	Indo Pacific	Suez Canal	unknown	Bogi and Galil 1997
Thais lacera (Born, 1778)	1928, Jaffa	alien	Indian Ocean	Suez Canal	unknown	Mienis 1977
Thais sacellum (Gmelin, 1791)	2004, Segavyon I.	alien	Indian Ocean	Suez Canal	unknown	Mienis 2006c
Trochus erithraeus Brocchi, 1821	before 1973, Shikmona	alien	Red Sea, Persian gulf	Suez Canal	unknown	Barash and Danin 1973
Turbonilla edgarii (Melvill, 1896)	1984, Haifa	alien	Indo Pacific	Suez Canal	unknown	van Aartsen et al. 1989

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Vexillum depexum (Deshayes in Laborde, 1834)	1964, Akhziv	alien	Red Sea	Suez Canal	unknown	Mienis 2004a
Voorwindia tiberiana (Issel, 1869)	1997, Haifa Bay	alien	Red Sea	Suez Canal	unknown	Bogi and Galil 1999
Zafra savignyi (Moazzo, 1939)	1954, Shavei Zion	alien	Red Sea	Suez Canal	unknown	Mienis 1976b
Zafra selasphora (Melvill & Standen, 1901)	1980, Haifa Bay	alien	Indian Ocean	Suez Canal	unknown	van Aartsen 1997
Bivalvia						
Acar plicata (Dillwyn, 1817)	1978, Netanya	single record	Indo Pacific	Suez Canal	unknown	Barash and Danin 1986
Afrocardium richardi (Audouin, 1826)	1997, Haifa Bay	alien	Red Sea, Arabian Sea	Suez Canal	unknown	Bogi and Galil 1999
Alectryonella crenulifera (Sowerby, 1871)	2005, Hadera Port	single record	Indian Ocean	Suez Canal	unknown	Sharon et al. 2005
Anadara natalensis (Krauss, 1848)	1935, unknown	alien	Indian Ocean	Suez Canal	unknown	Haas 1937
Angulus flacca Romer, 1871	1997, Haifa Bay	single record	Indo Pacific	Suez Canal	unknown	Mienis 2004a
Atactodea glabrata (Gmelin, 1791)	1973, Netanya	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1977
Barbatia trapezina Lamarck, 1819	2003, Ashkelon	single record	Indo Pacific	vessels	unknown	Mienis 2004a
Brachidontes pharaonis (Fischer P., 1870)	1935, unknown	alien	Indian Ocean	Suez Canal, vessels	displaced native species	Haas 1937
Chama asperella Lamarck, 1819	2003, Ashkelon	single record	Indo Pacific	vessels	unknown	Mienis 2004a
Chama aspersa Reeve, 1846	2002, Tel Aviv	alien	Indo Pacific	Suez Canal	unknown	Mienis 2004c
Chama brassica Reeve, 1846	2003, Haifa Bay	single record	Indo Pacific	vessels	unknown	Mienis et al. 1993b
Chama pacifica Broderip, 1834	1988, Haifa Bay	alien	Indo Pacific	Suez Canal	Engineering species, displaced native species	Mienis et al. 1993b
Circenita callipyga (von Born, 1778)	1972, Netanya	alien	Red Sea	Suez Canal	unknown	Mienis 2000a
Clementia papyracea (Gray, 1825)	1937, Gaza	alien	Indo Pacific	Suez Canal	unknown	Haas 1948
Divalinga arabica Dekker & Goud, 1994	1976, Netanya	alien	Red Sea, Persian Gulf	Suez Canal	unknown	Mienis 1979
Fulvia australis (Sowerby G.B., 1834)	before 1948, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Haas 1948
Fulvia fragilis (Forsskål *in* Niehbur, 1775)	1955, Haifa Bay	alien	Indian Ocean	Suez Canal	unknown	Barash and Danin 1973
Gafrarium pectinatum (Linnaeus, 1758)	1984, Palmahim	alien	Indo Pacific	Suez Canal	unknown	Mienis 1999

