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Review

Does Sand Beach Nourishment Enhance the Dispersion of Non-Indigenous Species?—The Case of the Common Moon Crab, *Matuta victor* (Fabricius, 1781), in the Southeastern Mediterranean

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Abstract: Sand beach nourishment (BN) is one of the commonest "soft solutions" for shore protection and restoration. Yet it may have ecological consequences. Can this practice enhance the introduction and dispersal of non-indigenous species (NIS)? There has been little research on the impacts of nourishment on NIS, especially in the southeastern Mediterranean, a region considered most affected by invading biota. However, so far only one study referred to the possible interaction between BN and the success of invading species. It reports increasing numbers and densities of the aggressive, omnivorous Indo-Pacific moon crab, *Matuta victor* (Fabricius, 1781) in Haifa Bay (northern Israel) between 2011 and 2017. This research suggests a possible role of anthropogenic disturbance in the outbreak of *M. victor* and blames the Israel Ministry of Environmental Protection for authorizing a (rather small scale) BN in Haifa Bay in 2011 as an alleged cause for this outbreak. Circumstantial indirect evidence is not sufficient to establish the role of nourishment in promoting the establishment and dispersal of NIS. There are plenty of examples of successful settlement and rapid and large-scale distribution of NIS (including another member of the genus *Matuta*), especially in the eastern Mediterranean, without any BN in the region. Furthermore, the location where the *M. victor* specimens were sampled was exposed to more prevailing and frequent anthropogenic marine stressors than BN, such as eutrophication, pollution, fishing activities and particularly port construction. To firmly establish an assumed role of nourishment in the invasion of NIS, assessments must be based on solid and orderly planned scientific research to be designed well before the beginning of any BN. It is suggested that direct communication between environmental regulators and scientists is crucial for improving both scientific research and environmental management policies.

Keywords: invasive species; Lessepsian migration; coastal processes; dredging; Levant; Haifa Bay

1. Introduction

Beach nourishment (BN), mainly by sand, is one of the commonest "soft solutions" for beach restoration and shore protection [1–4] and is considered more environmentally acceptable than coastal defenses such as seawalls, revetments and detached breakwaters [5]. It is widely applied as a soft coastal measure because of its reduced ecological impact relative to hard coastal protection [6]. However, the nourished sand may be eroded after a relatively short period, and this costly practice must be repeated periodically [7,8]. In recent years, coastal ecosystems have been severely threatened by climate change due to changes in sea level, storms and wave regimes, flooding, altered sediment budgets and the loss of coastal habitat [9,10]. Because sandy beaches form the single largest coastal ecosystem on Earth, covering 70% of all continental margins [11], these threats are global. Sandy beaches have a multitude of ecosystem functions as they are important habitat for a variety of biota and are concurrently of enormous economic, social and cultural importance to humans [11–14]. Thus, BN may affect natural ecosystems as well as human societies.

BN has further environmental effects in the imported site (i.e., borrow area) as well as on the nourished beach [15–19]. The ecological consequences of the nourishment on coastal biota may be short- or long-term. The environmental impacts may lead to sedimentation and turbidity that affect light penetration and filtering organisms. It may cause burial of organisms that reside in the nourished area, and the effects of heavy equipment used in the nourishment operation may injure, kill or affect the behavior and physiology of the native biota. BN can change the nature of the local habitat (e.g., altering the grain size and type, or change hard substrate to a soft one). Changing the sediment composition may alter the types of organisms that inhabit the nourished beach [8,20–24]. BN may also displace native biota, but, does this activity enhance the introduction and dispersal of non-indigenous marine species? The goal of the present review is to reveal if there is solid evidence for this assumption.

Invasive species are considered one of the four major threats to the world oceans together with terrestrial and marine pollution sources, overutilization of marine resources and physical changes and destruction of coastal and marine habitats [25]. Shipping, via ballast water, is considered the most important marine invasion pathway, but other anthropogenic factors, such as man-made canals between previously separated biogeographic marine provinces, transport of marine species in aquaculture, research projects and aquarium trade, fishing activities and global warming also have important roles in invasion processes [26].

2. Research on Beach Nourishment and Non-Indigenous Species

Localized negative impacts of BN on many coastal species of fauna and flora are well documented [26]. Burial, habitat alteration (e.g., changing wet habitats to dry ones and vice versa) and habitat reduction may have harmful implications for many coastal populations of plants and invertebrates in the short term. They can be impacted not only by burial itself but also by sand compaction, which affects gas, nutrient and water availability in interstitial spaces [13,27].

