



REVIEW ARTICLE

# Article Review: Lessepsian migration of zooplankton through Suez Canal and its impact on ecological system



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**Abstract** The marine environment of the East Mediterranean has been considerably impacted in modern times by two man-made changes: the creation of a waterway between the Indo-Pacific and the Mediterranean basins and the control of the Nile fresh-water outflow. The opening of the Suez Canal caused a migration generally from the Red Sea to the Mediterranean, and rarely in the opposite direction as the Red Sea is generally saltier and more nutrient-poor than the Atlantic, so the Red Sea species have advantages over Atlantic species in the salty and nutrient-poor eastern Mediterranean. Accordingly Red Sea species invaded the Mediterranean ecosystem and not vice versa; this phenomenon is known as the Lessepsian migration or erythrean invasion. The composition of zooplankton in the eastern Mediterranean has been shown to include a large proportion of Indo-Pacific and other circumtropical species which have successfully settled and proliferated in this environment. During the present study, an overview is provided on zooplankton migration through Suez Canal and its impact on the ecological system based on published literature. It is also meant with the hydrographic and zooplankton characteristics of the adjacent seas. It is clear that, except jellyfish *Rhopilema nomadica*, the negative impact of zooplankton Lessepsian migratory species in the Egyptian Mediterranean waters is not evident. Finally, it would be concluded that, a continuous monitoring programme will be needed to record the recent erythrean zooplankton species and follow up the distribution and abundance of those previously recorded as aliens to assess their impacts on the native biodiversity of the Mediterranean.

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## Background

The Mediterranean Sea is one of the most oligotrophic semi-enclosed basins and its marine life is heavily threatened by habitat degradation due to human activities (Lancelot et al., 2002). In the last few decades, the Mediterranean Sea environment had been affected as responses to climate change. Evidence of a significant increase in temperature had been recorded in the intermediate and deep waters in the Ligurian Sea (Sparnocchia et al., 1994; Bethoux and Gentili, 1999). The marine environment of the East Mediterranean has been considerably impacted in modern times by two man-made changes: the creation of a waterway between the Indo-Pacific and the Mediterranean basins and the control of the Nile fresh-water outflow (Halim, 1990). The Eastern Mediterranean particularly the Levantine Basin is the most impoverished oligotrophic water body in terms of productivity and nutrient concentrations (Krom et al., 1991). The supply of nutrients to the Mediterranean is limited by inputs from the Atlantic Ocean and those of various rivers surround it (Hecht and Gertman, 2001).

In aquatic environments, zooplankton plays an important role in the transfer of energy from primary producers to the higher levels in the food chain. Furthermore they are themselves favourite food items for many animals including economic fishes. In this respect, the quantitative and qualitative investigation of zooplankton organisms in any aquatic environment is essential regarding the knowledge about the productivity and diversity in that specific environment (Toklu and Sarihan, 2003). The most numerous, important and wide spread group of marine zooplankton is the Copepoda, forming usually 50–90% numerically of the zooplankton community (Mauchline, 1998; Steinberg et al., 2002; Steinberg et al., 2004; Walter and Boxshall, 2008; Al-Mutairi, 2009; Krsinic and Grbec 2012; El-Naggar, 2014). They constitute an important part of the marine food chain because they serve as a primary food source for many carnivores (Bouley and Kimmerer 2006). El-Rashidy (1987) found that, most of the fish larvae in the south-eastern Mediterranean feed on pelagic copepods.

The Suez Canal was opened in order to shorten the commercial navigation ways between the Mediterranean and Indian Ocean in 1869. Its effect on the water and salt budgets of the adjacent seas had almost no significant impact, but its biological role is especially more effective (Halim, 1990). The opening of the Suez Canal caused a migration generally from the Red Sea to the Mediterranean, and rarely in the opposite direction as the Red Sea is generally saltier and more nutrient-poor than the Mediterranean Sea, so the Red Sea species have advantages over Mediterranean species in their tolerance to the new environment. Accordingly, Red Sea species invaded the Mediterranean biota and not vice versa; this phenomenon is known as the Lessepsian migration or erythrean invasion. Several authors have focused their research activities on the role of the Suez Canal as a pathway to the migration of

several marine organisms and their impact on the ecological changes that occur in the Canal area. (Steinitz, 1967, 1968; Por and Ferber, 1972; Kimor, 1972, 1983; Alvarino, 1974; Lakkis, 1976; Halim, 1990; Por, 1990; Avsar, 1999; Abdel-Rahman, 1997, 2005; Mavruk and Avsar, 2008). Studies related to this phenomenon were concentrated mainly on fish migration because of their economical importance. Therefore, the present work provides an overview on zooplankton migration through Suez Canal and its impact on the ecological system based on published literature. It is also meant with the hydrographic and zooplankton characteristics of the adjacent seas.

## Hydrographic characteristics of Mediterranean Sea, Red Sea and Suez Canal

The Mediterranean Sea, as depicted in Fig. 1, is an enclosed basin connected to the Atlantic Ocean by the narrow Strait of Gibraltar whose width is 13 km and sill depth is 300 m and connected to the Black Sea by the Dardanelles/Marmara Sea/Bosphorus system. It is comprised of two sub-basins, the Western Mediterranean (WMED) and the Eastern Mediterranean (EMED), connected by the Strait of Sicily whose width is about 35 km and whose sill depth is about 300 m. The EMED is more complicated than the WMED. It consists of four sub-basins; the Ionian Sea, the Levantine, the Adriatic, and the Aegean Seas.

The circulation and hydrography of the Mediterranean Sea waters as described by Zavatarelli and Mellor (1995) are driven by the net fresh water loss and heat loss to the atmosphere and the exchange of salinity and heat through the Strait of Gibraltar. The loss by evaporation exceeds the input by precipitation and river runoff and Black Sea exchange. The existence of the two counterflows in the Strait of Gibraltar requires a basin transformation to link the inflowing Atlantic Water with the outflowing Levantine Intermediate Water (LIW). The surface waters, the Modified Atlantic Water (MAW), flowing into the Mediterranean are subject to evaporation and mixing with the underlying waters, causing a progressive increase of the salinity; the surface value increases from 36.25 psu in the Gibraltar area to 37.25 psu in the Strait of Sicily and to values higher than 38.50 psu in the Levantine Sea. Its west to east path across the Mediterranean can be tracked by a subsurface salinity minimum (Lacombe and Tchernia, 1960), representing the signature of their Atlantic origin, which progressively deepens 20–50 m.

The LIW depth range is 300–700 m in the WMED and 200–400 m in the EMED. LIW is the result of winter convection processes in the EMED occurring in the Rhodes-Cyprus area, and probably in other sections of the Levantine Sea in winter (Morcos, 1972; Said and Karam, 1990; Abdel-Moati and Said, 1987). At its source, LIW has a salinity of about 39.10 psu and spreads to the whole Mediterranean ( $S_{‰} = 38.70$  psu at the



Figure 1 The Mediterranean Sea.

Strait of Sicily), reaching Gibraltar where it forms the Mediterranean outflow into the Atlantic Ocean.

The Red Sea forms a long and narrow trench, roughly NNW-SSE oriented, about 1930 Km long and 270 Km wide between 12°N and 28°N (Maillard and Soliman, 1986). North of 28°N the sea is bounded by the shallow Gulf of Suez to the west and the deep Gulf of Aqaba on the eastern side. The continental shelf (less than 50 m depth) is widely extended in the southern half of the Red Sea. The central trough more than 1000 m, deep is found north of 16°N; its width is about 50 Km and the deepest parts reach 2700 m. This long and narrow basin is connected with the Indian Ocean through the narrow Strait of Bab al Mandab at the south.

In the Red Sea, evaporation is active and largely exceeds precipitation so that salinity and temperature are comparatively high. Surface salinity rapidly rises from less than 37 psu at the southern entrance, to 40–41 psu in the northern Red Sea and the Gulf of Aqaba, and to more than 41 psu in the Gulf of Suez. The average surface temperature fluctuates between 25 °C and 32 °C in the south, 21.3 °C and 27.9 °C in the northern Red Sea. The Gulf of Suez shows a slightly greater amplitude, from 17.9 °C to 26.5 °C. The lower layers from about 300 m downwards, are almost homothermal, near 21.7 °C, except for an adiabatic increase in the deeper waters, and homohaline around 40.5–40.6 psu. The Red Sea deep waters are warmer than any other marine basin at corresponding levels. A layer of minimum oxygen is present at 300–600 m, with very low values of 0.4–0.6 ml/l at the minimum (Halim, 1969).

The outline of the circulation pattern in the Red Sea (cited in Morcos, 1970) is the inflowing water from the Gulf of Aden in the south, which after passing the Strait, is deflected towards the eastern coast. This less dense water occupies the upper stratum, which by penetrating to the north, undergoes a gradual increase of salinity and decrease of temperature. Arriving at the northern edge of the Red Sea, it sends a branch in the

Gulf of Aqaba, turns to the west, and sends another branch to the Gulf of Suez, but its main mass reaches the African coast where becoming more saline through the influence of the Gulf of Suez, it sets southwards along this coast.

The Suez Canal lies between longitudes 32°20' and 32°35'E, and between latitudes 29°55' and 31°15'N (Fig. 2). It is a passage between the Mediterranean Sea at Port Said and Red Sea at Port Taufiq. The Suez Canal has a total length of 193 Km and a depth of 26 m creating the first salt-water passage between the Mediterranean and Red Seas. The Red Sea is higher than the Eastern Mediterranean, so the Canal serves as a tidal strait that pours Red Sea waters into the Mediterranean. The physico-chemical conditions within the Suez Canal remained inhospitable for marine organisms from both seas for long and hence the species that succeeded in crossing the Canal and surviving in the opposite sea must have remained limited in number until the conditions improved. The Suez Canal being a narrow and shallow water course, its turbidity and temperature are higher than those of the adjacent seas. In addition, the Bitter Lakes, which are hyper saline natural lakes that form part of the Canal, south, and the Nile fresh water dilution, north, acted as two selective salinity barriers blocking the migration of the Red Sea species into the Mediterranean for many decades, but as the salinity of the lakes gradually equalized with that of the Red Sea, the barrier to migration was removed, and plants and animals of the Red Sea have begun to colonize the Eastern Mediterranean. The construction of Aswan High Dam across the Nile River in the 1965 reduced the inflow of fresh water and nutrient-rich silt from the Nile into the Eastern Mediterranean, making conditions there even more like the Red Sea and worsening the impact of the invasive species. The migration process is increasing from south towards the north of the Suez Canal particularly after the disappearance of hydrological barriers (Kimor, 1972) and the increasing salinity in the Levantine Basin after the construction of Aswan High Dam (Oren, 1969; Por, 1971, 1978). The uplifting of the two salinity

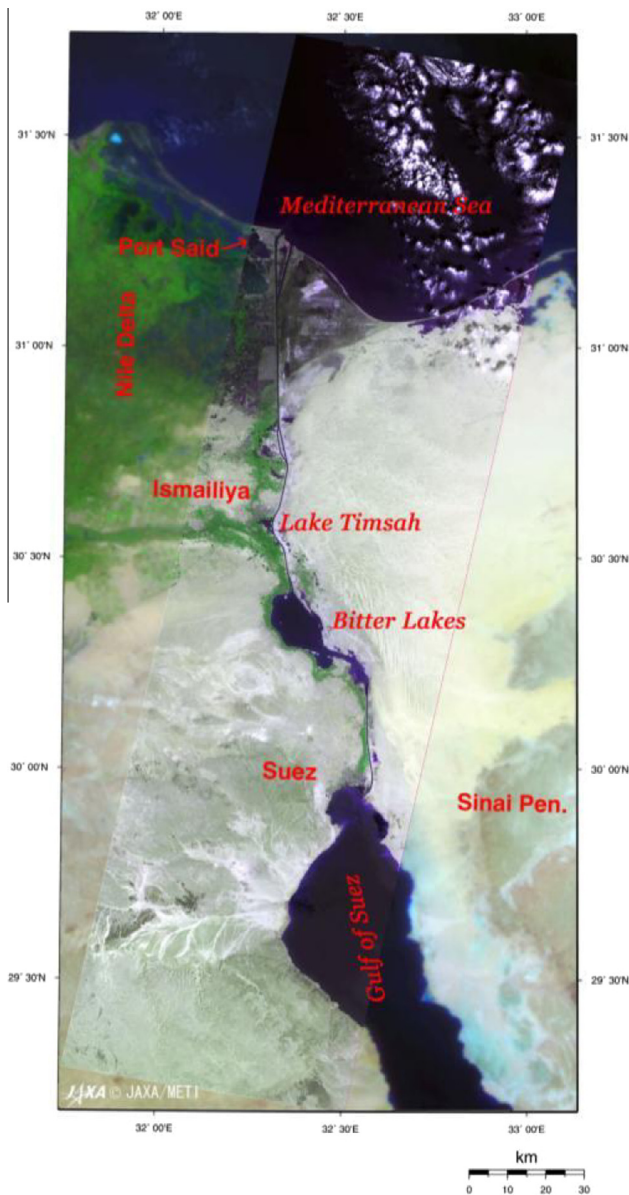


Figure 2 The Suez Canal.

barriers and considerable widening and deepening of the Canal in recent times have created conditions which are likely to accelerate the biological exchanges (Halim, 1990).

#### Zooplankton characteristics of Mediterranean Sea, Red Sea and Suez Canal

The marine biota of the Mediterranean is derived primarily from the Atlantic Ocean. The North Atlantic is considerably colder and more nutrient-rich than the Mediterranean, and the marine life of the Mediterranean had to adapt to its differing conditions in the five million years since the basin was reflooded. A study of the currents and the general hydrography of the area may provide a clue to the pattern of distribution. The composition of zooplankton has been shown to include a large proportion of Indo-Pacific and other circum-tropical species which have successfully settled and

proliferated in this environment. Emig and Geistdoerfer (2004) mentioned the origin of the Mediterranean species as follows; Atlantic origin 50.2%, endemic species 28.6%, Atlantico-Pacific origin 16.8% and Indo-Pacific origin 4.4%.