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Gastrochaena cymbium (Spengler, 1783)	1954, Palmahim	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1973
Glycymeris arabicus (Adams H., 1871)	1966, Dor	single record	Indian Ocean	Suez Canal	unknown	Barash and Danin 1977
Hyotissa hyotis Linnaeus, 1758	2003, Ashkelon	single record	Indo Pacific	vessels	unknown	Mienis 2004a
Isognomon ephippium Linnaeus, 1758	2003, Ashkelon	single record	Indian Ocean	vessels	unknown	Mienis 2004a
Laternula anatina (Linnaeus, 1758)	1958, Shikmona	alien	Indo Pacific	Suez Canal	unknown	Barash and Danin 1973
Leiosolenus hanleyanus Reeve, 1857	2003, Ashkelon	single record	Indo Pacific	vessels	unknown	Mienis 2004a
Limopsis multistriata (Forsskål, 1775)	1965, Dor	single record	Indo Pacific	Suez Canal	unknown	Barash and Danin 1977
Mactra lilacea Lamarck, 1818	2001, Acre	alien	Indo Pacific	Suez Canal	unknown	Mienis 2002c
Mactra olorina Philippi, 1846	before 1973, Tel Aviv	alien	Red Sea	Suez Canal	unknown	Barash and Danin 1973
Malvufundus regulus (Forsskål, 1775)	before 1937, unknown	alien	Indo Pacific	Suez Canal	unknown	Haas 1937
Modiolus auriculatus (Krauss, 1848)	1935, Acre	alien	Indian Ocean	Suez Canal	unknown	Haas 1937
Musculista perfragilis (Dunker, 1857)	1960, Bat Yam	alien	Indian Ocean	Suez Canal	unknown	Barash and Danin 1973
Musculista senhousia (Benson *in* Cantor, 1842)	1960, Tel Aviv	alien	NW Pacific	Aquaculture, vessels	unknown	Barash and Danin 1971
Nanostrea exigua Harry, 1985	2004, Haifa Bay	single record	Indo Pacific	Suez Canal, vessel	unknown	Lubinevsky and Mienis 2005
Paphia textile (Gmelin, 1791)	1946, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Haas 1948
Parahyotissa imbricata Lamarck, 1819	2003, Ashkelon	single record	Indian Ocean	vessels	unknown	Mienis 2004a
Pinctada margaritifera (Linnaeus, 1758)	2003, Ashkelon	alien	Indo Pacific	vessels	unknown	Mienis 2004a
Pinctada radiata (Leach, 1814)	before 1899, unknown	alien	Indo Pacific	Suez Canal	unknown	Monterosato 1899
Planostrea pestigris Hanley, 1846	2003, Ashkelon	single record	Indian Ocean	vessels	unknown	Mienis 2004a
Plicatula chinensis Morch, 1853	2003, Ashkelon	single record	Indian Ocean	vessels	unknown	Mienis 2004a
Pseudochama corbieri (Jonas, 1846)	1963, Jaffa	alien	Red Sea	Suez Canal	unknown	Barash and Danin 1973
Redicrice sulcata Gray, 1838	1970, Ashdod	single record	Indo Pacific	vessels	unknown	Mienis 2004a

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Septifer bilocularis (Linnaeus, 1758)	2003, Ashkelon	single record	Red Sea	vessels	unknown	Mienis 2004a
Sphenia ruppellii Adams A., 1850	1978, Netanya	alien	Red Sea, Arabian Sea	Suez Canal, vessels	unknown	Barash and Danin 1986
Spondylus groschi Lamprell & Kilburn, 1995	before 1998, unknown	?	Indian Ocean	Suez Canal, vessels	unknown	Lamparell 1998
Spondylus nicobaricus Schreibers, 1793	2002, Akhziv	alien	Indo Pacific	vessels	unknown	Mienis 2004a
Spondylus spinosus Schreibers, 1793	1988, Haifa Bay	alien	Indo Pacific	Suez Canal, vessels	Engineering species, displaced native species	Mienis et al. 1993a