Yet there has been little research on the consequences of BN on the impacts of invasive plants and animal species [13]. Non-indigenous species (NIS), also known as non-native, alien, or exotic organisms, are species that have been introduced outside of their natural previous or present range by human activities. They might survive and subsequently reproduce in the new environment. If these species become established and their spread threatens the local biodiversity or causes economic damage, they are known as invasive species ([28] and references therein).

Lessepsian migration, the influx of Indo-Pacific species into the Mediterranean, is the largest marine bioinvasion on the planet (e.g., [29,30]). The Suez Canal (Figure 1) is the primary vector for transfer of Indo-Pacific biota into the Mediterranean Sea, and climate change and warming of Mediterranean waters are known as the main protagonists exacerbating this process [31]. In the last decade, the species richness of marine organisms in the Mediterranean Sea has been reported to have reached $\sim$17,000 taxa, among which some 820 can be considered NIS [32–34]. The southeastern Mediterranean is considered the region most affected by invading biota [35], especially Indo-Pacific species termed Lessepsian migrants. Israel has by far the highest number and percentage of earliest records of NIS in the Mediterranean Sea [30], of which, over 70% were subsequently recorded in other Mediterranean countries [33–36]. Thus, Israel may indeed be an ideal location to study the effect of BN on establishment and dispersal of NIS.

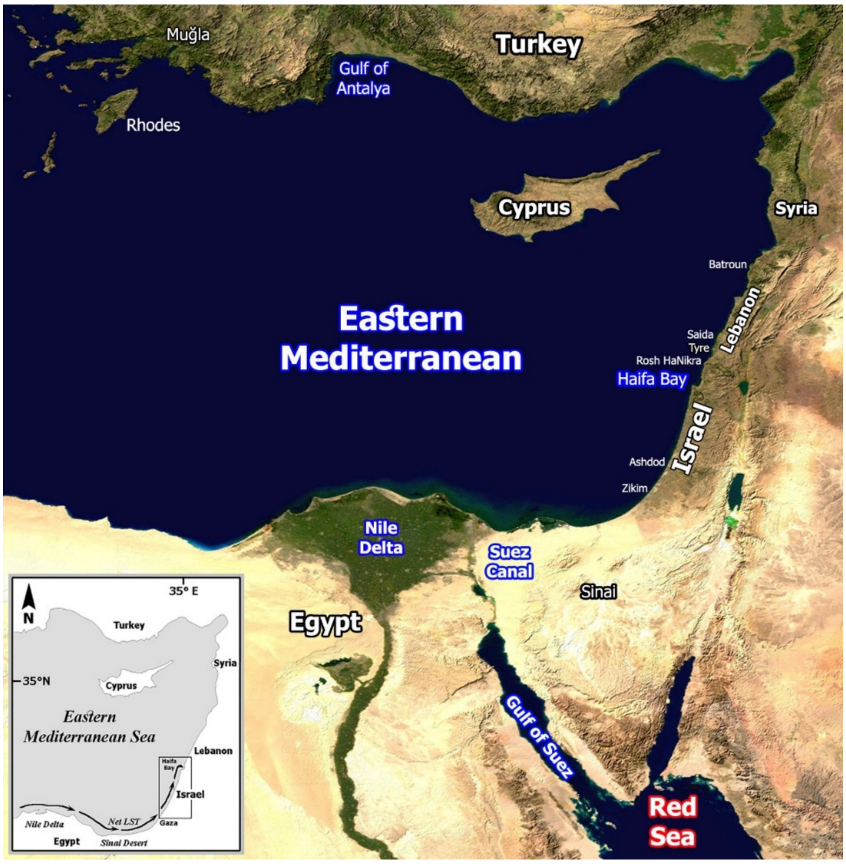

Figure 1. Eastern Mediterranean. The Nile littoral cell net longshore sand transport (LST) direction (black arrows) (bottom inset). Background: part of "Blue Marble: Land Surface, Shallow Water, and Shaded Topography". NASA Goddard Space Flight Center Image by Reto Stöckli, Robert Simmon and MODIS Groups; https://visibleearth.nasa.gov/images/57752/blue-marble-land-surface-shallow-water-and-shaded-topography (accessed on 11 February 2002).

