

Viewpoint

The enlargement of the Suez Canal – Erythraean introductions and management challenges

Bella Galil^{1*}, Agnese Marchini², Anna Occhipinti-Ambrogi² and Henn Ojaveer³

¹The Steinhardt Museum of Natural History, Israel National Center for Biodiversity Studies, Tel Aviv University, Tel Aviv, Israel

²Department of Earth and Environmental Sciences, University of Pavia, Pavia, Italy

³Estonian Marine Institute, University of Tartu, Pärnu, Estonia

*Corresponding author

E-mail: galil@post.tau.ac.il

Received: 28 July 2016 / Accepted: 8 November 2016 / Published online: 12 December 2016

Handling editor: Cynthia McKenzie

Editor's note:

This study was first presented at the 9th International Conference on Marine Bioinvasions held in Sydney, Australia, January 19–21, 2016 (<http://www.marinebioinvasions.info/previous-conferences>). Since their inception in 1999, ICMB series have provided a venue for the exchange of information on various aspects of biological invasions in marine ecosystems, including ecological research, education, management and policies tackling marine bioinvasions.

Abstract

The Suez Canal is the main pathway of introduction of non-indigenous species into the Mediterranean Sea. The successive enlargements of the Suez Canal have raised concern over increasing propagule pressure resulting in continuous introductions of new non-indigenous species and associated degradation and loss of native populations, habitats and ecosystem services. The United Nations Environment Programme (UNEP) through its Barcelona Convention has pledged to protect the biological resources, habitats and ecosystem services of the Mediterranean Sea, and have committed to spatial protection measures. Yet, UNEP shied away from discussing, let alone managing, the influx of tropical non-indigenous biota introduced through the Suez Canal. Surveys, funded by the Regional Activity Centre for Specially Protected Areas (UNEP RAC/SPA), established by the Contracting Parties to the Barcelona Convention, revealed that marine protected areas in the eastern Mediterranean have been inundated by these non-indigenous species, and may in fact function as hubs for their secondary dispersal. We call attention to the failure of an environmental policy that left the entire Mediterranean Sea prone to colonization by highly impacting non-indigenous species, including poisonous and venomous ones. Scientific research has been documenting this bioinvasion for over a century, yet beyond the ambit of marine scientists there is a lack of awareness of the scale of Mediterranean-wide consequences and scant appetite to enact the necessary environmental policies.

Key words: marine protected areas, Mediterranean Sea, non-indigenous species, United Nations Environment Programme, Barcelona Convention

“If we do not understand and mitigate the ecological risks associated with the expansion of the Suez Canal, the integrity of a large part of the Mediterranean ecosystem could be in jeopardy.”

Samaha, zu Dohna and Bariche, 2016

Introduction: erythraean introductions and their consequences

Complex and fundamental alterations to the Mediterranean Sea are underway, including increases in non-indigenous species (NIS), which have affected

the structure and functioning of the sea and the consequent provision of goods and services (Micheli et al. 2013; EEA 2015; Galil et al. 2016). The number of recorded introductions into the Mediterranean Sea is far higher than in other European seas: nearly triple the number of records known from the Western European margin (Galil et al. 2014). About two thirds of the 751 multicellular NIS introduced into the Mediterranean Sea are considered Erythraean NIS (ENIS)—species introduced through the Suez Canal. As concerns ENIS, a succession of spatially and temporally directional (“stepping stones”) records

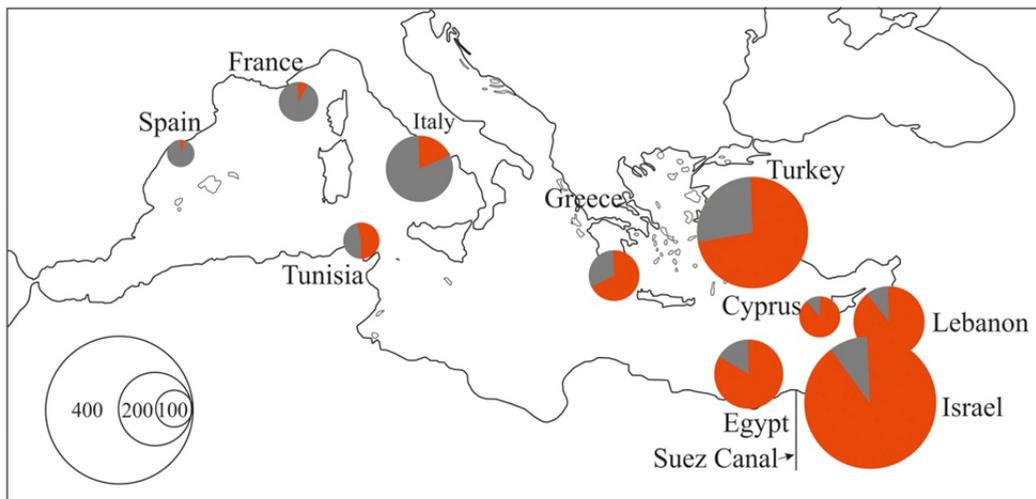


Figure 1. The number of non-indigenous species (NIS) in some Mediterranean countries. In red, the fraction of species probably introduced through the Suez Canal. The circle sizes are proportionate to the total number of NIS recorded in the country.

from the Red Sea, the Suez Canal, and along the coasts of the Levant confirms a species status as a naturally dispersing ENIS (Galil 2006). ENIS numbers more than doubled between 1980 and 2016 and are substantially greater in the Levant than in the western Mediterranean (Galil et al. 2016). The Levantine countries (Egypt, Israel, Lebanon, Syria, Turkey, Cyprus, Greece), and to lesser degree Malta, Libya and Tunisia, saw an increase in the number of introductions through the Suez Canal (Figure 1).

These Erythraean macrophytes, invertebrates and fish are prominent in many coastal habitats in the Mediterranean Sea and in particular have profoundly altered the composition of the biota of the south-eastern Mediterranean Sea (Steinitz 1970; Por 1978; Galil 2007). It is difficult to disentangle confounding factors in evaluating impacts of most bioinvasions: where populations of indigenous Mediterranean species appear to have been outcompeted or displaced by ENIS, these changes could be part of a profound anthropogenic alteration of the marine environment. With few exceptions, the ecological impact of NIS on the indigenous Mediterranean biota is poorly known (Zibrowius 1992; Boudouresque 2004; Katsanevakis et al. 2014b), although it is believed that some species have caused major shifts in community composition. A number of ENIS have drawn the attention of scientists, managers and media for the conspicuous impacts on the native biota attributed to them.

Perhaps the best studied ENIS are two species of rabbitfish, *Siganus rivulatus* and *S. luridus*, which were first recorded in the Mediterranean Sea off the

coast of Israel in 1924 and 1955, respectively (Steinitz 1927; Ben-Tuvia 1964). The two species are now found as far west as Tunisia and France (Ktari-Chakroun and Bahloul 1971; Ktari and Ktari 1974; Daniel et al. 2009). These schooling, herbivorous fishes form thriving populations in the Levant Sea where "...million of young abound over rocky outcropping grazing on the relatively abundant early summer algal cover" (George and Athanassiou 1967). These siganids recently comprised a significant segment (up to 95%) of fish biomass in Levantine shallow rocky habitats (Goren and Galil 2001; Bariche et al. 2004; Sala et al. 2011), and have replaced native herbivorous fish in the Levant (Papaconstantinou 1987; Bariche et al. 2004). Their food-web interactions have significant impacts on the structure of the algal community: the siganids, by selective feeding, have nearly extirpated some of their favorite algal taxa locally (Lundberg et al. 2004); "once flourishing algal forests have disappeared to leave space to sponges and wide areas of bare substratum... The shift from well-developed native algal assemblages to 'barrens' implies a dramatic decline in biogenic habitat complexity, biodiversity and biomass... with effects that may move up the food chain to the local fisheries." (Sala et al. 2011). In the southern Cyclades, where *S. luridus* accounted for 90% of herbivorous fish abundance in 2008, a significant decline was noted in the cover of canopy-forming algae, mainly Dictyotales and *Cystoseira* spp. (Giakoumi 2014). A survey along one thousand kilometers of Greek and Turkish coasts found that in regions with abundant siganids canopy-forming

algae were 65% less abundant, benthic biomass was reduced by 60%, and species richness by 40% (Vergés et al. 2014).