In separate areas of the Mediterranean Sea, many observations on zooplankton have given valuable information on systematic, population structures and distribution. The zooplankton of the Mediterranean Sea particularly the western basin has attracted the attention of several investigators: Giesbrecht (1892, 1897), Rose (1924, 1926, 1929, 1931, 1933), Tregouboff and Rose (1957), Bernard (1958), Furnestin (1960, 1965, 1966, 1968), Gaudy (1962, 1963, 1972, 1985), Mazza (1962, 1963, 1966), Boucher and Thiriot (1972).

There were several articles concerning the specific composition and population assemblages of zooplankton in limited or more extended areas of the western Mediterranean Sea (Riera and Blasco, 1967; Bernard, 1967; Vives, 1967, 1978; Ehrhardt, 1967; Soenen, 1969; Hure and Scotto di Carlo, 1969; Hure et al., 1980; Scotto di Carlo and Ianora, 1983; Seguin et al., 1993; Ragosta et al., 1995; Champalbert 1996; Fernandez de Puelles et al., 2007).

Copepods usually account for 45–95% of the zooplankton population. They are particularly abundant in the Liguro-Provençal zone (Gilat et al., 1965; Gaudy, 1971b, 1972; Champalbert, 1971a,b, 1975; Gaudy, 1985; Razouls and Kouwenberg, 1993; Ragosta et al., 1995), as in the Balearic Sea (Fernández de Puelles and Salvà Picó, 1992; Jansà and Fernández de Puelles, 1990; Fernandez de Puelles et al., 2007). Similarly, in the Bay of Alger and surroundings, proportions of copepods ranged between 70 and 80% (Bernard, 1955).

In neritic waters, *Clausocalanus arcuicornis*, *Centropages furcatus*, *Paracalanus parvus*, *Centropages typicus*, *Centropages chierchiae*, *Temora stylifera*, *Acartia clausi*, *Oithona helgolandica*, *Oithona nana*, *Euterpina acutifrons*, *Oncaeiidae* and *Corycaeiidae* are the most abundant species or families (Gaudy, 1962, 1971a,b, 1985). In the euphotic layer *C. arcuicornis*, *C. furcatus*, *P. parvus* and *C. typicus* often contribute for 75–95% of the copepods, *Calanus minor*, *Pleuromamma*, *Oncaeiidae*, *Corycaeiidae*, *Microsetellidae*, *Euchaetidae*, *Candacidae*, *Sapphiriniidae* are more characteristic of oceanic waters (Gaudy, 1985). In the neuston layer, pontellids often constitute the major diurnal biomass (Champalbert, 1969, 1975; Zaitsev, 1968), among the most abundant species, *Anomalocera patersoni*, *Pontella lobiancoi*, *Pontella atlantica*, *Pontellopsis regalis* have an Atlantic origin and are abundant in oceanic waters whereas *Pontella mediterranea* and *Labidocera wollastoni* are rather neritic species.

Cladocerans rank second in importance. They can account for 19% (Rodríguez Martínez, 1979). In the Balearic Sea, cladocerans often were about 7% of total planktons (Fernández de Puelles and Salvà Picó, 1992). Frequently, they are numerous in ports and eutrophicated areas (Patriiti, 1973, 1984). In the Gulf of Naples, *Podon polyphemoides*, *Evadne tergestina* and *Penilia avirostris* contribute 60% of the whole zooplanktonic population during summer (Ianora et al., 1985).

Appendicularians represent about 19% of the planktonic population in the Catalan Sea (Vives, 1966), 4–6% in the Balearic Sea (Fernández de Puelles and Salvà Picó, 1992) and 3.7% in the Sardinia channel (Ehrhardt, 1967). Usually, they do not constitute high biomass in zooplankton communities but their intense metabolisms induce immediate responses to trophic conditions (Gorsky and Palazzoli, 1989; Gorsky et al.,

1991) and as a consequence of their high excretion rate, they participate in nitrogen remineralization in the euphotic zone. Moreover, their house secretions contribute significantly to organic matter fluxes (Gorsky et al., 1984; Gorsky et al., 1991).

Chaetognaths (*Sagitta setosa*, *Sagitta enflata*) may represent about 2.5% of total zooplankton near Castellon (Vives, 1966), 2–3% in the Balearic Sea (Fernández de Puelles and Salvà Picó, 1992).

Ostracods are more numerous in deep waters than in the epipelagic zone (Leveau, 1965; Alcaraz, 1977; Scotto di Carlo et al., 1984).

Gelatinous plankton is numerous in the Ligurian Sea (Laval et al., 1989) and the Catalan coast (Sabatés et al., 1989). Two species often occur sporadically in swarms (*Thalia democratica*, *Doliolum nationalis*) making the major part of the planktonic biomass.

From the Alboran Sea to the Sicilo-Tunisian Strait zooplankton diversity is high. In frontal structures such as the Almeria-Oran front Seguin et al. (1993) and Thibault et al. (1994) found that copepods (both neritic and oceanic in origin) made up 85–95% of the organisms among which more than 50% belonged to *Oithona*, *Paracalanus*, *Clausocalanus* genera; *Oncaea*, *Temora* and *Calanus* were also fairly abundant. Along the Algerian coast the Atlantic influence is important. In the Bay of Alger, Bernard (1955) has highlighted the prevalence of Atlantic elements often with a tropical character (*Temora longicornis*, *Acartia danae*, *C. chierchiai*, *Sagitta friderici*, *S. tasmanica*, *S. planctonis*). In the Sardinia channel, Soenen (1969) reported 235 planktonic species among which 104 copepod species were always more than 50% of the total plankton. He noted the simultaneous presence of neritic and oceanic species in areas with a narrow continental shelf. Among the copepods, *C. minor*, *C. araucornis*, *Eucalanus elongatus*, *T. stylifera*, *C. typicus*, *Oithona plumifera* were the most frequent and among the other groups, *S. enflata*, *Oikopleura fusiformis*, *Oikopleura longicauda* and *Limacina inflata*.

In lagoons or very littoral and eutrophic areas, only a few eurybiotic species such as *A. clausi*, *Sagitta setosa*, *P. polyphemoides*, *Balanus* larvae can resist (Patrioti, 1976, 1984; Della Croce and Boero, 1976; Sertorio et al., 1980; Sertorio and Zoli, 1980; Arfi et al., 1982; Champalbert and Patrioti, 1982).

The eastern Mediterranean has received intensive work by many authors: Kimor (1965, 1971), Chakroun (1966), Kimor and Berdugo (1967), Evans (1968), Berdugo and Kimor (1968), Seguin (1968), Kiortsis (1969), Lakkis (1971, 1974, 1976), Soenen (1972), Kimor and Wood (1975), Pasteur et al. (1976).

Many studies have shown similar standing stocks in the western and the eastern parts of the Mediterranean Sea. Most species were found in both basins. In the eastern basin the fauna is rich, but the Adriatic and the Black Sea behave as specific ecosystems (Vucetic, 1957, 1971; Gamulin, 1979; Hure et al., 1980; Porumb et al., 1981; Fonda Umani et al., 1985, 1992; Petran, 1985; Vinogradov et al., 1985).

The Copepoda is by far the most important group in the composition of the zooplankton both in regard to biomass and number of species. This had been shown by Berdugo (1969) regarding The Mediterranean coastal waters of Israel and by Pasteur et al. (1976) in relation to coastal and inshore waters of the eastern Mediterranean. *Centropages violaceus* was considered by Della Croce (1959) and Gaudy (1963) as an indicator of Atlantic species in the eastern Mediterranean. Forty species of Copepoda had been recorded in the eastern

Mediterranean basin by Kimor and Wood (1975). Among them, *C. araucornis*, *C. furcatus*, *T. stylifera* and *Haloptilus longicornis* were the most important as biomass components. In the Ponto-Mediterranean Province, the geographical distribution of 19 species belonging to the family Acartiidae was studied by Belmonte and Potenza (2001).

The Adriatic Sea encompasses two main parts with different characteristics: the shallow northern region has a neritic character and is influenced by river discharge; the southern region, much deeper, has an oligotrophic character (Fonda Umani et al., 1994; Fonda Umani, 1996; Russo and Artegiani, 1996). Specific composition of zooplankton communities is very similar to that observed in other Mediterranean regions (Hure et al., 1980; Regner et al., 1985; Fonda Umani et al., 1992, 1994). Copepods are numerous, especially in the north (41–99% in coastal areas; ~94% in open sea). In the central Adriatic, they represent 82% and 68% of overall plankton in coastal and open sea waters respectively and, in southern Adriatic 41% and 61% (Regner et al., 1985). In the north and the central Adriatic Sea, *P. avirostris*, *E. tergestina*, *Euphausia spinifera*, *Evadne nordmanni* and *A. clausi* are numerous; *A. clausi* often alternates with *P. avirostris* (Fonda Umani et al., 1985). The cladoceran species *P. polyphemoides* known as a neritic euryhaline species was considered by Komarovskiy (1952) as a possible indicator of the Nile flood off the Mediterranean coast of Israel.

In the Aegean and the Levantine Seas, copepods were by far the dominant component (64–92%), chaetognaths (10%) were more abundant in deep zooplankton samples whereas appendicularians mainly occurred in the upper layer (21%), doliolids made 6–9% (Weikert and Trinkaus, 1990; Pancucci-Papadopoulou et al. 1992; Lakkis and Toklu, 2007). Uysal et al. (2002) identified 76 copepod species from the northern Levantine basin including four new species. 33 species of Copepoda and 3 species of Cladocera were recorded along Iskenderun Bay by Toklu and Sarihan (2003). An increased number of ostracods were found in deep layers as previously reported in Rhodes island waters by Kimor and Wood (1975). These observations also agree with previous investigations carried out in the Aegean and the Levantine Sea (Delalo, 1966a; Pasteur et al., 1976; Moraitou-Apostolopoulou, 1985; Siokou-Frangou and Pancucci-Papadopoulou, 1988; Brautovic et al., 2007).

The diversity of copepods from Lebanese and Egyptian waters is high and almost equivalent. Dowidar and El Maghraby (1972), Dowidar (1985), Lakkis (1984, 1990, 1998), Lakkis and Zeidane (2004) found some Indo-pacific species such as *Labidocera pavo*, *Labidocera Madura*, *Calanopia elliptica* and *Calanopia media* whose presence is limited to a short period of the year. The number of copepod species (173) found in the eastern basin (Lakkis, 1990) is very close to the number of species (70–176 species) found in the western basin (Mazza, 1966; Vives, 1966; Razouls, 1972; Vives et al., 1975; Gaudy, 1985). *O. longicauda* and *Oikopleura dioica* represent about 86% of the whole appendicularian populations in the Lebanese waters (Lakkis and Zeidane, 1985).

Comparison of data from the eastern basin showed uniformity of zooplankton composition in the western and eastern Mediterranean Sea (Champalbert, 1996). Specific diversity is lower inshore, especially when the continental shelf is narrower than offshore. The neritic community consists of a few species with  $\geq 50\%$  copepods. Specific assemblages with low diversity

inhabit brackish or eutrophic areas. The oceanic community encompasses neritic and oceanic species in low densities; but its diversity is high. In the western basin, specific diversity tended to decrease eastwards from the strait of Gibraltar and the Alboran Sea, which is rich and influenced by water of Atlantic origin (Champalbert, 1996). In the eastern basin, the diversity was a maximum in the easternmost Levantine waters. The deep water fauna, mainly composed of mesopelagic species, is fairly uniform all over the Mediterranean but poorer than the Atlantic deep fauna. Beside variations related to hydrology and biotic factors, important changes of zooplankton composition are induced by passive horizontal transport (Champalbert, 1996).

Water mixing and consequent uniformization change the distribution of zooplankton and induce important interactions between neritic, oceanic and deep plankton: some species such as *Calanus helgolandicus*, common in the neritic zone of Atlantic waters, and frequent in Mediterranean offshore waters, come from subsurface or deep waters by upwelling (Champalbert, 1996). Comparisons between the western and the eastern basin show that zooplankton composition is not very different and the number of species is equivalent despite a few exceptions and local fluctuations. In both basins, diversity indexes decrease from the oceanic to the neritic and the most coastal waters. The oceanic community includes species of oceanic character with low densities and neritic species. The neritic community is composed of few species which constitute the bulk of the community. The deep water fauna, which consists of mesopelagic species essentially, constitutes a uniform community throughout the Mediterranean Sea, with limited geographic variations (Mazza, 1967; Hure and Scotti di carlo, 1968; Casanova, 1974). Eutrophic or brackish areas are inhabited by specific assemblages with low diversity.

The Mediterranean zooplankton assemblage is very close to that of the Atlantic and reveals both temperate and tropical influences. Endemic species are rare and speciation seems restricted to littoral waters (Crisafi, 1974; Furnestin, 1979). The majority of copepods, from Indo-pacific origin (Sewell, 1948), belongs to the Mediterranean-Atlantic fauna and a few species come from the Atlantic or the Arctic Ocean (Gaudy, 1985). In the Alboran Sea and the southwestern basin, enriched by the Atlantic flow, specific diversity and abundance are much higher than in the Catalan Sea (Furnestin, 1968). Species seem to be transferred towards the Sicilo-Tunisian strait; their number decreasing eastwards with the lesser importance of the Atlantic flow. In the eastern basin, tropical and subtropical elements dominate and diversity is fairly high. Some copepod species from Lebanese waters belong to the hot temperate and subtropical types of the Mediterranean fauna (Lakkis 1971; Gaudy, 1985) and a few species (genera *Calanopia*, *Arietellus*) have been reported as new immigrants through the Suez Canal in the eastern Mediterranean.