To date, the only study that refers to an alleged effect of BN on species invasion in the southeastern Mediterranean is that of Innocenti et al. [37], which referred to nourishment activities carried out in Haifa Bay, northern Mediterranean coast of Israel (Figure 1). This study, however, lacks any before-after-control-impact (BACI) methodology.

3. Study Area

3.1. Haifa Bay Physical Setting

The Mediterranean coastline of Israel extends about 195 km from Zikim near the border with Gaza Strip in the south, to Rosh HaNikra near the Lebanese border in the north (Figure 1). It is generally a smooth coastline open to the west that gradually changes in orientation from northeast to almost north, except for Haifa Bay, the Mount Carmel headland and a few small rocky promontories [38].

From a sedimentological perspective, the Israeli coast and its inner shelf (i.e., from the shore to maximum water depth of about 30 m), can be divided into two main provinces. The Southern Province, stretching 175 km from Zikim to the Akko promontory (northern Haifa Bay) [39] (Figure 2), is considered the northern flank of the Nile littoral (sedimentary) cell [40,41]. This coastal compartment is mainly composed of Nile-derived quartz fine sand, transported from the Nile Delta eastward to the northern Sinai [41–46], then northeastward to Gaza Strip and the Israeli coasts by longshore currents [47–52] (Figure 1: bottom inset). These currents are generated by the radiation stress of breaking waves and shear stress of local winds [53,54]. Wave-induced and wind-induced longshore currents occur in both directions. However, the long-term net longshore sand transport has drifted northward up to Haifa Bay [50–52], the northernmost final depositional sink of the Nile littoral cell, in the last 7900–8500 years [55,56]. The Northern Province (i.e., the western Galilee coast) however, is a small, isolated and rocky littoral cell, partly covered with locally carbonated coarse sand [40,47,57,58].

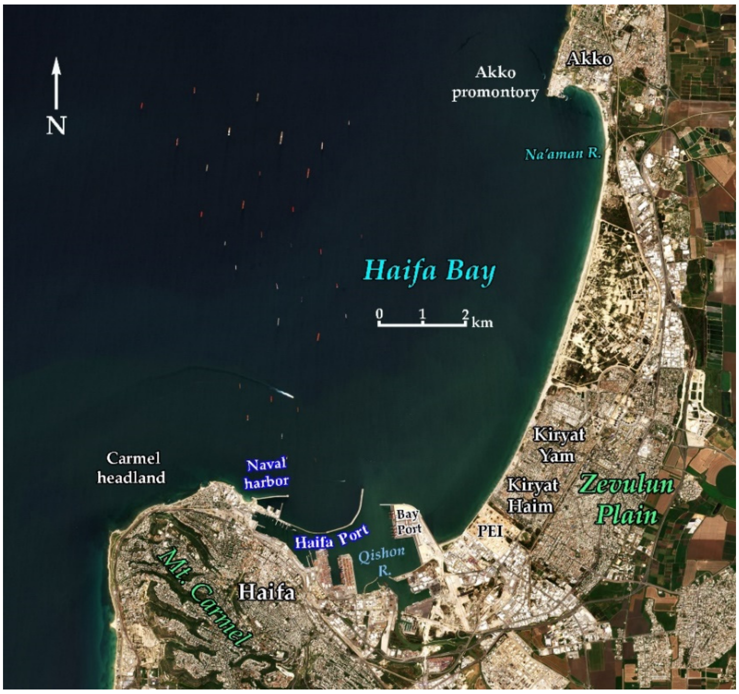

Figure 2. Haifa Bay area. Background: part of Sentinel-2 L2A, True color imagery,365XB https://www.sentinel-hub.com (accessed on 15 April 2021).

Haifa Bay is bordered by the Carmel headland to the south, the Akko promontory to the north, and the Zevulun Plain to the east. Two rivers traverse the Zevulun Plain: the Na'aman River in the north and the Qishon River in the south (Figure 2). Both transport silt and clay to the bay's offshore region [59]. The bay's coastline is crescent-shaped and includes a large port area, about 6 km long on its southern part, and about 12 km of sandy beaches along its eastern part. Haifa Bay's floor (0–30 m deep) consists of three sub-areas [52]: (1) a smooth seabed that extends from the shore to a maximum water depth of 10 to 20 m along the bay's coasts, and is mainly covered by Nile-derived quartz fine sand [56,60]; (2) a submerged calcareous sandstone (locally termed Kurkar) ridge area [61,62], which covers about two-thirds of the bay's floor at a water depth of 10 to 25 m; (3) a smooth seabed that is located in the bay's deep area (25–30 m deep) and covered by silty sand.