The non-indigenous mytilid mussel *Brachidontes pharaonis* in the early 1970s was "...250 times rarer" than the native mytilid *Mytilaster minimus*, which formed dense *Mytilaster* beds on intertidal rocky ledges along the Israeli coastline (Safriel et al. 1980). Recently "the same rocks are completely covered with the Erythrean *B. pharaonis*, while *M. minimus* is only rarely encountered." (Mienis 2003). The non-indigenous mytilid has spread westwards: in southern Italy it forms dense populations with over 25,000 specimens per m² (Sarà et al. 2006), and has spread to Corsica, France (Merella et al. 1994). Many more replacements have been observed in the southeastern Mediterranean Sea (Galil 2007).

Some ENIS pose substantial health hazards. The most notorious is the lethally poisonous pufferfish, *Lagocephalus sceleratus*, which has spread throughout the Levant and westwards to Italy, Spain, Tunisia and Algeria (Jribi and Bradai 2012; Kaporis et al. 2014; Katsanevakis et al. 2014a; Kara et al. 2015) and northwards to Croatia (Sulić Šprem et al. 2014). Its internal organs contain tetrodotoxin, a strong paralytic neurotoxin inducing symptoms ranging from vomiting to respiratory arrest, seizures, cardiac arrest, coma and death (Islam et al. 2011). Between 2005 and 2008 several persons were treated for poisoning by this species in Israel (Bentur et al. 2008). The striped eel catfish, *Plotosus lineatus*, has venom glands in the spines of the dorsal and pectoral fins, as well as glandular cells in its skin secreting a potent proteinaceous toxin. It has spread along the Levant coastline from Egypt to Turkey (Doğdu et al. 2016), and the injuries it inflicts, mainly to fishers, are quite severe (Gweta et al. 2008). Twenty years after the first specimen of *Pterois miles*, the highly venomous lionfish, was recorded from the Levant, a spate of records from Israel, Lebanon, Cyprus, Turkey and Tunisia (Bariche et al. 2013; Turan et al. 2014; Oray et al. 2015; Kletou et al. 2016; Dailianis et al. 2016) attests to the presence of an established population in the Levant and north Africa. If its population expands, injuries to bathers, divers and fishers may be expected (Steinitz 1959) as well. Yet the largest numbers of envenomisations along the southern Levant coast have been caused by the scyphozoan jellyfish *Rhopilema nomadica*. First recorded in the Mediterranean in the 1970s, it is notorious for the large swarms it has formed each summer since the early 1980s (Galil et al. 1990; Galil 2012). Lately it has spread to Pantelleria Island (Crocetta et al. 2015), as well as to Tunisia,

where, in summer 2013, densities as high as 10–100 individuals per 1000 m³ were observed (Daly Yahia et al. 2013). The annual swarming results each year in victims of envenomation suffering effects that may last for weeks and months after the event and which may require hospitalization (Benmeir et al. 1990; Silfen et al. 2003; Yoffe and Baruchin 2004; Sendovski et al. 2005; Öztürk and İşinibilir 2010). The swarms adversely affect tourism: a socio-economic survey, carried out in Israel in 2013, estimated that swarming reduces the number of seaside visits, with an annual monetary loss of up to 6.2 million € (Ghermandi et al. 2015). Coastal trawling and purse-seine fishing are disrupted for the duration of the swarming due to net clogging and difficulty to sort the catch. Water intake pipes blocked by jellyfish occasionally pose a threat to desalination plants and the seawater cooling systems of coastal power plants: in the summer of 2015 the Israel Electric Company had to remove tons of jellyfish from its seawater intake pipes at its Ashkelon power plant (<http://www.haaretz.com/Israel-news/premium-1.662930>). Outbreaks of *R. nomadica* may impact the ecosystem in ways we are neither able to predict nor fully understand, and which may be more significant than the obvious impacts to the economy and human health.

When opened in 1869 the Suez Canal was 8 m deep. In time, the waterway was widened, deepened and five sections were doubled (Port Said, Ballah, Timsah, Deversoir, Kabret). The typical cross-sectional area was 304 m² (8 m deep) in 1869, 1200 m² (14 m) in 1956, 1800 m² (15.5 m) in 1962, 3600 m² (19.5 m) in 1980, and 5200 m² (24 m) in 2010 (<http://www.suezcanal.gov.eg/sc.aspx?show=12>). In August 2015 the latest expansion, dubbed the "New Suez Canal" was opened, added a 72.4 km lane parallel to the existing canal (<https://www.theguardian.com/world/2014/aug/05/egypt-build-new-suez-canal>).

The successive enlargements of the Suez Canal have raised concern over increasing propagule pressure resulting in introductions of additional ENIS and associated degradation and loss of native populations, habitats and ecosystem services.

In this study we examine the environmental policy as it relates to NIS in the Mediterranean Sea, and especially the role of the Suez Canal as the main pathway of NIS introduction. Specifically, we highlight the implications of the successful establishment of ENIS at Marine Protected Areas (MPAs) and how this has led to a failure to fulfill the obligation to protect native biodiversity. We follow the identification of policy shortfalls with suggestions for feasible and viable management interventions.

Conservation challenge: no reserve is an island

Marine protected areas, created to conserve the indigenous diversity, are meant to offer an ecosystem-based approach to conservation, and to provide protection to species, habitats, ecosystems, and insurance against environmental or management uncertainty (Lubchenco et al. 2003). The prevailing theory holds that MPAs, owing to their high species diversity and putative abundance of indigenous predators/competitors/parasites, are resistant to introduction of NIS (Francour et al. 2010). It is, however, questionable whether MPAs, or even networks of MPAs, are able to conserve the indigenous biota under a high NIS load (Simberloff 2000). We present examples from MPAs in several countries (Turkey, Syria, Lebanon, Israel, Libya, Italy) which suggest that these MPAs have been overwhelmed by ENIS, and that unless bioinvasion management is incorporated in the spatial planning of the Mediterranean Sea, we endanger the conservation of the indigenous biota.

Extensive diving surveys conducted in 2005–2006 in the Gökova Specially Protected Area, Turkey, documented scores of ENIS, including the barren-forming rabbitfish. A study of rabbitfish populations at three sites on the coast of Turkey—Kaş-Kekova, Fethiye-Göcek and Bodrum—found that their percentage of the herbivorous fish biomass was only a little lower in the protected (Kaş-Kekova and Fethiye-Göcek; 83%) than in a non-protected area (Bodrum; 95%) (Sala et al. 2011). Similarly, the four MPAs—Karpachos, Fethiye, Kaş and Adrasan—examined by Vergés et al. (2014) were all characterized by a high abundance of rabbitfish. Indeed, the highest abundance of Erythraean fish (*Fistularia commersonii*, *Pteragogus pelycus*, *Sargocentron rubrum*, *S. luridus*, *S. rivulatus*) among rocky reef fish assemblages in the Mediterranean was observed at Gökova, Fethiye, Kaş, and Adrasan, Turkey (Guidetti et al. 2014). These results led the authors to suggest that “the mechanisms of invasion are not affected by protection” and that conversely, MPAs may enhance the number and densities of NIS. Indeed, a survey of opisthobranch species along the coast of Turkey from Bodrum to the Gulf of Iskenderun revealed that the largest numbers (13 of 18 ENIS) were recorded in the Kaş-Kekova Specially Protected Area (Yokes et al. 2012).