Theora lubrica Gould, 1861	2006, Haifa Bay	alien	Indo Pacific	vessels	unknown	Bogi and Galil 2007
Timoclea marica (Issel, 1869)	1997, Palmahim	alien	Red Sea	Suez Canal	unknown	Bogi and Galil 1999
Cephalopoda						
Octopus aegina Gray, 1849	1934, Atlit	alien	Indo Pacific	Suez Canal	unknown	Mienis 2004a
Octopus cyanea Gray, 1849	1997, Mikhmoret, Acre	alien	Indo Pacific	Suez Canal	unknown	Mienis 2003b
Sepia gibba Ehrenberg, 1831	2001, Ashdod	single record	Red Sea	Suez Canal	unknown	Mienis, unpublished
Sepia pharaonis Ehrenberg, 1831	2003, Rishon leziyyon to Shiqmona	alien	Indian Ocean	Suez Canal	unknown	Mienis 2003c
Sepioteuthis lessoniana Lesson, 1830	2004, Akhziv	alien	Indo Pacific	Suez Canal	unknown	Mienis 2004a
Echinodermata						
Asterina burtoni Gray, 1840	1953, Haifa	alien	subcosmopolitan	Suez Canal	displaced native species	Tortonese 1966
Ophiactis parva Mortensen, 1926	1968, Haifa Bay	alien	Red Sea	Suez Canal	unknown	Tom and Galil 1991
Ophiactis savignyi Müller & Troschel, 1842	1948, Atlit	alien	circumtropical	Suez Canal	unknown	Tortonese 1953
Synaptula reciprocans Forskål, 1775	1971, Rosh HaNikra	alien	Red Sea	Suez Canal	unknown	Cherbonnier 1986
Chordata						
Chondrichthyes						
Himantura uarnak (Forsskål, 1775)	1954, unknown	alien	Indo Pacific	Suez Canal	unknown	Ben Tuvia 1955
Osteichthyes						
Abudefduf vaigiensis (Quoy & Gaimard, 1825)	1997, Rosh Hanikra	alien	Indo Pacific	Suez Canal	unknown	Goren and Galil 1998
Alepes djedaba (Forsskål, 1775)	1924, Haifa Bay	alien	Indo Pacific	Suez Canal	Commercially valuable	Steinitz 1927
Aphanius dispar (Rüppell, 1829)	1944, Tel Aviv	alien	Indian Ocean	Suez Canal	Hybridizes with the native *A. fasciatus*	Mendelssohn 1947

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Apogon pharaonis Cuvier, 1828	before 1947, unknown	alien	Indo Pacific	Suez Canal	unknown	Haas and Steinitz 1947
Atherinomorus lacunosus (Forster *in* Bloch & Schneider, 1801)	1924, Haifa	alien	Indo Pacific	Suez Canal	Commercially valuable in some countries	Norman 1927
Bregmaceros atlanticus Goode & Bean, 1886	2004, Palmahim	alien	circumtropical	Suez Canal, vessels	unknown	Goren and Galil 2006
Callionymus filamentosus Valenciennes, 1837	before 1953, unknown	alien	Indo Pacific	Suez Canal	displaced native species	Ben Tuvia 1953
Chilomycterus spilostylus Leis & Randall, 1982	1992, Ashdod	alien	Indo Pacific	Suez Canal	unknown	Golani 1993
Crenidens crenidens (Forsskål, 1775)	before 1992, unknown	alien	Indian Ocean	Suez Canal	unknown	Golani 1992
Cynoglossus sinusarabici (Chabunaud, 1913)	before 1953, unknown	alien	Red Sea	Suez Canal	unknown	Ben Tuvia 1953
Decapterus russelli (Rüppell, 1830)	2005, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Golani 2006
Dussumieria elopsoides Bleeker, 1849	before 1949, unknown	alien	Indian Ocean	Suez Canal	commercially valuable	Lissner 1949
Epinephelus coioides (Hamilton, 1822)	1966, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Ben Tuvia and Lourie 1969