3.2. *Haifa Port Main Breakwater Morphological Impact*

During the last 4000 years, the sea level along the Mediterranean coast of Israel was relatively stable, and Nile-derived sand was continuously transported to Haifa Bay by longshore currents. As a result, the Zevulun Plain dried up and the bay's shoreline shifted 3 to 4.8 km to its present location [55,56]. This long-term trend ceased in 1932 after completion of the Haifa Port main breakwater, which became a large trap for sand transported to the bay.

Between 1978 and 1980, a container quay (Eastern Quay) was built in the eastern part of Haifa Port (Figure 3). To protect this terminal, the main breakwater was extended by 600 m to a total length of 2810 m, and the breakwater's head was located at a water depth of 13.5 m.

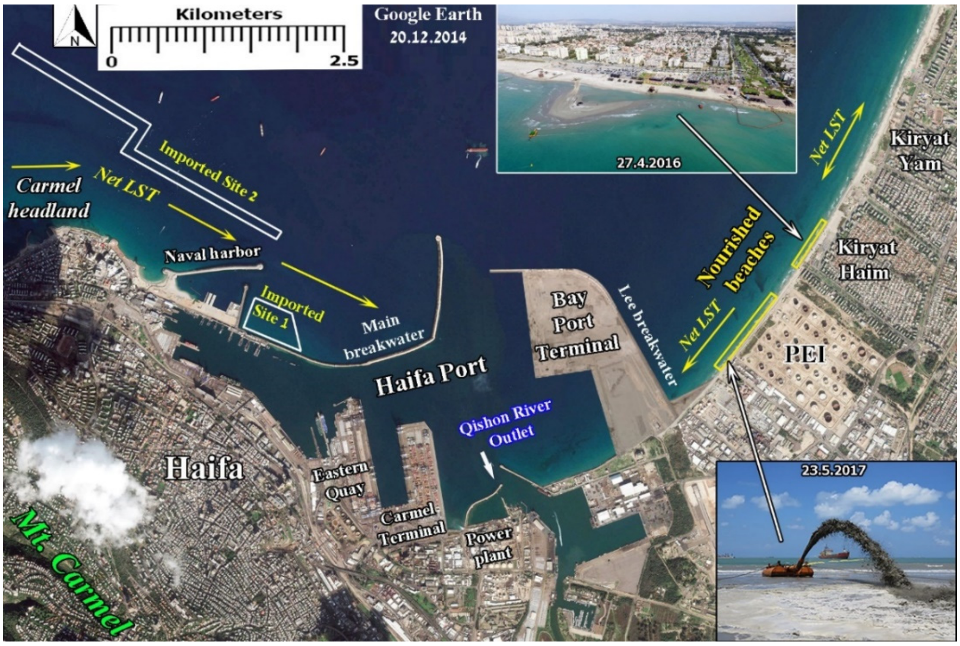

Figure 3. South Haifa Bay sand beach nourishment projects (May 2016–June 2017). Aerial photograph of Kiryat Haim bathing beach (Yehudit Naot Beach) during the first nourishment operation (top inset). Nourishment rainbowing operation via discharge pipe south of Petroleum and Energy Infrastructure Ltd. (PEI) (23 May 2017) (bottom inset). Background: Google Earth image, 20 December 2014 (after [39]).

The total amount of sand trapped along the main breakwater between 1929 and 2004 has been estimated at 5 million m^3 or an average of 66,000 m^3/year. Only a small amount of sand (8000–10,000 m^3/year) bypassed the breakwater's head and drifted to the eastern coast [52,55,63]. Analysis of shoreline migration between 1928 and 2006 shows that most of the bay's coasts were in a steady state, with seasonal fluctuations of less than about ±20 m and slight erosion [63].

During the years 2005–2008, another container quay (Carmel Terminal) was built in Haifa Port, and the last container quay (Bayport Terminal) was built in the last 5 years. This huge terminal is designed to handle Class EEE container vessels [39]. To protect the Bayport Terminal, the Haifa Port main breakwater once again was extended to 3682 m, and its head was located at a water depth of 20 m.