A survey along the Syrian coastline (from Ras Samra to Arwad Island and Tartous near the Syrian-Lebanese border), was aimed at identifying sites suitable for MPAs and was conducted in 2003 (Bitar et al. 2003). At Ras Samra the rocky banks were

totally covered with the Erythraean alga *Styopodium schimperi* and the fauna comprised many ENIS (*Conomurex persicus* (as *Strombus decorus*), *Malleus regula*, *Chama pacifica*, *Pinctada imbricata radiata*, *Synaptula reciprocans*, *F. commersonii*, *Pempheris rhomboidea* (as *P. vanicolensis*), *S. rubrum*, *S. rivulatus*). At Ras El Bassit, *S. schimperi* colonized the major part of the hard substrate whereas the sandy bottom was covered with a meadow of the Erythraean seagrass *Halophila stipulacea*, and *S. decorus* was “very abundant”. At Ibn Hani, the non-indigenous rhodophyte *Galaxaura rugosa* covered “almost entirely the rocky substrate” (Bitar et al. 2003), accompanied by many non-indigenous fish and invertebrates. In their summary Bitar et al. (2003) noted that *S. schimperi* formed very dense populations down to 40 meters depth, colonizing the major part of the hard substrates, and that Erythraean mollusks and fish formed a “large proportion” (7 of 24 spp., 8 of 36 spp., respectively) of the fauna. Yet, according to the Network of Marine Protected Area Managers in the Mediterranean (MedPan), three MPAs have been designated along that coast (Fonar Ibn Hani, Om al Toyour, Ras El Bassit). In December 2004, additional MPAs were proposed at Ras Samra, between Om al Toyour and Ras El Bassit, and between Ras Ibn Hani and Borg Islam, in a project co-financed by UNEP—Mediterranean Action Plan (MAP) (http://ec.europa.eu/maritimeaffairs/documentation/studies/documents/syria_01_en.pdf, viewed 5 October 2016).

Along the Lebanese coast (Enfeh Peninsula, Ras Chekaa cliffs, Raoucheh, Saida, Tyre and Nakoura) surveys were undertaken in 2012 and 2013 in the framework of the “Regional Project for the Development of a Mediterranean Marine and Coastal Protected Areas” (MedMPAnet Project). The resulting report (RAC/SPA - UNEP/MAP 2014) highlights the prevalence of ENIS at all sites, including 31% and 21% respectively of the recorded mollusc and fish species. ENIS have established large populations at all surveyed sites and have been frequently the most common species encountered: the mytilid *Brachidontes pharaonis* “dominates the abrasion platform and it forms a marked belt in the lower part of the midlittoral”, “...the rocky substrata is bare and empty of erected soft macroalgae this overgrazing is due to the herbivorous pressure of the fishes *Siganus rivulatus* and *S. luridus*”, the stinging feathery hydroid *Macrorhynchia philippina* “is distributed in all of the observed areas, between 0–7 m depths”, and on “vertical rock between 0–6 m depth... *Chama-Spondylus* reefs create a complex habitat... develop original facies, without comparison along the

whole Mediterranean” with another Erythraean bivalve, *M. regula*. *Synaptula reciprocans* is by far the most common echinoderm (RAC/SPA - UNEP/MAP 2014).

Along the Mediterranean coast of Israel there are 9 designated, and 8 proposed marine nature reserves (<http://www.mpatlas.org/region/nation/ISR/> viewed 5 October 2016). The Israel Nature and Parks Authority has yet to publish a faunal inventory for any of them (<http://www.parks.org.il/ParksAndReserves/yamTichon/Documents/boyaJuly2015.pdf>).

However, a biodiversity study of the Rosh Haniqra-Akhziv nature reserves was conducted in 2004, financed by UNEP-MAP and MedMPA (Ramos Esplá and Pérez 2004). It documents the overwhelming presence of NIS from the littoral to the depth of 40 m. The mytilid *B. pharaonis* forms a marked belt in the lower part of the midlittoral (Ramos Esplá and Pérez 2004). Shallow rocky reefs (1–22 m) are covered by *S. spinosus* and *C. pacifica* formations, overgrown with the stinging Erythraean hydrozoan *M. philippina*. Other common non-indigenous molluscs are *P. imbricata radiata*, *M. regula*, *C. persicus* (as *S. persicus*), *Trochus erythraeus*. *Stipopodium schimperi* is omnipresent (Ramos Esplá and Pérez 2004). The abundance of non-indigenous fish (*F. commersonii*, *P. rhomboidea* (as *P. vanicolensis*), *S. rubrum*, *S. luridus*, *S. rivulatus*, and *Stephanolepis diaspros*) “is noteworthy”, comprising 37.3% of the total number of individual fish observed. The most important NIS were the siganids “...because the genus *Siganus* sp. represented about the 100% of the observed herbivorous, since *Salpa salpa* has been very rare. With regards to the shadowy biotopes (caves, overhangs, crevices), *P. vanicolensis*, *S. rubrum* and *A. nigripinnis* [*Apogonichthyoides pharaonis*] (especially the first ones) have dominated these habitats.” The infralittoral rhodolith facies was noteworthy for “the great abundance of Red Sea alien species: *M. philippina*, *P. radiata*, *Spondylus spinosus*, *M. regulus*, *Phallusia nigra*, *S. persicus*, *Charybdis helleri*, *Apogon nigripinnis* (juv.), and *S. diaspros*.” (Ramos Esplá and Pérez 2004). Other studies confirm the results of that survey: an inventory of the mollusc fauna in the same Rosh Haniqra-Akhziv nature reserve, compiled from literature and samples deposited in the National Collections, private collections and the Zoological Museum of Copenhagen, comprised 283 species, including 38 Erythraean species, most of the latter only recently collected (Mienis and Ben-David-Zaslow 2004). Other newly reported ENIS were noted in that marine nature reserve: the apogonid *Cheilodipterus novemstriatus* (Rothman et al. 2012), the “marble shrimp”, *Saron marmoratus* (Rothman

et al. 2013), and the rare nudibranch *Plocamopherus ocellatus* (Rothman and Galil 2015).

A survey of El-Kouf National Park, Libya, was conducted in 2010 and 2012 within the framework of the MedMPAnet Project implemented by UNEP/MAP-RAC/SPA (Bazairi et al. 2013). As elsewhere, both siganids were abundant in El-Kouf, especially *S. luridus*; numerous schools were observed in different parts of the surveyed area, as well as *F. commersonii*, *P. rhomboidea* (as *P. vanicolensis*), *L. sceleratus* and *Sphyaena flavicauda*.

The presence of ENIS in MPAs is not restricted to the eastern Mediterranean Sea. Azzurro and Andaloro (2004) recorded *S. luridus* from Linosa Island, Italy, within the Isole Pelagie MPA. Surveys of the infralittoral fringe in 2010–2011 revealed an increase in its population distribution and abundance, as well as a population of *Pinctada imbricata radiata* (Lodola et al. 2013a, b).

Yet, despite ample evidence, bioinvasions have been largely disregarded in marine conservation plans (Giakoumi et al. 2016).

Biodiversity policies relating to NIS in the Mediterranean Sea

The Barcelona Convention and the Mediterranean Action Plan

The Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention) was adopted in 1976. In 1995 the Contracting Parties adopted an amended and renamed version as the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean that came into force on 9 July 2004. The Barcelona Convention and its protocols, together with the Mediterranean Action Plan, form part of the United Nations Environment Programme (UNEP) Regional Seas Programme. The Contracting Parties agreed they “...shall, individually or jointly, take all appropriate measures to protect and preserve biological diversity, rare or fragile ecosystems, as well as species of wild fauna and flora which are rare, depleted, threatened or endangered and their habitats, in the area to which this Convention applies.” (http://www.unep.org/NairobiConvention/docs/Barcelona_Convention_full_version.pdf, Article 10).

In recognition of the urgent need to address the impacts of invasive alien species, the Convention on Biological Diversity (CBD), signed in 1992, states that each contracting party shall, as far as possible and as appropriate “prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species” (<https://www.cbd.int/con>

vention/articles/default.shtml?a=cbd-08). The importance of marine and coastal biological diversity was underlined as part of the Ministerial Statement at the COP meeting in Jakarta in 1995 (the Jakarta Mandate) (<https://www.cbd.int/doc/publications/jm-brochure-en.pdf>). The Regional Seas Conventions and Action Plans are considered by UNEP to have a major role to play in the promotion of the Jakarta Mandate at the regional level (<http://www.unep.org/regionalseas/partners/meas/CBD/default.asp> viewed 5 October, 2016).