Studies carried out before and after the erection of Aswan dam in Egypt showed drastic changes in copepod composition and densities off Abu Kir and Nile delta (Dowidar, 1985). The problem of the immigration of species from the Red Sea remains complex (Dowidar, 1985). Zooplankton distribution and migration are affected by both biotic (e.g. predation, competition) and abiotic factors (David et al., 2005; Isari et al., 2007; Marques et al. 2007a,b). Hydrological parameters are directly influenced by climatic variations. Understanding how hydrological shifts affect communities can reveal the

importance of the ecological role played by climate change events on the structure of zooplankton communities (Marques et al. 2007a).

The climate variability and anthropogenic activities have great impacts on zooplankton community in the Egyptian Mediterranean waters; increased temperatures are associated with the successful establishment of both tropical non indigenous species and indigenous species with warm-water affinity (Zakaria, 2014). On the other side, the ballast water regarded as the main factor affecting the introduction of non-indigenous aquatic organisms (Subba Rao et al., 1994; Smith, 1995; Gollasch, 1996). Gollasch et al. (2000) emphasized that at least semiplanktonic organisms, such as harpacticoid copepods, are able to thrive and reproduce in ballast water tanks. A ballast water tank can thus function as an incubator during the cruise for some species. This fact may have some impact on the release of non-indigenous species in the destination harbour or in near-coastal waters where the ballast tanks are emptied (El-Naggar, 2014).

Horizontal transport during vertical migration may, to a certain extent, favour the exchange of fauna; transitional areas contribute to connect the Mediterranean Sea and the adjacent oceans and seas, i.e. the Alboran Sea with the Atlantic, the North Aegean Sea with the Black Sea and the south-eastern Mediterranean with the Red Sea (Champalbert, 1996).

Zooplankton of the Red Sea had been previously studied by different authors. Ponomareva (1966) made a quantitative estimation of zooplankton in the Red Sea. Delalo (1966b) estimated the zooplankton biomass in the Red Sea and Gulf of Aden. Halim (1969) reported a preliminary review on both phytoplankton and zooplankton in the Red Sea and Gulf of Aqaba. Further, Bergren and Boersma (1969) estimated the planktonic Foraminifera from the Red Sea. Gordeyeva (1970) studied the distribution of zooplankton in the northern and central parts of the Red Sea. Weikert (1982) described the vertical distribution of zooplankton as affected by the prevailing ecological conditions along the central part of the Red Sea. Al-Aidaros (1984) studied the zooplankton communities with special reference to Copepoda north of Jeddah. Echelman and Fishelson (1988, 1990) studied the seasonal surface zooplankton dynamics in the Gulf of Aqaba near Eilat. Beckmann (1988) studied the seasonal patterns of mesopelagic calanoid copepods in the central Red Sea. Almeida Prado-Por (1983, 1988) studied the diversity, dynamics and vertical migration of calanoid copepods in the Gulf of Aqaba. Qualitative estimation of phytoplankton and zooplankton of the northern Red Sea and Gulf of Aqaba were carried out by El-Sherif and Aboul-Ezz (2000). Dowidar (2003a) studied the mesozooplankton distribution and abundance in the Gulf of Aqaba and northern Red Sea. An examination of plankton samples collected from the inshore and offshore waters in the vacancy of Hurghada area in the Egyptian Red Sea coast revealed the presence of a diverse community of planktonic tintinnids (Abou Zaid and Hellal, 2012).

Planktonic Copepoda in the Red Sea attracted the attention of different investigators. Bottger-Schnack (1995) recoded that Copepoda were the dominant taxa in the central and southern parts of the Red Sea contributing 84–92% to the total number of the zooplankton. In the northern part of the Red Sea the copepod population represents 86% of the total community (Dowidar, 2003a). 158 species were compiled by Halim (1969) from the records of Giesbrecht (1891, 1897), Steuer

(1898), Cleve (1900, 1903), Scott (1902), Thompson (1900), Thompson and Scott (1903), Sciacchitano (1930), Santucci (1937) and Pesta (1941, 1943). Since then, nine more copepod species were recorded from the Gulf of Aqaba, four from the southern Red Sea and 32 from the main basin by Weikert (1982).

Recent investigations of the Red Sea Copepoda revealed a much greater wealth in species than was previously suspected (Abdel-Rahman, 1999; El-Sherif and Aboul-Ezz, 2000; Bottger-Schnack, 2001, 2002; El-Serehy and Abdel-Rahman, 2004; Abdel-Rahman and Aboul-Ezz, 2005). The recorded Red Sea copepods now reach about 74% of the Indian Ocean population. Their pattern of distribution characterized by a decreasing gradient from the south to north and a periodical winter influx through Bab el Mandab, as outlined earlier (Halim, 1969), remains valid and is confirmed by Schneider et al. (1994). A gradual impoverishment in winter immigrants is observed along the longitudinal axis of the Red Sea. In spite of this a small number of species will succeed to reach the Gulf of Suez, penetrate into the Canal and establish themselves in its lakes (Halim, 1990).

Calanoid copepods are outstanding holoplanktonic copepods and tend to dominate the zooplankton communities in the Red Sea and its nearby water bodies of Gulf of Aqaba, Gulf of Suez and Suez Canal. 124 calanoid copepods were recorded for the period extending from 1897 till 2000 (Abdel-Rahman and El-Serehy, 2004). Only 60 calanoid species are considered a distinctive local endemic fauna: Red Sea (43 species), Gulf of Aqaba (9 species), Gulf of Suez (5 species) and Suez Canal (3 species). The remainder 64 calanoid species have been considered with common but not local endemic distributional pattern.

Abdel-Rahman and El-Serehy (2004) recorded 43 calanoid species restricted to the Red Sea. These are: *Acartia danae* Giesbrecht, 1889, *Acrocalanus monachus* Giesbrecht, 1888, *Paracalanus denudatus* Sewell, 1929, *Paracalanus nanus* Sars, 1925, *Scolecithricella minor* Brady, 1883, *Scolecithricella orientalis* Mori, 1937, *Scolecithricella spinipedata* Mori, 1937, *Scolecithricella tropica* Grice, 1926, *Scolecithrix auropecten* Giesbrecht, 1892, *Scolecithrix chelipes* Giesbrecht, 1896, *Scolecithrix tenuipes* Scott, 1894, *Labidocera orsinii* Giesbrecht, 1889, *Pontella fera* Dana, 1849, *Pontellopsis krameri* Giesbrecht, 1896, *Calocalanus contractus* Farran, 1926, *Candacia aethiopica* Dana, 1863, *Candacia bispinosa* Claus, 1863, *Candacia samassae* Pesta, 1941, *Centropages orsinii* Giesbrecht, 1889, *Clausocalanus paululus* Farran, 1926, *Clausocalanus pergens* Farran, 1926, *Clausocalanus longicornis* Mori, 1937, *Eucalanus tenuatus* Dana, 1849, *Eucalanus bungii* Giesbrecht 1892, *Eucalanus crassus* Giesbrecht, 1888, *Eucalanus elongates* Dana, 1849, *Eucalanus mucronatus* Giesbrecht, 1888, *Eucalanus pileatus* Giesbrecht, 1888, *Eucalanus subcrassus* Giesbrecht, 1888, *Rhincalanus cornutus* Dana, 1849, *Euchaeta marina* Prestandrea, 1833, *Euchaeta plana* Mori, 1937, *Haloptilus acutifrons* Giesbrecht, 1889, *Haloptilus plumosus* Claus, 1863, *Lucicutia clausi* Giesbrecht, 1889, *Lucicutia gemina* Farran, 1926, *Lucicutia ovalis* Giesbrecht, 1889, *Lucicutia paraclausi* Park, 1970, *Pleuromamma robusta* Dahl, 1893, *Xanthocalanus gigas* Sciacchitano, 1930, *Temora turbinata* Dana, 1849, *Tortanus barbatus* Brady, 1883 and *Tortanus recticauda* Giesbrecht, 1889. A new species of calanoid copepod, *Centropages*

*aegypticus* sp. nov. was recently identified from the northern Red Sea by El-Sherbiny and Ueda (2008).

108 Tintinnid species have been recorded from the Red Sea by Cleve (1900), Santucci (1937) and Komarovskiy (1959, 1962). About 31 species are, so far, only known from south of 18°N. 39 species seem to be widespread and common since they have been recorded from different localities in the main basin and most of them also extend to the Gulf of Aqaba, the Gulf of Suez or both. The recent check list of plankton in the northern Red Sea prepared by El-Sherif and Aboul-Ezz (2000) indicated that only 23 tintinnid species were recorded. Most of them were encountered in the Mediterranean Sea. Few are typically Red Sea dwellers namely, *Rhabdonella brandt*, *Codonellopsis silvae*, *Codonellopsis parva*, *Tintinnopsis tubulosa*, *Petalotricha major* and *Sapingella secata*. Ninety two tintinnid species were recorded from the coast of Hurghada in the Red Sea by Abou Zaid and Hellal (2012). Most of them were found in the tropical waters, some are cosmopolitan while few are cold water inhabitants.

The Red Sea is poor in Cnidaria, representing about 2% of the total zooplankton density (Dowidar, 2003a). Only 26 siphonophore species were reported in Halim's (1969) review. Dowidar (2003b) recorded 29 Cnidaria species in the northern Red Sea and Gulf of Aqaba; 16 hydromedusae, 11 siphonophore and 2 species belonging to Class Scyphozoa. Most species were recorded in the upper 300 m layer, including: *Bougainvillea bitentaculata*, *Chelophyes contorta*, *Cytaeis tetrastylla*, *Euphysa aurata*, *Euphysilla pyramidata*, *Lensia meteori*, *Liriope tetraphylla*, *Nausithoe punctata*, *Persa incolorata*, *Podocoryne carnea*, *Podocoryne minima*, *Rhopalonema funerarium*, *Rhopalonema velatum*, *Sminthea eurygaster*, *Sphaeronectes irregularis*, *Sulculeolaria chuni*, *Sulculeolaria quadrialvis*, *Zanclaea costata*, and *Zanclaea orientalis*.

Three species of pelagic amphipods were recorded from the Red Sea namely; *Rhabdosoma whitei*, *Oxycephalus clausi* and *Oxycephalus erythraeus* (Halim, 1969). The first two species are diffused throughout the Red Sea basin, while *O. erythraeus* occurring down to 800–900 m. Barnard (1937) reported *Phronima sedentaria*, *P. atlantica* var. *solitaria*, *Platyscelus inermis* and *Rhabdosoma whitei* from the southern half of the Red Sea.

The chaetognath population of the Red Sea is decidedly tropical Indo-Pacific in its affinity. Only 13 species were recorded. The majority of the Red Sea chaetognaths appear to be well established in this sea. *Sagitta hexaptera*, *Sagitta inflata*, *Sagitta pacifica*, *Sagitta robusta*, *Sagitta serratodentata* and *Sagitta sibogae* are permanent inhabitants of the Red Sea and show no seasonal or geographical variation in relation to the inflowing Gulf of Aden current. Both the Gulf of Suez and Gulf of Aqaba are poorer in species than the main basin and the latter gulf is poorer than the former. Their populations are, however, less well known. The following seven species are recorded from the Gulf of Suez: *S. inflata*, *Sagitta neglecta*, *Sagitta regularis*, *S. robusta*, *S. serratodentata*, *Krohnitta pacifica*, *Krohnitta subtilis* and five from the Gulf of Aqaba, namely; *S. inflata*, *S. hexaptera*, *S. regularis*, *S. pacifica* and *K. subtilis* (El-Sherif and Aboul-Ezz, 2000 and Dowidar, 2003a). *Sagitta bipunctata*, abundant at Port Said, was totally absent from the Suez Canal. *S. neglecta* was found throughout the Canal.

Previous records of planktonic Copepoda studies in the Suez Canal were based on short collection periods, firstly estimated at the end of the 19th century by Giesbrecht (1891, 1897), then Thompson (1900), Cleve (1900, 1903), Scott (1902), Thompson and Scott (1903), Gurney (1927). Other estimations were carried out by Mac Donald (1933) on the distribution of phytoplankton and zooplankton in the Suez Canal during the period from July to December, 1928. Kimor (1972) studied the fauna of Suez Canal. Abu-Zeid (1990) reported on the zooplankton population in Lake Timsah with special reference to Copepoda. Halim (1990) gave a report on the potential migration of Indo-Pacific plankton through the Suez Canal. Abdel-Rahman (1997) studied the distribution of zooplankton communities in the Suez Canal. A compiled list of copepod species recorded from the Gulf of Suez, Suez Canal and Eastern Mediterranean by Abdel-Rahman (2005) indicated that 43 species derived from Red Sea, 15 species derived from Mediterranean and 19 species derived from both Red and Mediterranean Sea.

### Zooplankton migration through Suez Canal

The Red Sea is generally saltier and more nutrient-poor than the Atlantic, so the Red Sea species have advantages over Atlantic species in the salty and nutrient-poor eastern Mediterranean. Accordingly Red Sea species invade the Mediterranean biota and not vice versa; this phenomenon is known as the Lessepsian migration or erythrean invasion. Both the circulation pattern and the comparatively higher salinity of the Suez Canal have favoured the penetration and northward migration of erythrean species rather than of the Mediterranean species in the opposite direction (anti-Lessepsian migration). The infiltration of species successfully passing through the Suez Canal from the Red Sea into the Mediterranean Sea seems to continue for most of the year, except for two or three months during the summer, when the process is reversed and the waters of the Mediterranean flow towards the Red Sea (Wust, 1934; Morcos, 1960).