3.3. Haifa Bay Sand Beach Nourishment Activity

In December 2010, an extremely strong storm with significant wave heights (Hs) above 7 m occurred along the coast of Israel and caused severe erosion in many places, including in Haifa Bay [39]. To restore part of the eroded bathing beaches in southeast Haifa Bay, a small amount of sand (50,000 m^3) was dredged along the Haifa port main breakwater and used to nourish the Kiryat Haim beaches via a discharge pipe at a water depth of 3 m (Figure 3). The limited nourishment was inefficient and the Kiryat Haim beaches remained eroded. In February 2015, another extreme storm with Hs > 7 m hit the Israeli coast, and for the first time a severe erosion developed along the southern part of the PEI fence coast (Figure 3). This fence starts 730 m northeastwards of the Bayport lee breakwater and runs 800 m along the southeastern coast of Haifa Bay.

In March 2015, construction of the Bayport lee breakwater began. From then on, the erosion along the PEI fence coast continued to develop further north, including along Kiryat Haim bathing beaches, which extend for about 1 km north of the fence. To cope with the coastal erosion and prevent further damage to the PEI fence and the bathing beach infrastructure, several sand BN activities were carried out during 2016 and 2017 [39]. The first nourishment was carried out between April and May 2016, when a sand volume of

70,000 m^3 was dredged along the port's main breakwater (Figure 3: Imported Site 1) and deposited between the coastline and water depth of 2 m, in two sites: (1) a coastal section of 450 m along the Kiryat Haim bathing beaches (45,000 m^3); and (2) a coastal section of 250 m along the southern part of the PEI fence (25,000 m^3). The second nourishment was carried out in October 2016, when a sand volume of 100,000 m^3 was dredged north of the new Naval harbor main breakwater (Figure 3: Imported Site 2) and nourished a coastal section of 500 m along the PEI fence. Unfortunately, at the beginning of December 2016, a storm with Hs = 5.2 m eroded the nourished beach. The third nourishment was carried out between May and June 2017, when a sand volume of 185,000 m^3 was also dredged north of the naval harbor and used to nourish the same coastal section along the PEI fence again. When the nourishment along the PEI fence was completed, the coast had been widened by 40 m on average. However, by mid-January 2018 the beach was eroded again by storm waves [39]. The fourth nourishment was carried out along the Kiryat Haim bathing beaches, in May 2019. This operation was conducted in two stages. First, a sand volume of 28,000 m^3 was excavated from the beach near the Bayport lee breakwater and dumped directly on the shores, and a month later, a sand volume of 45,000 m^3 was dredged north of the Naval harbor and used to nourish the Kiryat Haim beaches via a discharge pipe.

4. The Erythraean Moon Crab *Matuta victor* and Beach Nourishment

The second-most abundant group of NIS in the Mediterranean Sea are crustaceans, among which more than 90 species belong to the order Decapoda [64]. Nearly 400 decapods have been recorded in the Mediterranean [65], of which about 24% are NIS [64]. Most recent records of decapod NIS in the Mediterranean include species of Indo-Pacific and Red Sea origin such as the moon crab, *Matuta victor* (Fabricius, 1781) from Turkey and Greece (Rhodes Island) [66,67] (Figure 1). *Matuta* species (moon crabs) belong to superfamily Calappoidae, which inhabit sandy beach areas [68]. Matutid crabs can bury themselves very quickly into sand [69]. *M. victor* is an omnivorous predator and a voracious scavenger, exhibiting intraspecific feeding competition and aggressive behavior [37]. It preys mainly on crustaceans and mollusks; smaller individuals prey on small, soft-shelled species while larger individuals eat slow-moving invertebrates such as anomurans, bivalves and gastropods [64]. It is widely distributed in the Indo-Pacific region, including the Red Sea, Southeast Asia to Fiji and New Hebrides [70], where it is caught by local communities in nets, by hand or beach seines. The establishment success of *M. victor* is further assisted by its reproductive plasticity and the production of numerous eggs [68].