The Mediterranean region became the first Regional Seas Programme to develop a dedicated strategy on marine and coastal invasive species when it adopted its Action Plan concerning species introductions and invasive species in the Mediterranean Sea in 2003 (http://www.unep.org/regionalseas/publications/brochures/pdfs/invasive_alien_brochure.pdf, viewed 5 October, 2016). The preamble to that Action Plan states that its main objective is to promote the development of coordinated measures and efforts throughout the Mediterranean region in order to prevent, control and monitor the effects of species introduction; that the main known vectors of species introduction into the Mediterranean Sea are entry of Red Sea organisms through the Suez Canal, shipping (ballast water and sediments, fouling), aquaculture and trade in live marine organisms; and that “it is imperative to take immediate steps to prevent the introduction of non-indigenous species, control the spread of those already introduced and endeavor to mitigate the damage they cause to the marine ecosystem.” (UNEP/MAP-RAC/SPA 2005). The implementation timetable was set out in the “Annex” (UNEP/MAP-RAC/SPA 2005). The 20 “Actions” comprise developing programmes to raise the awareness of the general public and of target groups, including decision-makers, concerning the risks associated with species introduction, inventorying introduction vectors, elaborating the regional project on fouling, ballast water and sediment; establishing a directory of relevant specialists and organizations; launching the procedures for enacting or strengthening national legislation governing the control of introduction; developing programmes for data collection and monitoring, preparing guidelines for controlling the vectors, setting up a regional mechanism for collecting, compiling and circulating information on invasive non-indigenous species, preparing guides for risk analysis and impact assessment; compiling an inventory of introduced species and identifying public and private actors whose activity could introduce marine non-indigenous species (Table 1).

The 19th Meeting of the Contracting Parties to the Barcelona Convention adopted an updated Action

Plan concerning “Species Introductions and Invasive Species” (UNEP/MAP 2016c). It repeats (nearly verbatim) the 2005 exhortation “It is imperative to take immediate steps to prevent the introduction of alien species, control the spread of those already introduced and endeavour to mitigate the damage they cause to the marine ecosystem”. More than a decade after the launch of the previous Action Plan, the “Actions” still mostly concern data gathering and dissemination, and repeat, with scant changes, the earlier “Actions” (Table 1). The marine Mediterranean invasive alien species database (MAMIAS) was announced in April 2013 (http://rac-spa.org/sites/default/files/racspa_newsletter_april_2013_pdf, viewed 5 October, 2016), and presented to the meeting of the sub-committee on marine environment and ecosystems (SCMEE) in February 2014 (https://gfcmsitestorage.blob.core.windows.net/documents/SAC/SCMEE/14/PPT/MAMIAS_SCMEE2014_GFCM-SAC-RACSPA.pdf). In April 2015 it was announced that MAMIAS “gives information on invasive non-indigenous species in the Mediterranean (list of alien species, list of marine invasive species, list of vectors, etc) and allows the use of different filters to find required data and retrieve statistics at regional and national level about aliens and invasive species.” (UNEP/MAP-RAC/SPA 2015). Yet, a visit to the website (<http://www.mamias.org>, viewed 3 July 2016) reveals the following announcement “We’re working hard to improve our website and we’ll ready to launch after 00 weeks 00 days, 00:00:00 Copyright © 2014 - RAC/SPA”). A comparison of the two documents (see also Table 1) reveals willful procrastination and unwillingness to undertake the necessary steps to prevent and control NIS introductions in the Mediterranean Sea.

The Suez Canal: the pathway that-must-not-be-named

UNEP-MAP provided for the 2007 meeting of Focal Points for Specially Protected Areas (SPAs) a “Draft Guidelines for controlling the vectors of introduction into the Mediterranean of non-indigenous species and invasive marine species” (UNEP/MAP 2007). The opening paragraph of that document states that “the greatest influx of invaders resulted from the opening of the Suez Canal in 1869 that allowed entry of Indo-Pacific and Erythraean biota.” Yet, the guidelines are limited to ballast water, hull fouling and aquaculture.

The “Draft decision on the Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and targets” presented to the MAP Focal Points in 2013 (UNEP/MAP 2013a), went one

Table 1. Comparison of implementation timetable items of the “Action Plan concerning Species Introductions and Invasive Species in the Mediterranean Sea” (UNEP/MAP-RAC/SPA 2005) and the “Updated Action Plan concerning Species Introductions and Invasive Species in the Mediterranean Sea” (UNEP/MAP 2016c).

Action Plan concerning Species Introductions and Invasive Species in the Mediterranean Sea UNEP-MAP-RAC/SPA 2005	Updated Action Plan concerning Species Introductions and Invasive Species in the Mediterranean Sea UNEP/MAP 2016c
Developing programmes to raise the awareness of the general public and of target groups, including decision-makers, concerning the risks associated with species introduction (as soon as possible)	Develop programmes to raise the awareness of the general public and target groups, including decision-makers, concerning the risks associated with species introduction (2017)
Inventorying introduction vectors, elaborating the regional project on fouling, ballast water and sediment, elaborating education and awareness material (9 months)	Preparation of material for public education and awareness (2020)
Establishing a directory of relevant specialists and organizations (12 months)	Establish/update a directory of relevant specialists and organizations (2017)
Launching the procedures for enacting or strengthening national legislation governing the control of introduction (18 months)	Launch the procedures for enacting or strengthening national legislation governing the control of alien species introduction (2017)
Developing programmes for data collection and monitoring; preparing the Guidelines for controlling the vectors of non-indigenous species and invasive marine species introduction into the Mediterranean; Preparing the Guide for risk analysis and impact assessment as regards the introduction of non-indigenous species (24 months)	Develop programmes for data collection and monitoring (2017); Developing and implementing risk-assessment techniques (2018)
Setting up the Regional Mechanism for collecting, compiling and circulating information on invasive non-indigenous species (24 months); Compiling an inventory of introduced species. Identifying public and private actors whose activity could introduce marine non-indigenous species (36 months)	Launch MAMIAS (2016); preparation of forms for reporting to MAMIAS (2016); Baseline study with information for MAMIAS (2016); Annual updates of national data for MAMIAS (2017-2019)
Elaborating the National Plans (36 months)	Elaborate the National Plans (2019)

step further and sought to exclude “introduction through the Suez Canal” from “NIS linked to human activities”, “IAS [invasive alien species] introduced as a result of human activities”, and “main human related pathways and vectors of NIS introduction” in the “Integrated list of Mediterranean Good Environmental Status and related targets”. A “Note by the Secretariat” (UNEP/MAP 2013b) to the participants of the 18th Meeting of the Contracting Parties to the “Barcelona Convention” in December 2013 annulled the exclusion. However, a few months later, in February 2014, in the “Secretariat Analysis of Common Indicators” presented to the meeting of the “Integrated correspondence groups of GES and Targets” the exclusion was bracketed, not removed (UNEP/MAP 2014).

The 19th Meeting of the Contracting Parties to the “Barcelona Convention” adopted an “Integrated monitoring and assessment programme of the Mediterranean Sea and coast and related assessment criteria” (UNEP/MAP 2016a,b). Its Annex specifies “... monitoring of non-indigenous species (NIS), following the risk based approach, needs to be focused on the invasive alien species (IAS) in IAS introduction “hot spots” (e.g. ports and their surrounding areas, docks, marinas, aquaculture

installations, heated power plant effluents sites, offshore structures).” The adopted “Integrated monitoring and assessment programme” fails to mention the hottest “hot spot” of all—the environs of the Suez Canal terminus and the southeast Levant.

The Regional Activity Centre for Specially Protected Areas (RAC/SPA) was established by the Contracting Parties to the “Barcelona Convention” in order to assist Mediterranean countries in implementing the creation, conservation, planning and management of SPAs. The Centre is fully aware that “For the Mediterranean, the introduction of marine non-native species is a phenomenon that has long been known and studied.” (<http://www.rac-spa.org/aliens>). In fact, surveys funded and directed by RAC/SPA in Syria, Lebanon and Israel (see above) have amply documented the dominance of NIS in MPAs along the Levant coast. Yet, the Centre’s publications concerning species introductions and invasive species fail to mention introductions through the Suez Canal (UNEP/MAP-RAC/SPA 2005, 2008a,b). Similarly, reports of meetings of focal points for specially protected areas (SPAs) fail to recognize the significance of introductions, and proceed to create additional SPAs, even in NIS dominated regions (e.g., UNEP/MAP 2011).