A total of 50 copepod species recorded in the Suez Canal, of which 35 species were observed as migrant species (15 species recorded as erythrean migrants "northward migration or Red-Med migrants", 7 species recorded as Med-Red migrants" migrated from Mediterranean to Red Sea, 13 species migrated from both Red and Mediterranean Seas Abdel-Rahman (2005).

Five copepod species of erythrean migrants were observed as new migrated species namely: *Acrocalanus gibber*, *L. pavo*, *C. furcatus*, *Centropages gracilis* and *Oncaea rufa* Abdel-Rahman (2005).

Five copepod species of Med-Red migrants were observed also as new migrated species namely: *Acartia longiremis*, *Aetideus armatus*, *Calocalanus pavo*, *Centropages ponticus* and *Oncaea mediterranea* Abdel-Rahman (2005).

Eight copepod species of Red-Med and Med-Red migrants were observed as new migrated species namely: *Paracalanus crassirostris*, *C. violaceus*, *C. arcuicornis*, *Ctenocalanus vanus*, *Lubbockia squillimana*, *Oncaea venusta*, *Corycaeus ovalis* and *Oithona plumifera* Abdel-Rahman (2005). Two Red Sea-Indo-Pacific copepod species, *C. elliptica* and *C. media*, widespread in the Red Sea and in the Gulf of Suez, remained unknown from the Canal until the survey of Gurney (1927). Afterwards, both species were present only in the southern

segment of the Canal. The two species have finally succeeded in crossing the Canal, and in extending along the east coast of the Levantine basin. Both are recorded from the hyper saline Bardaweel lagoon (Berdugo, 1968), the Bay of Haifa (Berdugo, 1974) and the Lebanese waters (Lakkis, 1976). *Acartia centrura* a species occurring in both the Atlantic and Indian Oceans is known to be fairly abundant in the Gulf of Suez and the central Red Sea. This species also remained unknown from the Canal until recorded by Gurney (1927). *Acartia centrura* extended then to all parts of the Canal, it now extends to the east Levantine waters (Halim, 1990; Belmonte and Potenza, 2001). *Acartia (Acanthacartia) fossae* Red Sea species, recorded along the Lebanese coasts (Lakkis, 1976 and Lakkis, 1990) and in the Ponto-Mediterranean Province (Belmonte and Potenza, 2001) as Lessepsian migrant.

Several other copepod species were reported as erythrean migrants: *Arietellus pavoninus* in the Aegean Sea (Moraitou-Apostolopoulou, 1985), *Arietellus aculeatus*, *L. madurae*, *Labidocera truncata* (Lakkis, 1976) and *Euchaeta concinna* (Casanova, 1973) in the East Mediterranean. Gurney (1927) noting the presence of *Canthocalanus pauper* (a Mediterranean-Indo-Pacific species) and of *Temora discaudata* (Indo-Pacific species) at Port Said concludes that this distribution affords evidence of a northward migration. Fox (1927) considers *T. stylifera*, *A. clausi* and *A. latisetosa* to have entered the Canal from the Mediterranean, and *O. nana*, *P. parvus* and *E. acutifrons* from both ends. *Acartia (Acartiura) clausi* and *Paracartia latisetosa* were recorded as anti-Lessepsian migrants by (Belmonte and Potenza, 2001).

The protozoan species *Tintinnopsis beroidea* is a neritic species found off the Syrian coast and *Tintinnopsis radix* recorded in the Nile Delta (Kimor and Wood, 1975). Both of these species had been recorded in the coastal waters from the Gulf of Eilat and the Dahlak Archipelago off Massawa in the Red Sea (Komarovskiy, 1959, 1962). *Tintinnopsis beroidea* was recorded among the frequent protozoan species in the coastal waters of Alexandria (Zakaria, 2007).

The siphonophore species *Chelophyes appendiculata* which had been recorded in the Levant Basin of the Mediterranean Sea is considered as immigrant from the Mediterranean to the Red Sea (Alvarino, 1974). The Red Sea siphonophore species: *Apolemia uvaria*, *Diphyes dispar*, *Lensia campanella*, *L. meteori*, *L. subtilis* and *Sulcularia turgida* were recorded in the eastern Mediterranean basin by Kimor and Wood (1975).

Zakaria (1992, 2004 and 2006), during her work in the Egyptian Mediterranean coast reported two siphonophore species: *Abyla trigona* and *Sulculeolaria angusta* and one Hydromedusa species: *Olindias singularis* which are belonging to the Indian Ocean species (Browne, 1916, 1926; Kramp, 1965; Patrity, 1970; Vannucci and Navas, 1973) as new records for Levant Basin and for the Mediterranean Sea as a whole and migrated from the Red Sea through the Suez Canal.

The Indo-Pacific Chaetognatha *S. neglecta* is well represented in the Red Sea (Halim, 1969) and extends to the Suez Canal up to Port Said (Burfield, 1927). One mature specimen was found in the plankton of Alexandria in 1972 (Guegues and Halim, 1973).

Zakaria (1992, 2006) found the pelagic amphipod species *Rhabdosoma whitei* in the Eastern Mediterranean for the first time. It was previously recorded in the Western Mediterranean (Tregouboff and Rose, 1957), Indian Ocean and Red Sea (Barnard, 1937; Fag, 1960; Halim, 1969).



### Impact of zooplankton migration on the ecological system

The significance of alien species in marine ecosystems worldwide has been highlighted in recent years. International organizations (UNEP/MAP/RAC/SPA, FAO/DIAS, IUCN, ICES, IMO, CIESM, 2015) and the scientific community have addressed the issue through articles, review papers, databases and directories (Zenetos et al., 2006). Following Por (1978) who focused on introductions via the Suez Canal, the so-called Lessepsian migrators, Zibrowius (1992) attempted a compilation of data on alien species in the Mediterranean. He pointed out that while taxa with well-known taxonomy and established historical distribution records (e.g. benthic organisms, fish) have received more attention than other groups, many of the small, less-conspicuous, less studied species are necessarily overlooked, leading to an underestimation of the extent of aliens' presence.

The previous work on aliens has been focused on certain taxonomic groups, mainly fish and benthos (major "popular" groups treated extensively in the recent CIESM atlas series) while many pelagic groups have not even been mentioned (Zenetos et al., 2006). The recent efforts to compile updating lists in zooplankton are those by Uysal et al. (2002) and Bouillon et al. (2004). The list of marine zooplankton alien species in the Mediterranean Sea is updated based on species records up to December 2005 by Zenetos et al. (2006). Only 18 zooplanktonic alien species seem to be well established in the Mediterranean, while 32 are considered casual or questionable records (Table 1a–c) (Zenetos et al., 2006).

In the eastern Mediterranean, the huge increase of aquaculture and commercial and tourism activities during the last century have obviously enhanced the transport of planktonic species in ballast waters. Relatively few seem to be planktonic

lessepsian migrants, even though it is believed that their contribution will increase with time, due to the decreasing of the Nile fresh water inflow into the Mediterranean and lower salinity in the Bitter lakes (Halim, 1990).

Documenting impacts of marine invaders is a subject of strong debate. The evidence and nature of the impact of invasive species on particular ecosystems and habitats are often unclear and it appears that it is the interaction between invaders and other anthropogenic stresses that influence the impact (Ruiz et al., 1999). Invasion success depends not only on the invader's advantage over potential native enemies/competitors but also on the environmental characteristics of the host ecosystem (primarily species richness and disturbance) and the level of stress already imposed on it (Simberloff, 1989; Ribera, 1995; Cohen and Carlton, 1998; Goodwin et al., 1999; Occhipinti-Ambrogi, 2000; Keane and Crawley, 2002).

The adverse impacts of invasive species on genetics, populations, ecosystems and economics in the Mediterranean have been discussed to some extent in studies (Boudouresque, 1994; Boudouresque and Ribera, 1994; Verlaque, 1994; Ribera, 1995; Golani, 1998; Occhipinti-Ambrogi, 2000, 2001, 2002a,b; Galil, 2000a,b, 2006; Zibrowius, 2002; Bouley and Kimmerer 2006; Boudouresque and Verlaque, 2002a,b; Galil and Zenetos, 2002; Occhipinti Ambrogi and Savini, 2003; Gofas and Zenetos, 2003). According to the available literature, except jellyfish *Rhopilema nomadica*, the negative impact of zooplankton Lessepsian migratory species in the Egyptian Mediterranean waters is not evident.

In the Mediterranean, stressed environments (polluted or physically degraded) appear to be more prone to invasion than pristine sites (Ribera and Boudouresque, 1995; Galil, 2000b, 2006; Occhipinti-Ambrogi, 2000; Ribera, 2002; Occhipinti Ambrogi and Savini, 2003). The fact that, mariculture

**Table 1** Check list of zooplankton alien species in the Mediterranean Sea (Zenetos et al., 2006).

Group	Species		
<i>a. Zooplankton established:</i>			
Copepoda	<i>Acartia (Acanthacartia) tonsa, Acartia centrura, Arietellus pavoninus, Calanopia elliptica, Calanopia media, Centropages furcatus, Labidocera madura, Labidocera pavo, Paracartia grant, Pontellina plumata, Pseudocalanus elongatus, Pteriacartia josephinae</i>		
Ctenophora	<i>Mnemiopsis leidyi</i>		
Cnidaria/Scyphozoa	<i>Rhopilema nomadic</i>		
Siphonophora	<i>Forskalia Formosa</i>		
Cnidaria/Hydrozoa	<i>Eucheilota paradoxica, Moerisia carine, Tetrorchis erythrogaster</i>		
<i>b. Zooplankton casual:</i>			
Copepoda	<i>Acartia (Acanthacartia) fossae, Calanopia biloba, Calanopia minor, Corycaeus speciosus, Eucalanus crassus, Eucalanus subcrassus, Euchaeta concinna, Labidocera agilis, Labidocera truncata, Labidocera orsinii, Oncaea rufa, Paracalanus crassirostris, Parvocalanus elegans, Parvocalanus latus, Scaphocalanus amplius, Scaphocalanus brevirostris, Scolecithrix valens, Spinocalanus terranova</i>		
Cnidaria/Hydrozoa	<i>Aequorea conica, Kantiella enigmatica, Laodiceafijiana, Nubiella mitra, Paracytaeis octona, Russellia mirabilis</i>		
Cnidaria/Scyphozoa	<i>Phyllorhiza punctata</i>		
Group	Species	Cited by	Reasoning
<i>c. Zooplankton questionable:</i>			
Copepoda	<i>Canuellina insignis</i>	Por (1972)	Old record. Only in Bardawil lagoon
	<i>Enhydrosoma hopkinsi</i>	Por (1972)	Old record. Only in Bardawil lagoon
	<i>Robertsonia salsa</i>	Por (1972)	Old record. Only in Bardawil lagoon
	<i>Scottolana longipes</i>	Por (1964)	Possible pre-lessepsian element (Por, 1978)
	<i>Stenheïtia inopinata</i>	Por (1972)	Old record. Only in Bardawil lagoon
	<i>Stenhelina rnimtta</i>	Por (1964)	Possible pre-lessepsian element (Por, 1964)

introductions are mostly restricted to lagoonal or estuarine habitats and vessel-transported aliens to polluted harbours, environments that are known for their low biodiversity, support this theory (Zibrowius, 1992). A recent study of macrofouling organisms concluded that many more species are found in a polluted than in a non-polluted marina (Koçak et al., 1999). However, there are suggestions of the opposite. According to Klein et al. (2005) there is no relationship between the number of introductions, diversity of the host ecosystem and disturbance acting on the community when examining the impact of introduced macrophytes on the shallow subtidal macrophytic assemblages along the French Mediterranean coast.

## Conclusion

The problem of immigration from the Red Sea to the Mediterranean remains complex. The zooplankton distribution and migration are affected by both biotic and abiotic factors. The climate variability and anthropogenic activities have great impacts on zooplankton community composition in the south eastern Mediterranean coast. Increased water temperatures are associated with the successful establishment of both tropical non indigenous species and indigenous species with warm-water affinity. On the other side, the ballast water regarded as the main factor affecting the introduction of non-indigenous aquatic organisms. A ballast water tank can thus function as an incubator during the cruise for some species. This fact may have some impact on the release of non-indigenous species in the destination harbour or in near-coastal waters where the ballast tanks are emptied.

The immigration process of zooplankton organisms through the Suez Canal is still going on and with the improved conditions within the Canal, it might be accelerating. The infiltration of alien species via the Suez Canal may have both positive and negative impacts on the marine ecosystem of the Mediterranean and Red Sea. The positive impact is enriching the biodiversity of both seas as the well diversified ecosystem become more stable and healthy. The negative impact happens when the occurrence of alien species might threaten the diversity or abundance of the native species of both seas. Another negative impact is concerned with the human activities, health and/or economic interest such as the invasion of jellyfish *R. nomadica* that entered the Mediterranean via the Suez Canal and forms large swarms annually along the Levantine coast. However, according to the available literature, except jellyfish *R. nomadica*, the negative impact of zooplankton Lessepsian migratory species in the Egyptian Mediterranean waters is not evident.

A continuous monitoring programme is needed to record the recent erythrean zooplankton species in the Egyptian waters and follow up the distribution and abundance of those previously recorded as alien species in the Egyptian Mediterranean and Red Sea waters to assess their impacts on the native biodiversity of both seas. The monitoring programme must be accompanied with studies on the feeding habits of commercial fishes and other living resources of economic importance in the Mediterranean and Red Seas to detect the role of these alien species in the food web (i.e. are these species preferable as a food or not grazed by the native species). In this way, a more advanced technique should be developed for identification such as DNA analysis to reach the species level.