Innocenti et al. [37] studied the distribution, feeding habits and behavior of the invasive common moon crab *M. victor*, mainly in Haifa Bay. Two separate adult specimens of this species were first recorded in Haifa Bay in 2012 [71]. One male was caught by trammel net in 10 m water depth, about 1 km north of the Qishon River outlet (Figure 2), on 31 October 2012, and one female *M. victor* was caught by seine net in 5 m water depth off the coast of Kiryat Yam (Figures 2 and 3), on 20 November 2012. This initial report was followed by reports of several dozens of *M. victor* in Tyre and Saida, (Figure 1: South Lebanon) in 2014 [72], a record of a single individual off Antalya (Turkey) in August 2015 [73] and later multiple observations in Israel, including on Ashdod bathing beach [38], southern Mediterranean coast of Israel (Figure 1), in June 2021 (Figure 4). It is interesting to note that this beach, which is located between the Ashdod Marina and Ashdod Port, has never been a sand nourishment site [39].

In the autumn of 2013, Innocenti et al. [37] observed the largest densities of *M. victor* ever recorded in Israel (1–10 crabs/10 m^2) in water shallower than 30 cm near Kiryat Yam (Figure 2). Their surveys of the Haifa Bay coast (Figure 1) in 2013 and 2015 revealed the presence of numerous specimens at its northern end, near the Na'aman River estuary (Figure 2) (up to 27 specimens/m^2 in 2013). By 2016 they recorded *M. victor* along the Israeli coast from Ashdod to Akko (Figure 1). They also reported that in May 2017, *M. victor* densities in Kiryat Yam reached 2 specimens/m^2. There was no description of the survey methodology used by Innocenti et al. [37], but they did mention that bait was used to attract the *M. victor* crabs, which might explain the sudden high densities observed.

Figure 4. A specimen of the common moon crab *Matuta victor* at Ashdod beach, southern Israel, (photographed by Shani Tubul, 9 June 2021).

In view of these findings, Innocenti et al. [37] suggested a possible role of anthropogenic disturbance in the outbreak of *M. victor*. They blamed the Israel Ministry of Environmental Protection (MOEP) for authorizing the November 2011 "massive" BN scheme depositing 50,000 m^3 of sand along a 2 km stretch of Kiryat Haim and Kiryat Yam beaches (Figures 2 and 3), at a depth of 3 m. They also accused MOEP of continuous operations "ever since" in 2016. They suggested that the most obvious and direct effect of BN was the obliteration of the resident benthic fauna (which they previously described as "almost barren"). They pointed out that anthropogenic disturbances such as eutrophication, pollution and the physical disturbance had been considered risk factors, reducing native diversity and increasing invader dominance. Innocenti et al. [37] accused MOEP of allegedly not considering the long-term consequences of providing suitable habitat for Erythraean NIS when authorizing BN in the polluted and eutrophic Haifa Bay. They stated: "It seems likely that the rapid increase in the population of *M. victor* in the newly "disturbed" Kiryat Yam beach next to the highly eutrophic Qishon River estuary, and soon after, next to the similarly polluted Na'aman River estuary, established the beachhead for its subsequent spread". They concluded by suggesting that to reduce the risk of the spread of NIS already present in the Mediterranean Sea and the establishment of new introductions, it was essential to lessen coastal eutrophication, pollution and physical disturbance.

5. The Possible Implications of the Appearance of *M. victor* in Haifa Bay

Innocenti et al. [37] point at eutrophication, pollution and BN as the main stressors affecting the biota of Haifa Bay. Sadly, this is not correct. The site of the *M. victor* study is located less than 2 km from a major marine stressor (i.e., Haifa Port—one of Israel's two busiest international seaports) recognized as a hotspot for NIS establishment [26]. Additionally, since 2005 the port has undergone several changes increased turbidity levels in the bay, including reclamation and construction of two new container terminals (i.e., the Carmel Port and the Bayport projects) and dredging and deepening of the entrance canal and the inner port basin. Moreover, the limited amount of sand (50,000 m^3) deposited in November 2011 and termed by Innocenti et al. [37] as "massive beach nourishment" was less than the natural annual average volume of sand deposited along the bay's coast before the construction of the port and after its completion [52,55]. It should also be mentioned that before 2011, no BN was carried out along the Israeli coast, and due to technical issues at that time, the sand was not deposited directly on the beach as planned, but at a depth of 3 m, some 200 m offshore. According to Innocenti et al. [37], a 2 km stretch was completely covered by deposited sand in 2011 and this had been repeated again and again ever since. The sand of the 2011 BN was deposited in four different point locations, 500 m apart, creating local sand spots at 3 m water depth, which were later dispersed by waves. There was no further deposition of sand at 3 m water depth in the bay. The sand of the 2016 BN was deposited directly on the beach [37]. This information appears in technical documents at the MOEP and is open and available to the public upon request.