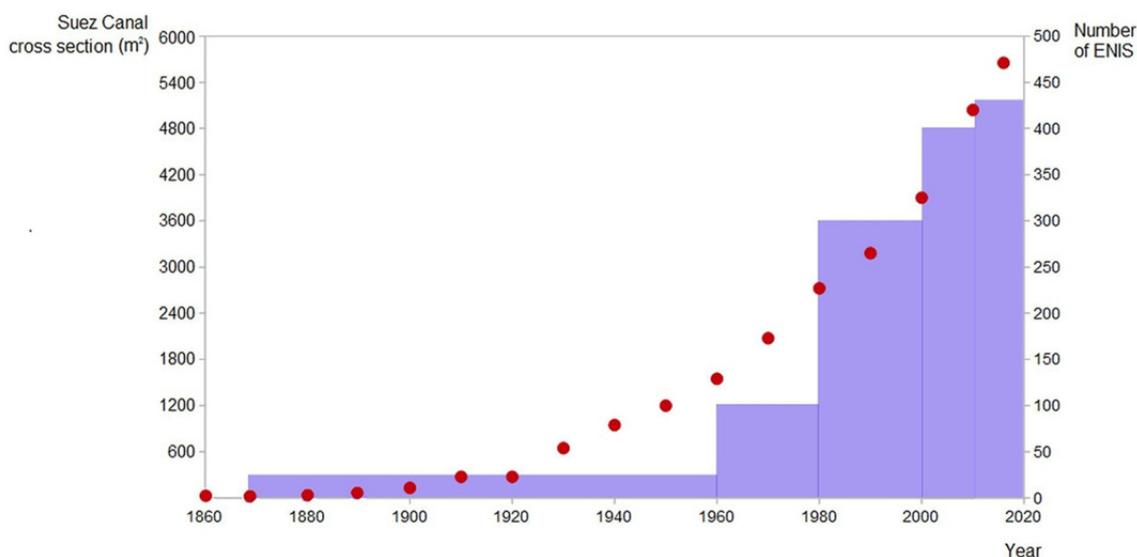


Figure 2. The enlargement of the Suez Canal (cross section, m²) and the numbers of species probably introduced through the Suez Canal.

The RAC/SPA professes “Protected areas were conceived and set up as a tool of conservation and sustainable management of the littoral and marine environment so as to preserve the sites of great ecological value and the Mediterranean ecosystems in particular.” (http://www.rac-spa.org/sites/default/files/doc_cop/asp_2010_en.pdf, viewed 18 October, 2016). In point of fact, ENIS-ridden MPAs serve as “hotspots”, beachheads and dispersal hubs for their secondary spread, to the detriment of their ecological value, and undermine their declared function as conservation tools.

Conclusions

The unabated influx of the Erythraean biota into the Mediterranean Sea is rooted in the unceasing enlargement of the Suez Canal that has enhanced its potential as a corridor allowing increasingly greater numbers of organisms to pass through it (Galil 2006; Galil et al. 2015). Complex changes in the Mediterranean marine environment have undoubtedly increased the sea’s susceptibility to invasion by modifying its hydrologic and biological properties (Galil 2006; Occhipinti-Ambrogi 2007; Lejeune et al. 2009). Many aspects of the Erythraean introductions remain unforeseeable. Amongst others, it is unknown which new species will pass through the Suez Canal and establish themselves and when, and what will be their interactions with the Mediterranean biota. However, it is clear that a larger and deeper Suez Canal allows cohorts of new potentially invasive

species to gain admittance to the Mediterranean Sea (Figure 2), where increasing temperatures permit their further expansion westwards and northwards.

There is a vast amount of scientific evidence confirming that the Contracting Parties to the Barcelona Convention who agreed, 40 years ago, that they “...shall, individually or jointly, take all appropriate measures to protect and preserve biological diversity”, failed completely to effectively manage the introduction of NIS through the Suez Canal. In the face of a century’s worth of scientific documentation, they dithered, shrank away from and evaded action. The biota across wide swaths of the Mediterranean Sea, including precious MPAs, has already been altered with dire ecological, economical and human health impacts. In an era of increased environmental concern, it is surprising that the environmental impacts associated with the expansion of the Suez Canal on the well-being of the Mediterranean Sea have raised no controversy, or even discussion on “environmental accountability” beyond the ambit of marine scientists.

Recommendations

We recommend the following actions to evaluate **ENIS introductions through the Suez Canal**

- A. Research focused on identification and quantitative assessment of the ecosystem services, human health and socio-economic impacts;

- B. An independent, transparent and scientifically sound Environmental Impact Assessment (EIA) of transboundary ENIS impacts associated with the enlargement of the Suez Canal (the EIA would facilitate evaluation of choices for the implementation of cost-effective mitigating strategies);
- C. Research evaluating the efficacy of reinstating the former salinity barrier of the Bitter Lakes in curtailing viability of transported propagules;
- D. Research focused on the hydrodynamic regime throughout the Suez Canal and its impact on propagule transport. Should it be determined that currents drive the propagules northwards, engineering solutions may be sought.

We recommend the following actions to manage spread of ENIS throughout the Mediterranean Sea

- A. Ballast taken in Levantine coastal waters should be held to exacting standards on release;
- B. Recreational vessels which berthed in Levantine coastal waters should be held to exacting standards concerning fouling.

Recognizing that high ENIS load nullifies **marine conservation strategies in MPAs**, we recommend the following immediate actions

- A. New MPAs to be located away from the regional hubs of vectors and pathways of NIS introduction, i.e. the entire Levant littoral as well as ports and marinas;
- B. Established MPAs with high ENIS load to conduct risk assessment of secondary spread and analyze cost of effective options for long term control of ENIS populations. Should ENIS populations be at levels that adversely affect the MPA's natural biodiversity and natural habitats, or risk secondary spread, mitigation actions or changes to the protection status should be implemented;
- C. Stakeholders should be informed of the extent of bioinvasions in MPAs, consulted as to management actions and commitment of resources for their control, and possible changes to protection status.

Finally, the recent entry into force of the Convention for the Control and Management of Ships' Ballast Water and Sediments—a key international measure for environmental protection that aims to stop the spread of NIS (<http://www.imo.org/en/MediaCentre/PressBriefings/Pages/22-BWM-.aspx> viewed October 19, 2016) proves that scientists, stakeholders, national and international organizations can work together

and achieve a significant milestone in the management of marine NIS. Unlike the global reach of shipping-transported NIS, the bioinvasion through the Suez Canal affects mostly the Mediterranean Sea (but see Mantelatto and Dias 1999), and thus it falls to the Mediterranean countries to prevent and control it.

Acknowledgements

The study was partially funded by the Estonian Ministry of Education and Research (grant SF0180005s10). The authors are grateful to the anonymous reviewers for their perceptive and helpful comments on an earlier version of the manuscript.