Epinephelus malabaricus (Bloch & Schneider, 1804)	1966, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Ben Tuvia and Lourie 1969
Etrumeus teres (DeKay, 1842)	1961, Haifa, Tel Aviv	alien	Cosmopolitan	Suez Canal	commercially valuable	Whitehead 1963
Fistularia commersonii Rüppell, 1835	2000, Jaffa	alien	Indo Pacific	Suez Canal	limited commercial interest	Golani 2000b
Hemiramphus far (Forsskål, 1775)	1924, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Steinitz 1927
Herklotsichthys punctatus (Rüppell, 1837)	before 1943, unknown	alien	Red Sea	Suez Canal	limited commercial interest	Bertin 1943
Hippocampus fuscus Rüppell, 1838	2001, Hadera Port	alien	Indian Ocean	Suez Canal	unknown	Golani and Fine 2002
Lagocephalus sceleratus (Gmelin, 1789)	2004, Jaffa	alien	Indo West Pacific	Suez Canal	poisonous	Golani and Levy 2005
Lagocephalus spadiceus (Richardson, 1844)	1951, unknown	alien	Indo Pacific	Suez Canal	poisonous	Ben Tuvia 1953
Lagocephalus suezensis Clark & Gohar, 1953	1987, Haifa Bay	alien	Red Sea	Suez Canal	poisonous	Golani 1993b
Leiognathus klunzingeri (Steindachner, 1898)	before 1934, unknown	alien	Red Sea	Suez Canal	unknown	Liebman 1934
Liza carinata (Valenciennes, 1830)	Before 1970, Haifa Bay	alien	Indian Ocean	Suez Canal	commercially valuable	Ben Tuvia 1971

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Muraenesox cinereus (Forsskål, 1775)	1979, Tel Aviv	single record	Indian Ocean	Suez Canal	unknown	Golani and Ben Tuvia 1982
Nemipterus japonicus (Bloch, 1791)	2005, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Golani and Sonin 2006
Omobranchus punctatus Valenciennes, 1836	2003, Ashdod	single record	Indo Pacific	Suez Canal, vessels	unknown	Golani 2004
Oxyurichthys petersi (Klunzinger, 1871)	1982, Tel Aviv	alien	Red Sea	Suez Canal	unknown	Ben Tuvia 1983
Papilloculiceps longiceps (Ehrenberg *in* Valenciennes, 1829)	1986, Haifa Bay	alien	Indian Ocean	Suez Canal	unknown	Golani and Ben Tuvia 1990
Parexocoetus mento (Valenciennes, 1846)	before 1935, unknown	alien	Indo Pacific	Suez Canal	limited commercial interest	Bruun 1935
Pelates quadrilineatus (Bloch, 1790)	1969, unknown	alien	Indo Pacific	Suez Canal	unknown	Ben Tuvia and Lourie 1969
Pempheris vanicolensis Cuvier, 1821	1979, Jaffa	alien	Indo Pacific	Suez Canal	unknown	Ben Tuvia 1985
Petroscirtes ancylodon Rüppell, 1835	1988, Nizzanim	alien	Red Sea, Persian Gulf	Suez Canal	unknown	Goren and Galil 1989
Platycephalus indicus (Linnaeus, 1758)	before 1953, unknown	alien	Indo Pacific	Suez Canal	unknown	Ben Tuvia 1953
Plotosus lineatus (Thunberg, 1787)	2001, Ashdod-Ashkelon	alien	Indo Pacific	Suez Canal	venomous	Golani 2002
Pomadasys stridens (Forsskål, 1775)	1971, Haifa Bay	alien	Indian Ocean	Suez Canal	unknown	Ben Tuvia 1977
Pteragogus pelycus Randall, 1981	1991, Haifa Bay	alien	Indian Ocean	Suez Canal	unknown	Golani and Sonin 1992
Pterois miles (Bennett, 1803)	1991, Herzeliya	alien	Indian Ocean	Suez Canal	venomous	Golani and Sonin 1992