## References

- Abdel-Moati, A.R., Said, M.A., 1987. Hydrographic structure of the Mediterranean shelf waters off the Egyptian coast during 1983–1986. *Thalassographica* 10 (2), 23–39.
- Abdel-Rahman, N.S., 1997. Suez Canal as a link in the migration of zooplankton between the Mediterranean and Red Sea. In: Dep. Zool. Fac. Sci. Suez Canal University, Egypt, Ph. D. thesis.
- Abdel-Rahman, N.S., 1999. Check-list of crustacean Copepoda in the Gulf of Aqaba. *Egypt. J. Aquat. Biol. Fish.* 3 (2), 35–54.
- Abdel-Rahman, N.S., 2005. The immigration progress of planktonic Copepoda across the Suez Canal, Egypt. *Egypt. J. Aquat. Biol. Fish.* 9 (3), 59–82.
- Abdel-Rahman, N.S., El-Serehy, H.A., 2004. The planktonic Copepoda of the Red Sea: a review 1- Calanoida. *Int. Conf. on Biol. Sci.* 3 (1), 328–350.
- Abdel-Rahman, N.S., Aboul-Ezz, S.M., 2005. A review on the planktonic Copepoda of the Red Sea 3: Cyclopoida, Harpacticoida, Monstrilloida, Mormonilloida and Siphonostomatoida. *J. Egypt. Ger. Soc. Zool. Invert. Zool. Parasitol.* 48, 35–47.
- Abou Zaid, M.M., Hellal, A.M., 2012. Tintinnids (Protozoa: Ciliata) from the coast of Hurghada Red Sea, Egypt. *Egypt. J. Aquat. Res.* 38, 249–268.
- Abu-Zeid, G.M., 1990. Distribution of Zooplankton in Lake Timsah with Special Reference to Copepoda. *Fac. Sci., Suez Canal University, Egypt, M. Sc. Thesis*, 96p.
- Al-Aidaros, A.M., 1984. Studies on the Zooplankton Community with Special Reference to Copepoda North of Jeddah. Thesis, Faculty of Marine Science, King Abdel-Aziz University, Jeddah, Saudia Arabia, Saudia Arabia, M. Sc. Thesis, 238p.
- Alcaraz, M., 1977. Cladóceros y ostrácos de los alrededores del estrecho de Gibraltar en junio-julio de 1972. *Res. Exp. Ci. B/O Cornide* 6, 41–63.
- Almeida Prado-Por, M.S., 1983. Diversity and dynamics of Copepoda Calanoida in the northern Gulf of Aqaba (Eilat) Red Sea. *Oceanol. Acta* 6, 139–145.
- Almeida Prado-Por, M.S., 1988. Vertical migration of calanoid copepods in the Gulf of Aqaba (Eilat). *Rapp. Comm. Int. Mer Médit.* 31 (2), 302p.
- Al-Mutairi, H.A., 2009. Non-Calanoid Copepods at the Bermuda Atlantic Time-series (BATS) Station: Community Structure and Ecology, 1995-1999. *Coll. of Mari. Sci, Univ. of S. Florida, USA, Ph.D. Thesis*, 215p.
- Alvarino, A., 1974. Distribution of siphonophores in the regions adjacent to the Suez and Panama Canals. *Fish. Bull. U.S.* 72 (2), 527–546.
- Arfi, R., Champalbert, G., Patriti, G., Puddu, A., Reys, J.P., 1982. Etude préliminaire comparée du plancton du vieux port, de l'avant port et du golfe de Marseille (Liaisons avec les paramètres physiques, chimiques et de pollution). *Téthys* 10, 211–217.
- Avsar, D., 1999. Physico-chemical characteristics of the Eastern Mediterranean in relation to distribution of the new Scyphomedusae (*Rhopilema nomadica*). *Turk. J. Zool.* 23 (2), 605–616.
- Barnard, K.H., 1937. Amphipoda, in: John Murray Expedition 1933–34. *Sci. Rep.* 4 (6), 131–201.
- Beckmann, W., 1988. Seasonal patterns of mesopelagic calanoid copepods in the central Red Sea. *Rapp. Comm. Int. Mer Médit.* 31 (2), 302p.
- Belmonte, G., Potenza, D., 2001. Biogeography of the family Acartiidae (Calanoida) in the Ponto-Mediterranean Province. *Hydrobiologia* 453/454, 171–176.
- Berdugo, V., 1968. Sur la presence dans la Mediternnee Oriental de deux especes du genre Calanopia (Copepoda Calanoida). *Rapp. Comm. Int. Mer Médit.* 19 (3), 445–446.
- Berdugo, V. (1969). The composition and seasonal fluctuations in the populations of Copepoda Calanoida along the Tira Profile in the

- coastal waters of Israel (In Hebrew) (M. Sc. thesis submitted to the Senate of the Hebrew University of Jerusalem), 47p.
- Berdugo, V., 1974. On the occurrence of *Acartia centrura* (Copepoda, Calanoida) in the neritic waters of the Eastern Mediterranean. Rapp. Comm. Int. Mer Médit. 22 (9), 85–86.
- Berdugo, V., Kimor, B., 1968. Consideration on the distribution of pelagic copepods in the eastern Mediterranean. Rapp. Comm. Int. Mer Médit. 19, 447–448.
- Bergren, W. A. & A. Boersma (1969). Late Pleistocene and Holocene planktonic Foraminifera from the Red Sea. In: Hot Brines and Recent Heavy Metal Deposits in the Red Sea. (Eds. E. T. Degens and D. A. Ross), Berlin-Heidelberg-New York: 282-291.
- Bernard, M.F., 1955. Etude préliminaire quantitative de la repartition saisonnière du zooplancton de la baie d'Alger. I. Année 1950-1951. Bull. Inst. océanogr. Monaco 52 (1065), 1–28.
- Bernard, M. F. (1958). Systematique et distribution saisonniere des tuniciers pelagiques d' Alger. Rapp. et Proc. Verb., 14 (N.S.): 211–231.
- Bernard, M.F., 1967. Recent advances in research on the zooplankton of the Mediterranean Sea. Oceanogr. Mar. Biol. Ann. Rev. 5, 231–255.
- Bethoux, J.P., Gentili, B., 1999. Functioning of the Mediterranean Sea: past and present changes related to freshwater input and climate changes. J. Mar. Syst. 20, 33–47.
- Bottger-Schnack, R., 1995. Summer distribution of micro- and small mesozooplankton in the Red Sea and Gulf of Aden, with special reference to non-calanoid copepods. Mar. Ecol. Prog. Ser. 118, 81–102.
- Bottger-Schnack, R., 2001. Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. II. Seven species of *Oncaea*. Bull. Nat. Hist. Mus. Lond. (Zool.) 67 (1), 25–84.
- Bottger-Schnack, R., 2002. Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. VI. Morphology and zoogeography of *Oncaea bispinosa* sp. nov. a sister taxonomy of *O. zernovi* Shmeleva. J. Plank. Res. 24 (11), 1107–1129.
- Boucher, J., Thiriot, A., 1972. Zooplancton and micronecton estivaux des deux cents premiers metres en Mediterranee occidentale. Mar. Biol. 15, 47–56.
- Boudouresque, C.F. (1994). Les espèces introduites dans les eaux côtières d'Europe et de Méditerranée: état de la question et conséquences. In: Introduced species in European coastal waters, edited by C.F.Boudouresque, F.Briand, C. Nolan, Bruxelles, European Commission, p. 8–24.
- Boudouresque, C. F. & M.A. Ribera (1994). Les introductions d'espèces végétales et animales en milieu marin consequences écologiques et économiques et problèmes législatifs. In: First International Workshop on Caulerpa taxifolia, edited by C.F.Boudouresque et al., France, Groupement d'Intérêt Scientifique Posidonie Publishers, p.29–102.
- Boudouresque, C.F., Verlaque, M., 2002a. Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes. Mar. Pollut. Bull. 44, 32–38.
- Boudouresque, C. F. & M. Verlaque (2002b). Assessing scale and impact of ship transported alien macrophytes in the Mediterranean Sea. In: Alien marine organisms introduced by ships in the Mediterranean and Black seas, edited by F.Briand, Monaco, CIESM Workshop Monographs No. 20, p. 53–61.
- Bouillon, J.; M.D. Medel, F. Pagès; J. M. Gili; F. Boero & C. Gravili (2004). Fauna of the Mediterranean Hydrozoa. Scientia Marina, 68 (2): 449 pp.
- Bouley, P., Kimmerer, W.J., 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Mari. Ecol. Prog. Ser. 324, 219–228.
- Brautovic, I., Bojanic, N., Vidjak, O., Skaramuca, D., Bogner, D., 2007. Plankton ostracods abundance in the Deep Adriatic Sea. Rapp. Comm. Int. Mer Médit. 38, 441.
- Browne, E.T., 1916. Medusae from the Indian Ocean. Reports on the Percy Sladen Trust Expedition to the Indian Ocean 1905. Trans. Linn. Soc. 17 (2), 169–210.
- Browne, E.T., 1926. Siphonophorae from the Indian Ocean. Trans. Zool. Soc., Lond. 19 (2), 55–86.
- Burfield, S.T., 1927. Report on the Chaetognatha. The zoological results of the Cambridge expedition to the Suez Canal, 1924. Trans. Zool. Soc. Lond. 22 (3), 355–357.
- Casanova, J.P., 1973. Penetration du copepode *Euchaeta concinna* en Mediterranee orientale par le Canal de Suez. Rapp. Comm. Int. Mer Médit. 21 (8), 513–514.
- Casanova, J.P., 1974. Les euphausiacés de Méditerranée (Systématique et développement larvaire. Biogéographie et biologie). Univ. Aix-Marseille, Thèse Doct.
- Chakroun, F., 1966. Plancton recolte en Libye. Bull. Inst. Oceanogr. Peche. Salommo. n. s. 1 (2), 67–74.
- Champalbert, G., 1969. L'hyponeuston dans le golfe de Marseille. Téthys 1, 585–666.
- Champalbert, G., 1971a. Variations nycthémerales du plankton superficiel. I. Holohyponeuston et hétérohyponeuston. J. Mar. Biol. Ecol. 6, 23–33.
- Champalbert, G., 1971b. Variations nycthémerales du plankton superficiel. II. Espèces non caractéristiques de l'hyponeuston et hyponeuston nocturne. J. Mar. Biol. Ecol. 6, 55–70.
- Champalbert, G., 1975. Répartition du peuplement animal de l'hyponeuston. Etude expérimentale de la physiologie et du comportement des Pontellidés Thèse Doct. ès Sci.. Univ. Aix Marseille.
- Champalbert, G., 1996. Characteristics of zooplankton standing stock and communities in the Western Mediterranean Sea: Relations to hydrology. Sci. Mar. 60 (Suppl. 2), 97–113.
- Champalbert, G., Patriti, G., 1982. Impact de la pollution sur les communautés zooplanctoniques dans la zone d'épandage de l'émissaire urbain de Marseille. Hydrobiologia 89, 17–27.
- CIESM on line: <<http://www.ciesm.org/on-line/atlas/index.htm>> .
- Cleve, P.T., 1900. Plankton from the Red Sea. Ofver. K. Vetensk. Akad. Forh 57 (9), 1025–1038.
- Cleve, P.T., 1903. Report on plankton collected by Mr. Thorild Wulff during a voyage to and from Bombay. Ark. Zool. Stockholm 1, 329–391, 19 plates.
- Cohen, A.N., Carlton, J.T., 1998. Accelerating invasion rate in a highly invaded estuary. Science 279, 555–558.
- Crisafi, P., 1974. Inquinamento e speciazione: *Acartia josephina* e *A. enzoii* (Copepoda, calanoida) specie nuove del Mar Mediterraneo. Boll. Pesca Piscic. Idrobiol. 29, 5–10.
- David, V., Sautour, B., Chardy, P., Leconte, M., 2005. Long-term changes of the zooplankton variability in a turbid environment: the Gironde estuary (France). Estu. Coast. Shelf Sci. 64, 171–184.
- Delalo, E. P. (1966a). The zooplankton in the eastern part of the Mediterranean (Levantine Sea and Gulf of Sirti). In: Investigacton of plankton in the South Sea, Okeanogr. Kom. Akad. Nauk SSSR: 62–81.
- Delalo, E.P., 1966b. Distribution of zooplankton biomass in the Red Sea and Gulf of Aden in winter 1961–1962. Okeanol. Issled 15, 131–139.
- Della Croce, N., 1959. Copepodi pelagici raccolti nelle crociere talassografiche del "Robusto" nel Mar Ligure ed Alto Tirreno. Boll. Musei Ist. biol. Univ. Genova 29, 29–114.
- Della Croce, N. & F. Boero. (1976). Ecologia e biologia dei porti del Mar Ligure e Alto Tirreno. 4. Aspetti termici del golfo di la Spezzia. IIIèmes Journées Etudes Pollution, CIESM, Split: 125–131.
- Dowidar, M.M., 2003a. Mesozooplankton communities in the Gulf of Aqaba and Northern Red Sea. Egypt J. Aquat. Biol. Fish. 7 (1), 1–21.
- Dowidar, M.M., 2003b. Distribution and abundance of Cnidaria community in the Gulf of Aqaba and Northern Red Sea. Egypt. J.