References

- Azzurro E, Andaloro F (2004) A new settled population of the Lessepsian migrant *Siganus luridus* (Pisces: Siganidae) in Linosa Island, Sicily Strait. *Journal of the Marine Biological Association UK* 84: 819–821, <https://doi.org/10.1017/S0025315404009993h>
- Bariche M, Letourneur Y, Harmelin-Vivien M (2004) Temporal fluctuations and settlement patterns of native and Lessepsian herbivorous fishes on the Lebanese coast (eastern Mediterranean). *Environmental Biology of Fishes* 70: 81–90, <https://doi.org/10.1023/B:EBF1.0000022928.15148.75>
- Bariche M, Torres M, Azzurro E (2013) The presence of the invasive lionfish *Pterois miles* in the Mediterranean Sea. *Mediterranean Marine Science* 14: 292–294, <https://doi.org/10.12681/mms.428>
- Bazairi H, Sghaier YR, Benamer I, Langar H, Pergent G, Bourass E, Verlaque M, Ben Souissi J, Zenetos A (2013) Alien marine species of Libya: first inventory and new records in El-Kouf National Park (Cyrenaica) and the neighbouring areas. *Mediterranean Marine Science* 14(2): 451–462, <https://doi.org/10.12681/mms.555>
- Benmeir P, Rosenberg L, Sagi A, Vardi D, Eldad A (1990) Jellyfish envenomation a summer epidemic. *Burns* 16: 471–472, [https://doi.org/10.1016/0305-4179\(90\)90080-G](https://doi.org/10.1016/0305-4179(90)90080-G)
- Benur Y, Ashkar J, Lurie Y, Levy Y, Azzam ZS, Litmanovich M, Golik M, Gurevych B, Golani D, Eisenman A (2008) Lessepsian migration and tetrodotoxin poisoning due to *Lagocephalus sceleratus* in the eastern Mediterranean. *Toxicon* 52: 964–968, <https://doi.org/10.1016/j.toxicon.2008.10.001>
- Ben-Tuvia A (1964) Two siganid fishes of Red Sea origin in the eastern Mediterranean. *Bulletin of the Sea Fisheries Research Station, Haifa* 37: 1–9
- Bitar G, Dupuy de la Grandrive R, Foulquié M (2003) Mission Report. Second mission relating to the Development of Marine Protected Areas on Syrian coasts, 1–18 August 2003. United Nations Environment Programme, Mediterranean Action Plan, Regional Activity Centre for Specially Protected Areas. Regional Project for the Development of Marine and Coastal Protected Areas in the Mediterranean Region, 42 pp
- Boudouresque CF (2004) Marine biodiversity in the Mediterranean: status of species, populations and communities. *Scientific Reports of the port-Cros National Park* 20: 319–323
- Crocetta F, Agius D, Balistreri P, Bariche M, Bayhan YK, Çakir M, Ciriaco S, Corsini-Foka M, Deidun A, El Zrelli R, Ergüden D, Evans J, Ghelia M, Giavasi M, Kleitou P, Kondylatos G, Lipej L, Mifsud C, Özvarol Y, Pagano A, Portelli P, Poursanidis D, Rabauoi L, Schembri PJ, Taşkin E, Tiralongo F, Zenetos A (2015). New Mediterranean Biodiversity Records (October 2015). *Mediterranean Marine Science* 16: 682–702, <https://doi.org/10.12681/mms.1477>
- Dailianis T, Akyol O, Babali N, Bariche M, Crocetta F, Gerovasileiou V, Chanem R, Gökoğlu M, Hasiotis T, Izquierdo-Muñoz A, Julian D, Katsanevakis S, Lipez L, Mancini E,

- Mytilineou Ch, Ounifi Ben Amor K, Özgül A, Ragkousis M, Rubio-Portillo E, Servello G, Sini K, Stamouli C, Steriotti A, Teker S, Tiralongo F, Trkov D (2016) New Mediterranean Biodiversity Records (July, 2016). *Mediterranean Marine Science* 17: 608–626, <https://doi.org/10.12681/mms.1734>
- Daly Yahia MN, Daly Yahia-Kefi O, Maïte Gueroun SK, Aissi M, Deidun A, Fuentes V, Piraino S (2013) The invasive tropical scyphozoan *Rhopilema nomadica* Galil, 1990 reaches the Tunisian coast of the Mediterranean Sea. *BiolInvasions Records* 2: 319–323, <https://doi.org/10.3391/bir.2013.2.4.10>
- Daniel B, Piro S, Charbonnel E, Francour P, Letourneur Y (2009) Lessepsian rabbitfish *Siganus luridus* reached the French Mediterranean coasts. *Cybiium* 33(2): 163–164
- Doğdu SA, Uyan A, Uygun N, Gürlek M, Ergüden D, Turan C (2016) First record of the Indo-Pacific striped eel catfish, *Plotosus lineatus* (Thunberg, 1787) from Turkish marine waters. *Natural and Engineering Sciences* 1(2): 25–32
- EEA (2015) State of Europe's Seas, Technical report No. 2/2015, European Environment Agency, Copenhagen, 220 pp, <http://www.eea.europa.eu/publications/state-of-europes-seas>
- Francour P, Mangialajo L, Pastor J (2010) Mediterranean marine protected areas and non-indigenous fish spreading. In: Golani D, Appelbaum-Golani B (eds), *Fish Invasions of the Mediterranean Sea: change and renewal*, Pensoft Publisher, Sofia-Moscow, pp 127–144
- Galil BS (2006) The marine caravan – the Suez Canal and the Erythrean invasion. In: Gollasch S, Galil BS, Cohen AN (eds), *Bridging Divides – Maritime Canals as Invasion Corridors*. Springer International Publishing, Cham, Switzerland, pp 207–300, https://doi.org/10.1007/978-1-4020-5047-3_6
- Galil BS (2007) Seeing red: alien species along the Mediterranean coast of Israel. *Aquatic Invasions* 2: 281–312, <https://doi.org/10.3391/ai.2007.2.4.2>
- Galil BS (2012) Truth and consequences: the bioinvasion of the Mediterranean Sea. *Integrative Zoology* 7: 299–311, <https://doi.org/10.1111/j.1749-4877.2012.00307.x>
- Galil BS, Boero F, Campbell ML, Carlton JT, Cook E, Fraschetti S, Gollasch S, Hewitt CL, Jelmert A, Macpherson E, Marchini A, McKenzie C, Minchin D, Occhipinti-Ambrogi A, Ojaveer H, Olenin S, Piraino S, Ruiz G (2015) ‘Double trouble’: The expansion of the Suez Canal and marine bioinvasions in the Mediterranean Sea. *Biological Invasions* 17: 973–976, <https://doi.org/10.1007/s10530-014-0778-y>
- Galil BS, Marchini A, Occhipinti-Ambrogi A, Minchin D, Naršcius A, Ojaveer H, Olenin S (2014) International arrivals: widespread bioinvasions in European Seas. *Ethology Ecology & Evolution* 26: 152–171, <https://doi.org/10.1080/03949370.2014.897651>
- Galil BS, Marchini A, Occhipinti-Ambrogi A (2016) East is east and west is west? Management of marine bioinvasions in the Mediterranean Sea. *Estuarine and Coastal Marine Science* (in press), <https://doi.org/10.1016/j.ecss.2015.12.021>
- Galil BS, Spanier E, Ferguson WW (1990) The scyphomedusae of the Mediterranean coast of Israel, including two Lessepsian migrants new to the Mediterranean. *Zoologische Mededelingen (Leiden)* 64: 95–105
- George CJ, Athanassiou V (1967) A two year study of the fishes appearing in the seine fishery of St. George Bay, Lebanon. *Annali del Museo Civico di Storia Naturale di Genova* 79: 32–44
- Ghermandi A, Galil B, Gowdy J, Nunes PALD (2015) Jellyfish outbreak impacts on recreation in the Mediterranean Sea: welfare estimates from a socio-economic pilot survey in Israel. *Ecosystem Services* 11: 140–147, <https://doi.org/10.1016/j.ecoser.2014.12.004>
- Giakoumi S (2014) Distribution patterns of the invasive herbivore *Siganus luridus* (Rüppell, 1829) and its relation to native benthic communities in the central Aegean Sea, Northeastern Mediterranean. *Marine Ecology* 35: 96–105, <https://doi.org/10.1111/maec.12059>
- Giakoumi S, Guilhaumon F, Kark S, Terlizzi A, Claudet J, Felline S, Cerrano C, Coll M, Danovaro R, Fraschetti S, Koutsoubas D, Ledoux JB, Mazor T, Mériot B, Micheli F, Katsanevakis S (2016) Space invaders; biological invasions in marine conservation planning. *Diversity and Distribution* 22: 1220–1231, <https://doi.org/10.1111/ddi.12491>
- Goren M, Galil BS (2001) Fish biodiversity and dynamics in the vermetid reef of Shiqmona (Israel). *Marine Ecology* 22: 369–378, <https://doi.org/10.1046/j.1439-0485.2001.01750.x>
- Guidetti P, Balata P, Ballesteros E, Di Franco A, Hereu B, Macpherson E, Micheli F, Pais A, Panzalis P, Rosenberg AA, Zabala M, Sala E (2014) Large-scale assessment of Mediterranean marine protected areas effects on fish assemblages. *PLoS ONE* 9: e91841, <https://doi.org/10.1371/journal.pone.0091841>
- Gweta S, Spanier E, Bentur Y (2008) Venomous fish injuries along the Israeli Mediterranean coast: scope and characterization. *Israel Medical Association Journal* 10: 783–788
- Islam QT, Razzak MA, Islam MA, Bari MI, Basher A, Chowdhury FR, Sayeduzzaman AB, Ahasan HA, Faiz MA, Arakawa O, Yotsu-Yamashita M, Kuch U, Mebs D (2011) Puffer fish poisoning in Bangladesh: clinical and toxicological results from large outbreaks in 2008. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 105(2): 74–80, <https://doi.org/10.1016/j.trstmh.2010.10.002>
- Jribi A, Bradai MN (2012) First record of the Lessepsian migrant species *Lagocephalus sceleratus* (Gmelin, 1789) (Actinopterygii: Tetraodontidae) in the Central Mediterranean. *BiolInvasions Records* 1: 49–52, <https://doi.org/10.3391/bir.2012.1.1.11>
- Kapiris K, Apostolidis C, Balducci R, Başusta N, Bilecenoglu M, Bitar G, Bobori DC, Boyacı YÖ, Dimitriadis C, Djurović M, Dulčić J, Durucan F, Gerovasileiou V, Gökoğlu M, Koutsoubas D, Lefkaditou E, Lipej L, Marković O, Mavrić B, Özvarol Y, Pesic V, Petriki O, Siapias A, Sini M, Tubullo D, Tiralongo F (2014) New Mediterranean biodiversity records (April 2014). *Mediterranean Marine Science* 15: 198–212, <https://doi.org/10.12681/mms.737>
- Kara MH, Ben Lamine E, Francour P (2015) Range expansion of an invasive pufferfish, *Lagocephalus sceleratus* (Actinopterygii: Tetraodontiformes: Tetraodontidae), to the south-western Mediterranean. *Acta Ichthyologica et Piscatoria* 45: 103–108, <https://doi.org/10.3750/AIP2015.45.1.13>
- Katsanevakis S, Acar Ümmar I, Balci BA, Bekas P, Belmonte M, Chintiroglou CC, Consoli P, Dimiza M, Fryganiotis K, Gerovasileiou V, Gnisci V, Gülşahin N, Hoffman R, Issaris Y, Izquierdo-Gomez D, Izquierdo-Munoz A, Kavadas S, Koehler L, Konstantinidis E, Mazza G, Nowell G, Önal U, Özen MR, Pafilis P, Pastore M, Perdikaris C, Poursanidis D, Prato E, Russo F, Sicuro B, Tarkan AN, Thessalou-Legaki M, Tiralongo F, Triantaphyllou M, Tsiamis K, Tunçer S, Turan C, Türker A, Yapici S (2014a) New Mediterranean Biodiversity Records (October, 2014). *Mediterranean Marine Science* 15: 675–695, <https://doi.org/10.12681/mms.1123>
- Katsanevakis S, Wallentinus I, Zenetos A, Leppäkoski E, Çinar ME, Öztürk B, Grabowski M, Golani D, Cardoso AC (2014b) Impacts of marine invasive alien species on ecosystem services and biodiversity: a pan-European review. *Aquatic Invasions* 9: 391–423, <https://doi.org/10.3391/ai.2014.9.4.01>
- Kletou D, Hall-Spencer JM, Kleitou P (2016) A lionfish (*Pterois miles*) invasion has begun in the Mediterranean Sea. *Marine Biodiversity Records* 9: 46, <https://doi.org/10.1186/s41200-016-0065-y>
- Ktari F, Ktari MH (1974) Présence dans le golfe de Gabes de *Siganus luridus* (Rüppell, 1829) et de *Siganus rivulatus* (Forsskal, 1775) (Poissons, siganides) parasités par *Pseudohaliotrematoides polymorphus*. *Bulletin de l'Institut National Scientifique et Technique d'Océanographie et de Pêche de Salammbô* 3: 95–98
- Ktari-Chakroun F, Bahloul M (1971) Capture de *Siganus luridus* (Rüppell) dans le golfe de Tunis. *Bulletin de l'Institut National Scientifique et Technique d'Océanographie et de Pêche de Salammbô* 2: 49–52