The conclusions of Innocenti et al. [39] regarding the increase in *M. victor* sightings imply that these authors may not be fully familiar with the process of BN and the habitat it creates. In their paper, these authors provided references that showed that BN obliterated the benthic fauna at the nourished site, which is to be expected when a benthic submerged habitat becomes a dry beach. Yet, they failed to acknowledge that BN can also provide habitat for resident biota such as the native sand crab, the tufted ghost crab, *Ocypode cursor*, or even endangered nesting sea turtles (e.g., [74]). Both species are protected in Israel.

Beach nourishment activities are aimed at enlarging an eroded stretch of beach, and sand is thus deposited from the swash zone towards offshore. The nourished area does not remain a part of the subtidal; the main nourished area becomes a dry land and only the edge of the nourished area is submerged, becoming the new tidal zone, into which some motile fauna can migrate from the previous shoreline that is now covered. We do not dispute the claim that sand deposition may promote marine invasions, but in the case of *M. victor*, solid evidence for this assumption was not provided.

Additionally, the bay intertidal community is under constant fishing pressures, with clear effects on the shallow intertidal crab population. In September 2015, MOEP's marine pollution inspectors found a large number of dead crabs on the Akko South Beach, located in north Haifa Bay (Figure 5). According to local fishermen, intertidal crabs are often caught as bycatch by local fishing boats and illegal beach seine operations which are active in the bay. Due to lack of demand, they are discarded dead back into the sea or on the beach. Dredging and depletion from fishing activities in the intertidal habitat are much more likely candidates facilitating *M. victor*'s invasion into the bay than a single BN project.

More than 50 crustacean species of Indo-Pacific origin have colonized the shallow Levantine continental shelf before *M. victor*, displacing many indigenous species from both soft and hard sediments [31]. Tracing the establishment of a specific species to a single localized BN in a highly bio-invaded littoral that has been undergoing massive sedimentary changes for almost a century as well as repeated exploitation, eutrophication and pollution, mandates more rigorous supporting research. For example, a genetic study can compare specimens from Israel with those from Lebanon [71] and nearly 1000 km away in Turkey [73,75], in areas where no BN projects have been carried out. A genetic study may tell us whether a bottleneck effect is observed (i.e., a single invasion event has occurred) or if there were multiple introductions, in which case BN is much less likely to have been a protagonist. Such a genetic study was done, for example, in the marine gastropod *Strombus (Conomurex) persicus* (Swainson, 1821) [75], where genetic analyses were performed in specimens from the Persian Gulf and the Mediterranean coasts of Israel and Turkey.

Figure 5. Large amount of discarded crabs, apparently a bycatch of intertidal fishing, Akko beach, north Haifa Bay (photographed by Gidi Bettelheim, 18 September 2015).

Finally, Innocenti et al. [37] suggested that the Israeli MOEP neglected to consider the long-term consequences of providing suitable habitat for Indo-Pacific NIS when authorizing BN in the polluted and eutrophic Haifa Bay. There are several considerations that MOEP takes into account when authorizing BN, including the social impact of the loss of beaches to the human population of Haifa Bay and the possibility of marine pollution due to damage to existing infrastructure located at the back of the eroding beaches, such as the oil terminal. However, the issue of invasive species was not overlooked during the 2016 nourishment activities and was a major component in the infauna monitoring programs and regulations regarding BN projects. For example, the use of imported sand from Turkey in a major BN project in southern Israel was not authorized by MOEP due to the discovery of *Caulerpa taxifolia*, a known invasive seaweed species, in the dredging borrow area [76]. A strain of the species bred for use in aquariums has established non-native populations in waters of the Mediterranean Sea, the United States, and Australia and altered the structure of native biotic communities (e.g., [77]). Soft bottom invasive species are also monitored by Israel's national monitoring program, funded by MOEP since the early 1980s. Hard bottom invasive species in Haifa Bay have been monitored every 3 months since 2015 as part of the Environmental Monitoring and Management Program (EMMP) for construction of the Bayport.