- Egypt. Acad. Soc. Environ. Devlop. 4 (3), 119–136 (D-Environmental studies).
- Dowidar, N.M., 1985. Epipelagic copepods of the south-eastern Mediterranean, general remarks. Rapp. Comm. Int. Mer Médit. 29, 239–243.
- Dowidar, N.M., El Maghraby, A.M., 1972. Notes on the occurrence and distribution of some zooplankton species in the Mediterranean waters of U.A.R. Rapp. Comm. Int. Mer Médit. 21, 521–525.
- Echelman, T., Fishelson, L., 1988. The seasonal surface zooplankton dynamics near Eilat (Gulf of Aqaba), Red Sea. Rapp. Comm. Int. Mer Médit. 31 (2), 304.
- Echelman, T., Fishelson, L., 1990. Surface zooplankton dynamics and community structure in the northern Gulf of Aqaba (Eilat), Red Sea. Bull. Nat. Inst. Oceanogr. Monaco 7, 67–77.
- Ehrhardt, J.P., 1967. Contribution à l'étude du plancton superficiel et sub-superficiel du canal de Sardaigne et de la mer sudtyrrhénienne. Cah. Océanogr. 19, 657–921.
- El-Naggar, H.A., 2014. Diversity and distribution of copepods in the Egyptian Mediterranean waters, with special reference to migratory species Ph.D. Thesis. Fac. Sci. Al-Azhar Univ, Egypt.
- El-Rashidy, H.H., 1987. Ichthyoplankton of the South Eastern Mediterranean Sea off the Egyptian Coast M. Sc. Thesis. Faculty of Science, Alexandria University.
- El-Serehy, H.A., Abdel-Rahman, N.S., 2004. Distribution patterns of planktonic copepod crustaceans in the coral reef and sandy areas along the Gulf of Aqaba, Red Sea, Egypt. Egypt. J. Biol. 6, 126–135.
- El-Sherbiny, M.M., Ueda, H., 2008. *Centropages aegypticus* sp. nov., a new calanoid copepod from the northern Red Sea. J. Mar. Biol. Assoc. United Kingdom 88 (1), 69–75.
- El-Sherif, Z.M., Aboul-Ezz, S.M., 2000. Check list of plankton of the Northern Red Sea. Pak. J. Mar. Sci. 9 (1&2), 61–78.
- Emig, C.C., Geistdoerfer, P., 2004. The Mediterranean deep-sea fauna: historical evolution, bathymetric variations and geographical changes. Car. Geol. 1, 1–10.
- Evans, F., 1968. Le zooplancton de Malta. Pelagos. Bull. Inst. Oceanogr. Alger 9, 5–20.
- Fag, L. (1960). Oxycephalidae. Amphipods pelagiques. Dana Report No 52: 1–145.
- Fernandez de Puelles, M.L., Morillas, A., Font, E.A., Vicente, L., 2007. The spatial zooplankton distribution in the North Balear Front Western Mediterranean): Early spring, 2005. Rapp. Comm. Int. Mer Médit. 38, 473.
- Fernández de Puelles, M.L., Salvà Picó, C., 1992. Variación temporal del zooplancton en la bahía de Palma, 1989. In: Alemany, A. (Ed.), . In: Historia Natural, 91, pp. 309–314.
- Fonda Umani, S., 1996. Pelagic production and biomass in the Adriatic Sea. Sci. Mar. 60 (2).
- Fonda Umani, S., Milani, L., Specchi, M., 1985. Observations on zooplankton in the north and central Adriatic Sea. Rapp. Comm. Int. Mer Médit. 29 (9), 303–305.
- Fonda Umani, S., P. Franco, E. Ghirardelli & A. Malej. (1992). Outline of oceanography and the plankton of the Adriatic Sea. In: G. Colombo et al., (eds.): Eutrophication and population dynamics. Proc. 25th EMBS, pp. 347–365. Olsen and Olsen Publ., Fredensborg, Denmark.
- Fonda Umani, S., Specchi, M., Cataletto, B., De Olazabal, A., 1994. Distribuzione stagionale del mesozooplankton nell'Adriatico settentrionale e centrale. Boll. Soc. Adriatica di Scienze 75, 145–176.
- Fox, M.H., 1927. Cambridge Expedition to the Suez Canal, 1924. I: General part. Trans Zool. Soc. Lond. 22 (1), 1–64.
- Furnestin, M.L., 1960. Zooplancton du Golfe de Lion et de la cote orientale de corse. Rev. Trav. Inst. Peches marit. 24 (2), 153–252.
- Furnestin, M.L., 1965. Le zooplancton de la Mediterranee (Bassin occidental). Comm. Int. Explor. Sci. Mer. Medit. 36, 1–41.
- Furnestin, M.L., 1966. Elements de planctologie appliquée. Iere Partie: Plancton et hydrologie. Le plancton indicateur hydrologique. Rev. Trav. Inst. Peches Marit. 30 (2), 119–142.
- Furnestin, M.L., 1968. Le zooplancton de la Mediterranee (Bassin occidental). Essai de synthese. J. Cons. Int. Explor. Mer 32, 25–69.
- Furnestin, M.L., 1979. Aspects of the zoogeography of the Mediteranean plankton. In: van der Spoel, S., Pierrot-Bults, A.C. (Eds.), . In: Zoogeography and diversity of plankton. Halsted Press (Wiley), New York, pp. 191–253.
- Galil, B.S., 2000a. The Silver Lining' the economic impact of Red Sea species in the Mediterranean. p. 265-267. In: Peterson, J. (Ed.), . In: Marine Bioinvasions: Proceedings of the First National Conference. MIT Press, Cambridge, Massachusetts.
- Galil, B.S., 2000b. A sea under siege-alien species in the Mediterranean. Biol. Invasions 2, 177–186.
- Galil, B.S., 2006. Shipwrecked: shipping impacts on the biota of the Mediterranean Sea. In: Davenport, J.L., Davenport, J. (Eds.), The ecology of transportation: managing mobility for the environment. Springer, Dordrecht, The Netherlands, pp. 39–69.
- Galil, B.S. & A. Zenetos (2002). A sea change - exotics in the Eastern Mediterranean Sea. In: Invasive aquatic species in Europe. Distribution, impacts and management, In: E.Leppakoski, S.Gollash and S.Olenin (Eds.), Dordrecht, Boston, London: Kluwer Academic Publishers, p.325-336.
- Gamulin, T., 1979. Le zooplancton de la côte orientale de l'Adriatique. Acta Biol., 177–270
- Gaudy, R., 1962. Biologie des copepodes pelagiques du Golfe de Marseille. Rec. Trav. Sta. mar. End., Bull. 42, 93–184, 27, F.
- Gaudy, R., 1963. Sur la presence a' Marseille d'especes planctoniques indicatrices d'eaux d'origine Atlantique. Rapp. Comm. Int. Mer Medit. 17, 539–544.
- Gaudy, R., 1971a. Etude expérimentale de la ponte chez 3 espèces de copépodes pélagiques (*Centropages typicus*, *Acartia clausi* et *Temora stylifera*). Mar. Biol. 9, 65–70.
- Gaudy, R., 1971b. Contribution à l'étude du cycle biologique des copépodes pélagiques du golfe de Marseille. I. L'environnement physique et biotique et la composition de la population de copépodes. Thèys 3, 921–942.
- Gaudy, R., 1972. Contribution a la connaissance du cycle biologique des copepods du Golf de Marseille. Thethys 4 (1), 175–242.
- Gaudy, R., 1985. Features and peculiarities of zooplankton communities from the western Mediterranean. In: Moraitou Apostolopoulou, M., Kiortsis, V. (Eds.), Mediterranean marine ecosystem.: 297–303. Plenum Press, New York and London.
- Giesbrecht, W. (1891). Elenco dei Copepodi pescati dalla corvetta "Vettor Pisani" secondo la lora distribuzione geographica. Atti Accad. Lin. (4), Rendiconti, 7, sem. 2, B: 276.
- Giesbrecht, W. (1892). Systematik und faunistik der pelagischen copepoden des Golfes von Neapel (Fauna und Flora des Golfes von Neapel). 19: 1–831, 45 pls.
- Giesbrecht, W., 1897. Ueber pelagische Copepoden des Roten Meeres. Zool. Jb (Syst.) 9, 315–328.
- Gilat, E., Kane, J.E., Martin, J.C., 1965. Study of an ecosystem in the coastal waters of the Ligurian Sea. II. Surface zooplankton. Bull. Inst. Océanogr. Monaco 65 (1353), 1–56.
- Gofas, S., Zenetos, A., 2003. Exotic molluscs in the Mediterranean basin: Current status and perspectives. Oceanogr. Mar. Biol. Annu. Rev. 41, 237–277.
- Golani, D., 1998. Impact of Red Sea fish migrants through the Suez Canal on the aquatic environment of the Eastern Mediterranean. Bull. Ser. Yale School Forestry Environ. Stud. 103, 375–387.
- Gollasch, S. (1996). Untersuchungen des Arteintrages durch den internationalen Schiffsverkehr unter besonderer Berücksichtigung nichtheimischer Arten. Dissertation, University of Hamburg, Dr. Kovac Verlag, Hamburg.
- Gollasch, S., Lenz, J., Dammer, M., Andres, H.G., 2000. Survival of tropical ballast water organisms during a cruise from the Indian Ocean to the North Sea. J. Plank. Res. 22 (5), 923–937.
- Goodwin, B.J., McAllister, A.J., Fahrig, L., 1999. Predicting invasiveness of plant species based on biological information. Conserv. Biol. 13, 22–426.