- Lejeune C, Chevaldonné P, Pergent-Martini C, Boudouresque CF, Peréz T (2009) Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. *Trends in Ecology and Evolution* 25: 250–260, <https://doi.org/10.1016/j.tree.2009.10.009>
- Lodola A, Nicolini L, Savini D, Deidun A, Occhipinti-Ambrogi A (2013a) Range expansion and biometric features of *Pinctada imbricata radiata* (Bivalvia: Pteriidae) around Linosa Island, Central Mediterranean Sea (Italy). *Italian Journal of Zoology* 80(2): 303–312, <https://doi.org/10.1080/11250003.2013.775363>
- Lodola A, Savini D, Occhipinti-Ambrogi A (2013b) Alien species in the central Mediterranean sea: the case study of Linosa island (Pelagian islands, Italy). *Biologia Marina Mediterranea* 19(1): 257–258
- Lubchenco J, Palumbi SR, Gaines SD, Andelman S (2003) Plugging a hole in the ocean: the emerging science of marine reserves. *Ecological Applications* 13(1) Supplement: S3–S7
- Lundberg B, Ogorek R, Galil BS, Goren M (2004) Dietary choices of siganid fish at Shiqmona reef, Israel. *Israel Journal of Zoology* 50: 39–53, <https://doi.org/10.1560/7QQJ-WN2F-J8PC-W6E2>
- Mantelatto FLM, Dias LL (1999) Extension of the known distribution of *Charybdis hellerii* (A. Milne-Edwards, 1867) (Decapoda, Portunidae) along the Western Tropical South Atlantic. *Crustaceana* 72(6): 617–620
- Merella P, Porcheddu A, Casu S (1994) La malacofauna della riserva naturale di Scandola (Corsica Nord-occidentale). *Bollettino Malacologico* 30(5–9): 111–128
- Micheli F, Halpern BS, Walbridge S, Ciriaco S, Ferretti F, Fraschetti S, Lewison R, Nykjaer L, Rosenberg AA (2013) Cumulative human impacts on Mediterranean and Black Sea marine ecosystems: assessing current pressures and opportunities. *PLoS ONE* 8: e79889, <https://doi.org/10.1371/journal.pone.0079889>
- Mienis HK (2003) Native marine molluscs replaced by Lessepsian migrants. *Tentacle* 11: 15–16
- Mienis HK, Ben-David-Zaslow R (2004) A preliminary list of the marine molluscs of the National Park and Nature Reserve of Akhziv-Rosh Haniqra. *Triton* 10: 13–37
- Occhipinti-Ambrogi A (2007) Global change and marine communities: alien species and climate change. *Marine Pollution Bulletin* 55: 342–352, <https://doi.org/10.1016/j.marpolbul.2006.11.014>
- Oray IK, Sinay E, Saadet Karakulak F, Yildiz T (2015) An expected marine alien fish caught at the coast of Northern Cyprus: *Pterois miles* (Bennett, 1828). *Journal of Applied Ichthyology* 31: 733–735, <https://doi.org/10.1111/jai.12857>
- Öztürk B, İşinibilir M (2010) An alien jellyfish *Rhopilema nomadica* and its impacts to the eastern Mediterranean part of Turkey. *Journal of Black Sea/Mediterranean Environment* 16(2): 149–156
- Papaconstantinou C (1987) Distribution of the Lessepsian fish migrants in the Aegean Sea. *Biologia Gallo-Hellenica* 13: 15–20
- Por FD (1978) Lessepsian Migration – the influx of Red Sea Biota into the Mediterranean by way of the Suez Canal. *Ecological Studies* vol. 23, Springer-Verlag, 228 pp
- RAC/SPA - UNEP/MAP (2014) Ecological characterization of sites of interest for conservation in Lebanon: Enfeh Peninsula, Ras Chekaa cliffs, Raoucheh, Saida, Tyre and Nakoura. Ramos-Esplá AA, Bitar G., Khalaf G, El Shaer H, Forcada A, Limam A, Ocaña O, Sghaier YR, Valle C (eds), RAC/SPA - MedMPAnet Project, Tunis, 168 pp
- Ramos Esplá AA, Pérez CV (2004) Marine biodiversity study of the Rosh Haniqra-Akhziv nature reserves (Israel) to the establishment of a management plan. United Nation Environment Programme Mediterranean Action Plan, Regional Activity Centre for Specially Protected Areas Final Report (Activity MP4), 126 pp
- Rothman BS, Goren M, Galil BS (2012) On the rapid establishment of the Indian Ocean twospot cardinalfish *Cheilodipterus novemstriatus* (Rüppell, 1838) along the Levantine coast of the Mediterranean Sea. *BioInvasions Records* 2: 85–88, <https://doi.org/10.3391/bir.2013.2.1.15>
- Rothman BS, Shlagman A, Galil BS (2013) *Saron marmoratus* (Olivier, 1811), an Indo-Pacific marble shrimp (Hippolytidae, Decapoda, Crustacea) in the Mediterranean Sea. *Marine Biodiversity Records* 6: e129, <https://doi.org/10.1017/S1755267213000997>
- Rothman S, Galil BS (2015) Not so rare: *Plocampherus ocellatus* (Nudibranchia, Polyceridae) in the Eastern Mediterranean. *Marine Biodiversity Records* 8, e144, <https://doi.org/10.1017/s1755267215001207>
- Safriel UN, Gilboa A, Felsenburg T (1980) Distribution of rocky intertidal mussels in the Red Sea coasts of Sinai, the Suez Canal, and the Mediterranean coast of Israel, with special reference to recent colonizer. *Journal of Biogeography* 7: 39–62, <https://doi.org/10.2307/2844546>
- Sala E, Kizilkaya Z, Yildirim D, Ballesteros E (2011) Alien marine fishes deplete algal biomass in the eastern Mediterranean. *PLoS ONE* 6: e17356, <https://doi.org/10.1371/journal.pone.0017356>
- Samaha C, zu Dohna H, Bariche M (2016) Analysis of Red Sea fish species' introductions into the Mediterranean reveals shifts in introduction patterns. *Journal of Biogeography* 43(9): 1797–1807, <https://doi.org/10.1111/jbi.12793>
- Sarà G, Romano C, Mazzola A (2006) A new Lessepsian species in the western Mediterranean (*Brachidontes pharaonis* – Bivalvia: Mytilidae): density, resource allocation and biomass. *Marine Biodiversity Records* 1: e8
- Sendovski U, Goffman M, Goldshlak L (2005) Severe delayed cutaneous reaction due to Mediterranean jellyfish (*Rhopilema nomadica*) envenomation. *Contact Dermatitits* 52: 282–283, <https://doi.org/10.1111/j.0105-1873.2005.00582.x>
- Silfen R, Vilan A, Wohl I, Leviav A (2003) Mediterranean jellyfish (*Rhopilema nomadica*) sting. *Burns* 29: 868–870, [https://doi.org/10.1016/S0305-4179\(03\)00162-1](https://doi.org/10.1016/S0305-4179(03)00162-1)
- Simberloff D (2000) No reserve is an island: marine reserves and nonindigenous species. *Bulletin of Marine Science* 66(3): 567–580
- Steinitz H (1959) Observations on *Pterois volitans* (L.) and its venom. *Copeia* 2: 158–160, <https://doi.org/10.2307/1440071>
- Steinitz H (1970) A critical list of immigrants via the Suez Canal. Biota of the Red Sea and Eastern Mediterranean, pp 59–63
- Steinitz W (1927) Beiträge zur Kenntnis der Küstenfauna Palästinas. I. *Pubblicazioni della Stazione Zoologica di Napoli* 8: 331–353
- Sulić Šprem JD, Dobroslavić T, Kožul V, Kuzman A, Dulčić J (2014) First record of *Lagocephalus sceleratus* in the Adriatic Sea (Croatian coast), a Lessepsian migrant. *Cybium* 38(2): 147–148
- Turan C, Erguden D, Gurlek M, Yaglioglu D, Uyan A, Uygur N (2014) First record of the Indo-Pacific lionfish *Pterois miles* (Bennett, 1828) (Osteichthyes: Scorpaenidae) for the Turkish marine waters. *Journal of Black Sea/Mediterranean Environment* 20(2): 158–163
- UNEP/MAP (2007) Annex XIII. Draft Guidelines for Controlling the Vectors of Introduction into the Mediterranean of Non-Indigenous Species and Invasive Marine Species. In: Report of the eighth meeting of national Focal Points for SPAs, UNEP(DEPI)/MED WG.308/14
- UNEP/MAP (2011) Report of the tenth meeting of Focal Points for SPAs. UNEP(DEPI)/MED WG.359/22, 288 pp
- UNEP/MAP (2013a) Draft decision on the Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and targets. Meeting of the MAP Focal Points. UNEP(DEPI)/MED WG.387/7, 46 pp
- UNEP/MAP (2013b) Note by the secretariat. The Annex to the present note sets out the revised elements of the Draft Decision IG21/3 on the Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and targets. 18th ordinary meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols, (UNEP(DEPI)/MED IG21/CRP.6), 24 pp

