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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