- Gordeyeva, K.T., 1970. Quantitative distribution of zooplankton in the Red Sea. A. O. Kovalevskiy Institute of Biology Southern seas. Ukrainian Academy Science, USSR, *Okenologiya* 10, 867–871.
- Gorsky, G., Palazzoli, I., 1989. Aspects de la biologie de l'appendiculaire *Oikopleura dioica* Fol. 1872 (Chordata: Tunicata). *Océanica* 15, 39–49.
- Gorsky, G., Fisher, F.S., Fowler, S.W., 1984. Biological debris from the pelagic tunicata, *Oikopleura dioica* and its role in the vertical transport of a transuranium element. *Estuar. Coast. Shelf Sci.* 18, 13–23.
- Gorsky, G., Lins da Silva, N., Dallot, S., Laval, P., Braconnot, J.C., Prieur, L., 1991. Midwater tunicates: are they related to the permanent front of the Ligurian Sea (NW Mediterranean)? *Mar. Ecol. Progr. Ser.* 74, 195–204.
- Guergues, S.K., Halim, Y., 1973. Chaetognathes du plancton d'Alexandrie. II. Un specimen mur de *Sagitta neglecta* Aida en Mediterranee. *Rapp. Comm. Int. Mer Médit.* 21 (8), 497–498.
- Gurney, R., 1927. VIII- Report on the Crustacea: Copepoda and Cladocera of the plankton. "The zoological results of the Cambridge Expedition to the Suez Canal, 1924". *Trans. Zool. Soc. London* 22, 139–172.
- Halim, Y., 1969. Plankton of the Red Sea. Harold Barnes Ed. *Oceanogr. Mar. Biol. Ann. Rev.* 7, 231–275.
- Halim, Y., 1990. On the potential migration of Indo-Pacific plankton through the Suez Canal. *Bull. Inst. Oceanogr.* 7, 11–27, no special.
- Hecht, A., Gertman, I., 2001. Physical features of the Eastern Mediterranean resulting from the integration of POEM data with Russian Mediterranean Cruises. *Deep Sea Res., Part I* 48/8, 1847–1876.
- Hure, J., Scotto di Carlo, B., 1968. Comparazione tra lo zooplankton del golfo di Napoli e dell'Adriatico meridionale presso Dubrovnik. I. Copepoda. *Pubbl. Staz. zool. Napoli* 36, 21–301.
- Hure, J., Scotto di Carlo, B., 1969. Copepodi pelagici dell'Adriatico settentrionale nel periodo gennaio-dicembre 1965. *Pubbl. Staz. zool. Napoli* 37 (Suppl. 2), 173–195.
- Hure, J., Ianora, A., Scotto di Carlo, B., 1980. Spatial and temporal distribution of copepod communities in the Adriatic Sea. *J. Plankton Res.* 2, 295–316.
- Ianora, A., Mazzocchi, M.G., Scotto di Carlo, B., 1985. Zooplankton community structure for coastal waters of the gulf of Naples, summer of 1983. *Rapp. Comm. Int. Mer Médit.* 29, 299–300.
- ICES: International Council for the Exploration of the Sea <http://www.ices.dk>.
- IMO: International Maritime Organization: <http://www.imo.org>.
- Isari, S., Psarra, S., Pitta, P., Mara, P., Tomprou, M.O., Ramfos, A., Somarakis, S., Tselepides, A., Koutsikopoulos, C., Fragopoulou, N., 2007. Differential patterns of mesozooplankters' distribution in relation to physical and biological variables of the northeastern Aegean Sea (Eastern Mediterranean). *Mar. Biol.* 151, 1035–1050.
- IUCN: International Union for the Conservation of Nature and Natural Resources <http://www.iucn.org>.
- Jansà, J., Fernández de Puelles, M.L., 1990. Distribucion espacio-temporal del zooplancton en el mar Balear. *Bol. Inst. Esp. Oceanogr.* 6, 107–136.
- Keane, R.M., Crawley, M.J., 2002. Exotic plant invasions and the enemy release hypothesis. *Trends Ecol. Evol.* 17, 164–170.
- Kimor, B., 1965. Fluctuations in the abundance and composition of the plankton communities off the Mediterranean coast of Israel in relation to the *Sardinella aurita* fishery during the years 1955–1960. *Proc. Gen. Fish. Coun. Medit.* 64, 1–15.
- Kimor, B., 1971. Some considerations on the distribution of Acantharia and Radiolaria in the eastern Mediterranean. *Rapp. Comm. Int. Mer Médit.* 20, 349–351.
- Kimor, B., 1972. The Suez Canal as a link and a barrier in the migration of plankton organisms. *Israel J. Zoo.* 21, 391–403.
- Kimor, B., 1983. Distinctive features of the plankton of the eastern Mediterranean. *Ann. Inst. Oceanogr.* 59 (5), 97–106.
- Kimor, B., Wood, E.J.F., 1975. A plankton study in the Eastern Mediterranean Sea. *Mar. Biol.* 29, 321–333.
- Kimor, B., Berdugo, V., 1967. Cruise to the eastern Mediterranean, C-03, Plankton reports. *Bull. Sea Fish. Res. Stn Israel* 45, 6–31.
- Kiortsis, V., 1969. Surface zooplankton of the Aegean Sea. Marine fauna of the Aegean Sea. *Zool. Labor. & Mus, Athens*, 82 p.
- Klein, J., Ruiton, S., Verlaque, M., Boudouresque, C.F., 2005. Species introductions, diversity and disturbances in marine macrophyte assemblages of the northwestern Mediterranean Sea. *Mar. Ecol. Progr. Ser.* 290, 79–88.
- Koçak, F., Ergen, Z., Çinar, M.E., 1999. Fouling organisms and their developments in a polluted and an unpolluted marine in the Aegean Sea (Turkey). *Ophelia* 50 (1), 1–20.
- Komarovsky, B., 1952. A cladoceran from the plankton as a possible indicator for the presence of the Nile flood off the coast of Israel. *Nature, Lond.*, 937–938
- Komarovsky, B., 1959. The Tintinnina of the Gulf of Eilat (Aqaba). *Bull. Sea Fish. Res. Stn Israel* 21, 1–40.
- Komarovsky, B., 1962. Tintinnina from the vicinity of the Straits of Tiran and Massawa Region. *Bull. Sea Fish. Res. Stn Israel* 30, 48–56.
- Kramp, P. L. (1965). The Hydromedusae of the Pacific and Indian Oceans. *Dana Report No.* 63, 162 p.
- Krom, M.D., Brenner, S., Israilov, I., Krumgalz, B., 1991. Dissolved nutrients, performed nutrients and calculated elemental ratios in the South-East Medierranean Sea. *Oceanol. Acta* 14 (2), 189–194.
- Krsinic, F., Grbec, B., 2012. Spatial distribution of copepod abundance in the epipelagic layer of the south Adriatic Sea. *Acta Adriat.* 53 (1), 57–70.
- Lacombe, H., Tchernia, P., 1960. Quelques trait generaux de Phydrologie Mediterranee. *Cah. Oceanogr.* 12, 525–547.
- Lakkis, S., 1971. Contribution à l'étude du zooplancton des eaux libanaises. *Mar. Biol.* 11, 138–148.
- Lakkis, S., 1974. Distributions saisonnieres du zooplancton dans les eaux Libanaises. *Rapp. Comm. Int. Mer Médit.* 22 (9), 117–118.
- Lakkis, S., 1976. Consideration on the distribution of pelagic copepods in the eastern Mediterranean off the coast of Lebanon. *Acta Adriat.* 18, 39–52.
- Lakkis, S., 1984. On the presence of some rare copepods in the Levantine basin. *Crustaceana* 7, 286–304.
- Lakkis, S., 1990. Composition, diversité et successions des copépodes planctoniques des eaux libanaises (Méditerranée orientale). *Oceanol. Acta* 13, 489–501.
- Lakkis, S. (1998). Biogeography of the plankton from Lebanese waters (eastern Mediterranean): the Levantine basin and species of Indo-Pacific origin. Pelagic biogeography. ICOPB II. In: Proceedings of the 2nd International Conference. A.C. Pierrot-Bults & S. Van der Spoel (Eds.): 233–238.
- Lakkis, S., Toklu, B., 2007. Contribution to the study of zooplankton community in Iskenderoun Bay (North-Eastern Mediterranean). *Rapp. Comm. Int. Mer Médit.* 38, 527.
- Lakkis, S., Zeidane, R., 1985. Les appendiculaires des eaux néritiques libanaises: observations faunistiques et écologiques. *Rapp. Comm. Int. Mer Médit.* 29 (9), 287–288.
- Lakkis, S., Zeidane, R., 2004. Exotic species and lessepsian migration of plankton in Lebanese waters, Levantine Basin, Eastern Mediterranean. *Rapp. Comm. Int. Mer Médit.* 37, 384.
- Lancelot, C., Staneva, J., Van Eeckhout, D., Beckers, J.M., Stanev, E., 2002. Modelling the Danube-influenced north-western continental shelf of the Black Sea. Part II: Ecosystem response to changes in nutrient delivery by the Danube River after its damming in 1972. *Tuar. Cost. Shelf Sci.* 54, 473–499.
- Laval, P., Braconnot, J.C., Carré, C., Goy, J., Morand, P., Mills, C.E., 1989. Small scale distribution of macroplankton and micronektonn in the Ligurian Sea (Mediterranean Sea) as observed from the manned submersible Cyana. *J. Plankton Res.* 11, 665–685.

- Leveau, M., 1965. Contribution à l'étude des ostracodes et cladocères du Golfe de Marseille. *Rec. Trav. St. mar. Endoume* 37 (53), 161–246.
- Mac Donald, R., 1933. An examination of plankton hauls made in the Suez Canal during the year 1928. *Notes Mem. Fish. Res. Dir Cairo* 3, 1–11.
- Maillard, C., Soliman, G., 1986. Hydrography of the Red Sea and exchanges with the Indian Ocean in summer. *Oceanol. Acta* 9 (3), 249–269.
- Marques, S.C., Azeiteiro, U.M., Martinho, F., Pardal, M.A., 2007a. Climate variability and planktonic communities: the effect of an extreme event (severe drought) in a southern European estuary. *Estu. Coast. Shelf Sci.* 73, 725–734.
- Marques, S.C., Pardal, M.A., Pereira, M.J., Gonçalves, F., Marques, J.C., Azeiteiro, U.M., 2007b. Zooplankton distribution and dynamics in a temperate shallow estuary. *Hydrobiol.* 587, 213–223.
- Mauchline, J., 1998. The biology of calanoid copepods. *Adv. Mar. Biol. New York and London* 33, 1–170.
- Mavruk, S., Avsar, D., 2008. Non-native fishes in the Mediterranean from the Red Sea by way of the Suez Canal. *Rev. Fish Biol. Fisheries* 18, 251–262.
- Mazza, J., 1962. Peches planctoniques superficielles et profondes, en Mediterranee occidentale (Campagne de la "Thalassa"- Janvier 1961-entre les îles Balears, la sardaigne et l'Algerois). II Copepodes. *Rev. Trav. Inst. Peches. Marit.* 26 (3), 329–356.
- Mazza, J., 1963. Copepodes des cotes occidentale et orientale de Corse. *Comm. Int. Explor. Sci. Mer. Medit., Rapp. et P.V.* 17 (2), 563–572.
- Mazza, J., 1966. Les copepods de la Mediterranee (Basin occidental). *Comm. Int. Explor. Sci. Mer. Medit., Congresso Bucarest*, 1–99.
- Mazza, J. (1967). Les copépodes pélagiques en Méditerranée occidentale. (Développement post-larvaire, biologie, écologie). Thèse Doct. es Sci., Univ. Aix-Marseille.
- Moraitou-Apostolopoulou, M. (1985). The zooplankton communities of the Eastern Mediterranean (Levantine Basin-Aegean Sea): Influence of man-made factors. In: Moraitou-Apostolopoulou, M. & V. Kiorsis (eds), Plenum Press: Mediterranean Marine Ecosystems: 303–331.
- Morcos, S.A., 1960. Die Verteilung des Salzgehaltes im Suez Kanal. *Kieler Meeresforsch* 16, 133–254.
- Morcos, S.A., 1970. Physical and chemical oceanography of the Red Sea. *Oceanogr. Mar. Biol. Ann. Rev.* 8, 73–202.
- Morcos, S.A. (1972). Sources of Mediterranean intermediate water in the Levantine Sea. In: *Studies in physical oceanography, a tribute to George Wust on his 80th birthday*, Ed. by A.L. Gordon: 185–206, Gordon and Breach, New York.
- Occhipinti-Ambrogi, A., 2000. Biotic invasions in a Mediterranean lagoon. *Biol. Invasions* 2 (2), 165–176.
- Occhipinti Ambrogi, A., 2001. Transfer of marine organisms: a challenge to the conservation of coastal biocoenoses. *Aquat. Conservation Mar. Freshwater Ecosystem* 11, 243–251.
- Occhipinti Ambrogi, A. (2002a). Current status of aquatic introductions in Italy. p. 311–324. In: *Invasive Aquatic species of Europe – distribution impacts and management*, edited by E. Leppakoski, S. Gollasch and S. Olenin, Dordrecht, Boston, London, Kluwer Academic Publishers.
- Occhipinti Ambrogi, A. (2002b). Susceptibility to invasion: assessing the scale and impact of alien biota in Northern Adriatic. p. 69–73. In: *Alien Marine Organisms Introduced by Ships in the Mediterranean and Black Seas*, edited by F. Briand. Monaco, CIESM Workshop Monographs No. 20.
- Occhipinti Ambrogi, A., Savini, D., 2003. Biological invasions as a component of global change in stressed marine ecosystems. *Mar. Pollut. Bull.* 46, 542–551.
- Oren, O.H., 1969. Oceanographic and biological influence of the Suez Canal, the Nile and the Aswan Dam on the Levant Basin. *Prog. In. Oceanogr.* 5, 161–167.
- Pancucci-Papadopoulou, M.A., Siokou-Frangou, I., Theocharis, A., Georgopoulos, D., 1992. Zooplankton vertical distribution in relation to hydrology in the NW Levantine and the SE Aegean Seas (spring 1986). *Oceanol. Acta* 15, 365–381.
- Pasteur, R., Berdugo, V., Kimor, B., 1976. The abundance, composition and seasonal distribution of epizooplankton in coastal and offshore waters of the eastern Mediterranean. *Acta Adriat.* 18 (4), 55–80.
- Patriiti, G., 1970. Aperçu systematique de la faune de Siphonophores des zones superficielles et sub-superficielles des eaux du large de Tulear (SW de l'Océan Indian, Madagascar). *Rev. Trav. St. Mar. End. Fasc. Hors. Suppl.* 10, 285–303.
- Patriiti, G., 1973. Les cladocères des milieux portuaires de Marseille. *Mar. Biol.* 20, 50–57.
- Patriiti, G. (1976). Structure et fonctionnement de la partie planctonique dans l'écosystème des zones fermées et semi-fermées des ports de Marseille. (Dystrophie et pollution). Thèse Doc. Es Sci., Univ. Aix-Marseille.
- Patriiti, G., 1984. Remarques sur la structuration des populations zooplanctoniques dans la zone de l'émissaire de Marseille-Cortiou. *Mar. Biol.* 82, 57–166.
- Pesta, O. (1941). Die Arten der Copepodengattungen *Candacia Dana* und *Calanopia Dana* aus dem Roten Meer. *Sber. Akad. Wiss. Wien. (mathem.-nat. Kl.)*, 150: 157–180.
- Pesta, O. (1943). Die Arten der Copepodengattungen *Rhincalanus Dana*, *Euchaeta Philippi*, *Centropages Kroyer*, *Temora Baird* und *Tortanus Giesbrecht* aus dem Roten Meer. *Sber. Akad. Wiss. Wien. (mathem.-nat. Kl.)*, 152: 7–32.
- Petran, A., 1985. Evolution des biomasses du zooplancton de la mer Noire dans le secteur situé devant les embouchures du Danube pendant les années 1977–1980. *Rapp. Comm. Int. Mer Médit.* 29, 319–320.
- Ponomareva, L. A. (1966). Quantitative distribution of zooplankton in the Red Sea as observed in the period May-June, 1966. *Institute of Oceanography USSR, Academy of Science USSR Oceanology*, 8: 240–242.
- Por, F.D., 1964. A study of the Levantine and Pontic Harpacticoida (Crustacea, Copepoda). *Zool. Verhandelingen* 64, 1–128.
- Por, F.D., 1971. One hundred years of Suez Canal. A century of lessepsian migration: retrospect and view points. *Syst. Zool.* 20, 138–159.
- Por, F.D., 1972. Hydrobiological notes on the high-salinity waters of the Sinai Peninsula. *Mar. Biol.* 14, 111–119.
- Por, F.D., 1978. Lessepsian migration. The influx of Red Sea biota into the Mediterranean by way of the Suez Canal. *Ecological studies*. Springer-Verlag, Berlin.
- Por, F.D., 1990. Lessepsian migration. An appraisal and new data. *Bull. Inst. Oceanogr. Monaco*, no special 7, 1–10.
- Por, F.D., Ferber, I., 1972. The Hebrew University. Smithsonian Institution collections from the Suez Canal (1967–1972). *Israel J. Zool.* 21, 149–166.
- Porumb, F., Onciu, I., Ialina, E., Petran, A., 1981. Sur les quantités de zooplancton dans les eaux de la Méditerranée du sud. *Rapp. Comm. Int. Mer Médit.* 27, 119–120.
- Ragosta, M., Mazzocchi, G.M., Macchiato, M., 1995. Differentiation of copepod assemblages in coastal waters of the Tyrrhenian Sea. *Oceanol. Acta* 18, 479–491.
- Razouls, C. (1972). Estimation de la production secondaire (copépodes pélagiques) dans une province néritique méditerranéenne (Golfe du Lions). Thèse Doct. es Sci., Univ. Paris VI.
- Razouls, C., Kouwenberg, H.M., 1993. Spatial distribution and seasonal variation of mesozooplankton biomass in the gulf of Lions (northwestern Mediterranean). *Oceanol. Acta* 16, 393–401.
- Regner, D., Specchi, M., Fonda Umani, S., 1985. The composition of net zooplankton of the Adriatic Sea. *Rapp. Comm. Int. Mer Médit.* 29, 301–302.