6. Discussion and Conclusions

Circumstantial indirect evidence is insufficient to undeniably establish the role of artificial BN in promoting the establishment and dispersal of NIS. There are many examples of successful settlement and rapid and long-range proliferation of NIS especially in the eastern Mediterranean without any BN in the region [30,35,36]. *M. victor* is not the first of its family to be recorded in Haifa Bay. Three decades earlier, confamilial *M. banksii* was identified in the bay [78] with no prior BN. Firmly establishing an assumed role of BN in invasion by NIS must be based on solid and orderly, planned scientific research (e.g., BACI). Such a study should be designed well before the beginning of any BN. It has to include test sites to be artificially nourished, as well as similar control sites with no artificial BN. Systematic quantitative sampling of benthic biota (e.g., using transects or quadrats) has to be performed before the beginning of the nourishment activities and for a long period after their completion. These types of scientific quantitative samplings should be performed in equal patterns and by the same team and in the same seasons in both the impact and control sites. Unfortunately, there are very few examples of this approach. One of these rare studies is an experimental research project dealing with the role of BN in the success of an invasive Asiatic sand sedge, *Carex kobomugi Ohwi* [79]. Dune communities were subjected to 5 burial depth treatments in ~15 cm increments ranging from 0 (control) to 60 cm burial. Growth responses were monitored by quantifying emergent individuals and by harvesting all aboveground benthic biomass at the end of the season. Physiological responses were evaluated using an infrared gas analyzer to quantify photosynthesis rates. Burials lead to a reduction in community diversity and native species biomass, while favoring the invasive species. In addition, seaside goldenrod, *Solidago sempervirens*, within invaded communities exhibited significantly lower photosynthesis rates than those individuals in non-invaded communities [79]. Their results suggest that nourishment will promote Asiatic sand sedge invasion to the detriment of native dune species.

Kondylatos et al. [67] discuss the spread of *M. victor* in the eastern Mediterranean after it was first recorded from Haifa Bay in 2012 [71]. Later it was reported from Lebanon, at Batroun in 2013 and Tyre and Saida in 2014 [72], from the Mediterranean coasts of Turkey, at Phaselis, Gulf of Antalya, in 2015 [73], and from the southeastern Aegean waters of Turkey, at İztuzu Beach, Muğla (Figure 1), in 2017 [66]. These authors suggest that the occurrence of *M. victor* was expected in Greek waters [80], and they add that its record in Rhodes Island is not surprising because the last finding came from the area of Muğla (Turkey), close to Rhodes [67] (Figure 1). In view of this spreading pattern, Kondylatos et al. [67] propose that, since its initial discovery in Haifa Bay in 2012 [71], *M. victor* followed a north and westward expansion, on a "classic" route for NISs entering the Mediterranean Sea through the Suez Canal. In 2019, *M. victor* was also reported for the first time in Cyprus [81].

It is interesting to note that one of the coauthors of the article by Innocenti et al. [37], M. Mendelson, in a recent article (in Hebrew) in a local newspaper (https://haipo.co.il/item/277966 accessed on 1 June 2021) entitled: "When the sea 'swallows' the beach" supports BN. Referring to BN carried out on 20 June 2021 in Kiryat Haim beach (Figure 2) with clean sand, he praises this activity. He reports that it enriches the coastal environment with an abundance of harmless native species (in contrast to Lessepsian species) that were brought with the nourished sand, including indigenous mollusks, echinoderms and crustaceans. Governmental environmental agencies, including the Israeli MOEP, welcome criticism from the scientific community and often consult with scientists before approval of large projects. MOEP personnel are frequently approached by scientists for data. We believe that direct communication between regulators and scientists is beneficial to both sides. Information held by MOEP, such as technical documents on BN and prior knowledge of future nourishment projects, can be very useful when designing a study targeted at measuring the effects of nourishment on marine habitats. Had Innocenti et al. [37] approached MOEP before or during their study, their field surveys could have been better designed to target the actual effects of the Haifa BN projects on the local and invasive biota. Like many scientists, they based their conclusions regarding BN mostly on information found on the MOEP website. Not all types of data and documents gathered by the public sector are made available on the internet, due either to lack of public interest or to a lack of manpower needed to upload it, but these are available upon request. We conclude that direct communication between scientists and the public sector is crucial for the advancement of both environmental research and policy.

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