- UNEP/MAP (2014) Secretariat Analysis of Common Indicators. Integrated Correspondence Groups of GES and Targets Meeting, UNEP(DEPI)/MED WG.390/Inf.3, 11 pp
- UNEP/MAP (2016a) Report of the 19th ordinary meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols, UNEP (DEPI)/MED IG.22/28, pp 5–32
- UNEP/MAP (2016b) Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria. (Decision IG.22/7), In: Report of the 19th ordinary meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols, UNEP (DEPI)/MED IG.22/28 (Decision IG.22/7), pp 419–452
- UNEP/MAP (2016c) Annex III. Updated Action Plan concerning Species Introductions and Invasive Species in the Mediterranean Sea. In: Report of the 19th ordinary meeting of the Contracting Parties to the Convention for the protection of the marine environment and the coastal region of the Mediterranean and its protocols, UNEP(DEPI)/MED IG.22/28 (Decision IG.22/15), pp 602–611
- UNEP/MAP-RAC/SPA (2005) Action Plan concerning species introductions and invasive species in the Mediterranean Sea. Ed. RAC/SPA, Tunis, 30 pp
- UNEP/MAP-RAC/SPA (2008a) Guide for Risk Analysis assessing the Impacts of the Introduction of Non-indigenous Species. Ed. RAC/SPA, Tunis, 30 pp
- UNEP/MAP-RAC/SPA (2008b) Guidelines for Controlling the Vectors of Introduction into the Mediterranean of Non-indigenous Species and Invasive Marine Species. Ed. RAC/SPA, Tunis, 18 pp
- UNEP/MAP-RAC/SPA (2015) Action Plan concerning Species Introductions and Invasive Species in the Mediterranean Sea. Status of implementation of the Action Plan concerning species introduction and invasive species in the Mediterranean Sea. UNEP(DEPI)/MED WG.408/inf.8 Rev.1, 22 pp
- Vergés A, Tomas F, Cebrian E, Ballesteros E, Kizilkaya Z, Dendrinis P, Karamanlidis AA, Spiegel D, Sala E (2014) Tropical rabbitfish and the deforestation of a warming temperate sea. *Journal of Ecology* 102: 1518–1527, <https://doi.org/10.1111/1365-2745.12324>
- Yoffe B, Baruchin AM (2004) Mediterranean jellyfish (*Rhopilema nomadica*) sting. *Burns* 30: 503–504, <https://doi.org/10.1016/j.burns.2004.01.013>
- Yokes MB, Dalyan C, Karhan SU, Demir V, Tural U, Kalkan E (2012) Alien opisthobranchs from Turkish coasts: first record of *Plocamopherus tilesii* Bergh, 1877 from the Mediterranean. *Triton* 25 supplement 1: 1–9
- Zibrowius H (1992) Ongoing modification of the Mediterranean marine fauna and flora by the establishment of exotic species. *Mésogée* 51: 83–107