- Ribera, M.A., 1995. Introduced marine plants, with special reference to macroalgae: mechanisms and impact. *Progress in Phycological Research* 11, 217–268.
- Ribera, M.A. (2002). Review of non-native marine plants in the Mediterranean Sea. p. 291–310. In: *Invasive Aquatic species of Europe distribution impacts and management*, edited by E. Leppakoski, S. Gollasch and S. Olenin, Dordrecht, Boston, London, Kluwer Academic Publishers.
- Ribera, M.A., Boudouresque, C.F., 1995. Introduced marine plants, with special reference to macroalgae: mechanisms and impact. *Progr. Phycol. Res.* 11, 217–268.
- Riera, T., Blasco, D., 1967. Plancton superficial del mar de Baleares en julio de 1966. *Inv. Pesq.* 31, 463–484.
- Rodríguez Martínez, V. (1979). *Zooplankton de la bahia de Malaga. Aproximacion al conocimiento de una comunidad planctonica neritica en el mar de Alboran*, Ph. D. thesis. Univ. Malaga.
- Rose, M., 1924. Notes faunistiques sur les copepods pelagiques des cotes de France. *Bull. Soc. Zool. France* 49, 328–332.
- Rose, M., 1926. Notes faunistiques sur les copepods pelagiques des cotes de France. *Bull. Soc. Zool. France* 51, 134–138.
- Rose, M., 1929. Copepods pelagiques particulièrement de surface provenant des campagnes scientifiques du Prince Albert Ier de Monaco. *Result. Camp. Sci. Monaco* 78, 1.
- Rose, M., 1931. Sur les affinités Atlantiques du plancton de la région d'Alger. *Bull. Stat. Acqui. Peches, Gastiglione* 11 (129), 119–120.
- Rose, M. (1933). Copepods pelagiques. *Faune de France*, 26: 1–374.
- Ruiz, G.M., Fofonof, P., Hines, A.H., 1999. Non-indigenous species as stressors in estuarine and marine communities: assessing invasion impacts and interactions. *Limnol. Oceanogr.* 44, 950–972.
- Russo, A., Artegiani, A., 1996. Adriatic Sea Hydrography. *Sci. Mar.* 60 (2).
- Sabatés, A., Gili, J.M., Pagès, F., 1989. Relationship between zooplankton distribution, geographic characteristics and hydrographic patterns off the Catalan coast (Western Mediterranean). *Mar. Biol.* 3, 153–159.
- Said, M.A., Karam, A.M., 1990. On the formation of the intermediate water masses off the Egyptian Mediterranean coast. *Arch. Hydrobiol.* 120 (1), 111–122.
- Salvà Picó, C. & M.L. Fernández de Puelles. (1992). Distribucion del mesozooplankton en el canal de Ibiza. In: *Alemany A. (ed.): Historia Natural* 91, pp. 315–319.
- Santucci, R., 1937. Ricerche sulla fauna del Mar Rosso. II. Plancton dei banchi madieporici. *Boll. Musei Lab. Zool. Anat. Comp. R. Univ. Genova* 17, 1–42.
- Schneider, G., Lenz, J., Rolke, M., 1994. Zooplankton standing stock and community size structure within the epipelagic zone: a comparison between the central Red Sea and the Gulf of Aden. *Mar. Biol.* 119, 191–198.
- Sciacchitano, I., 1930. Ricerche biologiche su material raccolti dal Prof. L. Sanzo. "Copepodi" *Memorie R. Com. Talassogr. Ital.* 177, 3–33.
- Scott, A., 1902. On some Red Sea and Indian Ocean Copepoda. *Proc. Trans. Lpool Biol. Soc.* 116, 397–427.
- Scotto di Carlo, B. & A. Ianora. (1983). Standing stocks and species composition of Mediterranean zooplankton. In: G.C. Carrada, T.S. Hopkins, Lj. Jęftić and S. Morcos (eds.): *Quantitative analysis and simulation of Mediterranean coastal ecosystems: The Gulf of Naples, a case study*. pp. 59–69, UNESCO Rep. mar. Sci., 20.
- Scotto di Carlo, B., Ianora, A., Fresi, E., Hure, J., 1984. Vertical zonation patterns for Mediterranean copepods from surface to 3000 m at fixed station in the Tyrrhenian Sea. *J. Plankton Res.* 6, 1031–1056.
- Seguin, G., 1968. Contribution à l'étude quantitative du zooplankton de Malte. *Pelagos* 10, 109–132.
- Seguin, G., Gaudy, R., Errhif, A., Thibault, D., 1993. Observations sur l'abondance, la composition taxonomique et les affinités écologiques des copépodes pélagiques récoltés dans la région du front Almería-Oran. *Mar. Life* 3, 19–29.
- Simberloff, D., 1989. Which insect introductions succeed and which fail? In: Drake, J.A., Mooney, H.A. (Eds.), *Biological invasions: a global perspective*. John Wiley and Sons Ltd, Chichester, pp. 61–75.
- Sertorio, T.Z., Della Croce, N., Picone, P., 1980. Ecologia e biologia dei porti del mar Liguria e alto Tirreno. 11. Parametri ambientali e popolamento zooplanctonico del porto di Genova. *Atti. dell'Accad. Ligure di Sci. e Lettere.* 37, 1–21.
- Sertorio, T.Z., Zoli, V., 1980. Ecologia e biologia dei porti del mar Liguria e alto Tirreno. 12. Condizioni ambientali e zooplankton della baia di San Jacopo (Livorno). *Atti Soc. ital. Sci. nat. Museo civ. Stor. nat. Milano* 121, 169–180.
- Sewell, R.B.S., 1948. The free swimming planktonic copepoda. Systematic account, John Murray Expedition, 1933–34. *Sci. Rep.* 8 (1), 1–303.
- Siokou-Frangou, I., Pancucci-Papadopoulou, M.A., 1988. Observations sur le zooplankton de la mer de Rhodes (NO mer du Levant et SE mer Egée). *Rapp. Comm. Int. Mer Médit.* 31, 236.
- Smith, L.L., 1995. Chesapeake Bay Ballast Study. IUCN Species Survival Commission, 1–16.
- Soenen, M. (1969). Contribution à l'étude du zooplankton superficial et profond du bassin sud-occidental méditerranéen. Thèse 3ème cycle, Univ. Aix-Marseille.
- Soenen, M. (1972). Contribution à l'étude du zooplankton superficial et sub superficial du détroit sicilo-tunisien, campagne du B. O. "ORIGNY" du sau 21 Mai, 1970. *Polycop.*, 66p.
- Sparnocchia, S., Manzella, G.M.R., La Violette, P.E., 1994. The interannual and seasonal variability of the MAW and LIW core properties in the Western Mediterranean Sea. *Coast. Estuar. Stud.* 46, 177–194.
- Steinberg, D.K., Nelson, N.B., Carlson, C.A., Prusak, A.C., 2004. Production of chromophoric dissolved organic matter (CDOM) in the open ocean by zooplankton and the colonial cyanobacterium *Trichodesmium* spp. *Mar. Ecol.-Prog. Ser.* 267, 45–56.
- Steinberg, D.K., Goldthwait, S.A., Hansell, D.A., 2002. Zooplankton vertical migration and the active transport of dissolved organic and inorganic nitrogen in the Sargasso Sea. *Deep-Sea Res. Part I Oceanogr. Res.* 49, 1445–1461.
- Steinitz, H., 1967. A tentative list of immigrants via the Suez Canal. *Isr. J. Zool.* 16, 166–169.
- Steinitz, H., 1968. Remarks on the Suez Canal as pathway and as habitat. *Rapp. Comm. Int. Mer Médit.* 19, 139–141.
- Steuer, A. (1898). Sapphirinen des Roten Meeres. *Denkschr. Akad. Wiss., Wien (mathem.-nat. Kl.)* 65:423–431.
- Subba Rao, D.V., Sprules, W.G., Locke, A., Carlton, J.T., 1994. Exotic phytoplankton from ships' ballast waters: Risk of potential spread to mariculture sites on Canada's East Coast. *Can. Data Rep. Fish. Aquat. Sci.* 937, 1–51.
- Thibault, D., Gaudy, R., Le Fèvre, J., 1994. Zooplankton biomass, feeding and metabolism in a geostrophic frontal area (Almeria-Oran Front, western Mediterranean). Significance to pelagic food webs. *J. Mar. Syst.* 5, 297–311.
- Thompson, I.C., 1900. Report on two collections of tropical and more northerly plankton. *Proc. Trans. Lpool Biol. Soc.* 14, 262–274.
- Thompson, I. C. & A. Scott (1903). Report on the Copepoda. Ceylon Pearl Fisheries. 1, Suppl., Royal Society London: 227–307.
- Toklu, B., Sarihan, E., 2003. The Copepoda and Cladocera (Crustacea) fauna along the Yumurtalik-Botas Coastline in Iskenderun Bay. *E.U. Journal of Fisheries & Aquatic Sciences* 20 (1–2), 63–68.
- Tregouboff, G. & M. Rose (1957). *Manuel de planctologie Méditerranéenne*. I (Texte), 587p, 2 (Fig.), 207 pl. C.N.R.S., Paris.
- Uysal, Z., Kideys, A.E., Shmeleva, A.A., Zagorodnyaya, J.A., Gubanova, A.D., 2002. Checklist of copepods (Calanoida and Podoplea) from the northern Levantine basin shelf waters. *Hydrobiologia* 482, 15–21.

- Vannucci, M., Navas, D., 1973. Distribution of Hydromedusae in the Indian Ocean. In: Zeitzschel, B. (Ed.), . In: *The Biology of the Indian Ocean*, 3. Springer-Verlag, Berlin, Heidelberg, New York, pp. 273–281.
- Verlaque, M., 1994. Inventaire des plantes introduites en Méditerranée: origines et repercussions sur l'environnement et les activités humaines. *Oceanol. Acta* 17, 1–23.
- Vinogradov, M.Y., Flint, M.V., Shushkina, E.A., 1985. Vertical distribution of mesoplankton in the open area of the Black Sea. *Mar. Biol.* 89, 95–107.
- Vives, F., 1966. Zooplankton nerítico de las aguas de Castellón (Mediterráneo occidental). *Inv. Pesq.* 30, 49–166.
- Vives, F., 1967. Los copépodos planctónicos del mar Tirreno, en septiembre y octubre 1963. *Inv. Pesq.* 31, 539–583.
- Vives, F., 1978. Distribucion de la poblacion de copepodos en el Mediterraneo occidental. *Res. Exp. Cient. B/O Cornide* 7, 263–302.
- Vives, F., Santamaría, G., Trepal, I., 1975. El zooplankton de los alrededores del estrecho de Gibraltar en Junio-Julio de 1972. *Res. Exp. Cient. B/O Cornide* 4, 7–100.
- Vucetic, T., 1957. Zooplankton investigation in the sea water “Malo Jerezo” and “Velico Jezero” in Island of Mljet (1951–1953). *Acta Adriat.* 4, 51–60.
- Vucetic, T., 1971. Long-term zooplankton standing crop fluctuation in the Central Adriatic coastal region. *Thalassia Jugosl.* 7, 419–428.
- Walter, T.C. & G.A. Boxshall (2008). *World of Copepods database*. Available online at <http://www.marinespecies.org/copepoda>.
- Weikert, H., 1982. The vertical distribution of zooplankton in relation to habitat zones in the area of the Atlantis II Deep Central Red Sea. *Mar. Ecol. Progr. Ser.* 8, 129–143.
- Weikert, H., Trinkaus, S., 1990. Vertical mesozooplankton abundance and distribution in the deep Eastern Mediterranean Sea SE of Crete. *J. Plankton Res.* 12, 601–628.
- Wust, G., 1934. Salzgehalt und Wasserbewegung im Suez Kanal. *Naturwissenschaften* 22, 447–450.
- Zaitsev, Y.P., 1968. La neustonologie marine: objet, méthodes, réalisations principales et problèmes. *Pelagos* 8, 1–47.
- Zakaria, H.Y., 1992. Distribution and ecology of some zooplankton organisms in the Egyptian Mediterranean waters M. Sc thesis. Thesis, Faculty of Science, Alexandria University.
- Zakaria, H.Y., 2006. The zooplankton community in Egyptian Mediterranean waters: a review. *Acta Adriat.* 47 (2), 195–206.
- Zakaria, H.Y., 2007. On the distribution of zooplankton assemblages in Abu Qir Bay, Alexandria, Egypt. *Egypt. J. Aquat. Res.* 33 (1), 238–256.
- Zakaria, H. Y. (2014): Impact of climate variability and anthropogenic activities on zooplankton community in the neritic waters of Alexandria, Egypt. *JKAU: Mar. Sci.*, 25 (2).
- Zavatarelli, M., Mellor, G.L., 1995. A numerical study of the Mediterranean Sea circulation. *J. Phys. Oceanogr.* 25 (6), 1384–1414.
- Zenetos, A., Cinar, M.E., Pancucci-Papadopoulou, M.A., Harmelin, J.G., Furnari, G., Andaloro, F., Bellou, N., Streftaris, N., Zibrowius, H., 2006. Annotated list of marine alien species in the Mediterranean with records of the worst invasive species. *Mediterr. Mar. Sci.* 6 (2), 63–118.
- Zibrowius, H., 1992. Ongoing modification of the Mediterranean marine flora and fauna by the establishment of exotic species. *Mésogée* 51, 83–107.
- Zibrowius, H., 2002. Assessing scale and impact of ship transported alien fauna in the Mediterranean. *CIESM Workshop Monographs* 20, 62–68.