Rachycentron canadum (Linnaeus, 1766)	1978, Haifa Bay	alien	Pantropical	Suez Canal	unknown	Ben Tuvia 1985
Rastrelliger kanagurta (Cuvier, 1816)	1967, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Collete 1970
Rhabdosargus haffara (Forsskål, 1775)	1991, Tel Aviv	alien	Red Sea, Persian Gulf	Suez Canal	unknown	Golani 1992
Rhynchoconger trewavasae Ben-Tuvia, 1993	before 1993, Haifa	single record	Red Sea	Suez Canal	unknown	Ben Tuvia 1993
Sargocentron rubrum (Forsskål, 1775)	1947, Haifa Bay	alien	Indo Pacific	Suez Canal	unknown	Haas and Steinitz 1947
Saurida undosquamis (Richardson, 1848)	1952, Haifa Bay	alien	Indo Pacific	Suez Canal	Commercially valuable, displaced native species	Ben Tuvia 1953
Scarus ghobban Forsskål, 1775	2001, Shikmona	alien	Indo Pacific	Suez Canal	unknown	Goren and Aronov 2002
Sciaenops ocellatus (Linnaeus, 1766)	1999, Hadera port	single record	W Atlantic Ocean	Aquaculture	unknown	Golani and Mires 2000

Taxa	Date and location of first record	Status	Native range	Vector/ Pathway	Impact	References
Scomberomorus commerson Lacepede, 1800	before 1935, unknown	alien	Indo Pacific	Suez Canal	Commercially valuable	Hornell 1935
Siganus luridus Rüppell, 1828	before 1964, unknown	alien	Indian Ocean	Suez Canal	Limited commercial value, venomous	Ben Tuvia 1964
Siganus rivulatus Forsskål, 1775	1924, Haifa Bay	alien	Red Sea	Suez Canal	Commercially valuable, venomous	Steinitz 1927
Silhouetta aegyptia (Chabanaud, 1933)	before 1998, Ashdod	alien	Red Sea	Suez Canal	unknown	Golani 1998
Sillago sihama (Forsskål, 1775)	1977, unknown	alien	Indo Pacific	Suez Canal	commercially valuable	Ben Tuvia 1985
Sorsogona prionota (Sauvage, 1873)	1946, unknown	alien	Indian Ocean	Suez Canal	unknown	Haas and Steinitz 1947
Sphyraena chrysotaenia Klunzinger, 1884	before 1931, unknown	alien	Indo Pacific	Suez Canal	commercially valuable	Spicer 1931
Sphyraena flavicauda Rüppell, 1838	1991, Jaffa	alien	Indo Pacific	Suez Canal	unknown	Golani 1992
Spratelloides delicatulus (Bennett, 1831)	1973, Atlit	alien	Indo Pacific	Suez Canal	unknown	Ben Tuvia 1978
Stephanolepis diaspros Fraser-Brunner, 1940	1924, Haifa Bay	alien	Red Sea, Persian Gulf	Suez Canal	unknown	Steinitz 1927
Tetrosomus gibbosus (Linnaeus, 1758)	1987, Shikmona	alien	Indo Pacific	Suez Canal	unknown	Spanier and Goren 1988
Torquigener flavimaculosus Hardy and Randall, 1983	1987, Haifa Bay	alien	Indian Ocean	Suez Canal	unknown	Golani 1987
Tylosurus choram (Rüppell, 1837)	2001, Hadera	alien	Indian Ocean	Suez Canal	unknown	Golani and Levy 2005
Upeneus moluccensis (Bleeker, 1855)	before 1947, unknown	alien	Indo Pacific	Suez Canal	commercially valuable, displaced native species	Haas and Steinitz 1947
Upeneus pori Ben-Tuvia & Golani, 1989	before 1953, unknown	alien	Red Sea, Gulf of Oman	Suez Canal	unknown	Ben Tuvia 1953
Chordata						
Tunicata, Ascidiacea						
Herdmania momus Savignyi, 1816	1955, Haifa Bay	alien	Indo Pacific	vessels	unknown	Peres 1958
Phallusia nigra Savigny, 1816	1952, Caeserea	alien	W Atlantic Ocean	vessels	unknown	Peres 1958