Received: 18 July 2017 | Revised: 29 January 2018 | Accepted: 17 February 2018
DOI: 10.1002/aqc.2916

RESEARCH ARTICLE

WILEY

Contributions of marine infrastructures to marine planning and protected area networking

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Funding information
Ministry of National Infrastructure, Energy and Water Resources, Grant/Award Number: 215-17-033

Abstract

1. Marine infrastructures are becoming ubiquitous as a result of the increasing exploitation of resources in the nearshore environment. These infrastructures are frequently linked with habitat degradation, pollution, and the establishment and spread of alien species. As marine infrastructures are perceived as threats to marine ecosystems, they are typically disregarded in conservation planning schemes.
2. Here, the presence of invertebrates and fish was surveyed in infrastructure areas with prohibited public access, as well as in nearby rocky reef areas that had no infrastructure and were open to the public.
3. It was found that species richness, Shannon diversity, and uniqueness of both fish and invertebrates were significantly higher in the infrastructure habitats than in the rocky reef habitats in most cases. Surprisingly, the findings show that the proportion of alien species was higher in the unprotected rocky reef habitats compared with that in the infrastructure habitats.
4. These counterintuitive findings suggest that marine infrastructures that limit unauthorized access to the surrounding territory may contribute to conservation if they are acknowledged and managed, according to their potential to provide a habitat for marine species. This suggests that these areas should be considered by planners as opportunities to enhance the connectivity of populations and to supplement marine protected areas in heavily impacted marine environments.

KEYWORDS

coastal infrastructure, fish, invertebrates, nearshore development, special area of conservation

1 | INTRODUCTION

Growing human populations increasingly exploit resources from the marine environment, such as energy, food, and space. As a consequence, marine habitats are rapidly becoming degraded and fragmented (Coll et al., 2010, 2012; Halpern et al., 2008). Therefore, efforts are underway to establish marine protected areas (MPAs), so as to conserve vulnerable and threatened habitats and species (Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and University of Nice Sophia Antipolis (UNS), 2016). Although MPAs make significant contributions to marine conservation, and to the protection of marine habitats and species, this contribution is limited if they function as isolated islands, without connectivity between populations (Agardy, Di Sciara, & Christie, 2011; Magris, Pressey, Weeks, & Ban, 2014). Thus, a major focus of current marine conservation efforts is to form a network of connected areas that protect life in marine ecosystems (e.g. Marine Strategy Framework Directive (MSFD), 2015).

A network that achieves connectivity between populations need not be limited to undeveloped natural habitats, however, but should also include marine areas that are subject to intense human activity, as wildlife protection can be achieved within these areas (Rosenzweig, 2003). The main challenges of such an approach would be to identify conservation opportunities within areas of human activity, and to implement wildlife protection within these areas by reconciling management goals with marine conservation goals. Identifying opportunities for conservation in areas of human activity is especially difficult, as such areas are usually managed by stakeholders, few of whom – if any – are concerned with conservation monitoring (e.g. biodiversity assessments).

Marine infrastructures serve various purposes, such as energy production, as well as military and maritime uses, all of which are human activities that have been shown to threaten the marine environment by causing habitat degradation, pollution, and vulnerability to alien species (Airoldi, Turon, Perkol-Finkel, & Rius, 2015; Heery et al., 2017). Attempts to reduce these threats have included regulation (e.g. Naylor, Coombes, Venn, Roast, & Thompson, 2012), green engineering (e.g. Sella & Perkol-Finkel, 2015), and marine spatial planning, through the implementation of ecosystem-based management (Communication Partnership for Science and Sea (COMPASS), 2005; Douvere, 2008). Many marine planning initiatives conceive these activities as conflicting with the goals of marine environment protection (e.g. Blæsbjerg, Vestergaard, Pawlak, & Sorensen, 2009; Ehler, 2011; Israel Marine Plan, 2016; Israel Marine Spatial Policy Project (IMSPP), 2016; Seychelles Marine Spatial Plan (SEYMSP), 2014; Vallega, 1995); hence, they often attempt to locate the related infrastructures far from sensitive marine habitats.

Recently, however, some studies have reported on the unique ecosystems that develop around marine infrastructures (Bulleri & Chapman, 2010; Dyson & Yocom, 2015; García-Gómez, López-Fé, Espinosa, Guerra-García, & Rivera-Ingraham, 2011). Specifically, conservation opportunities were discovered in infrastructure areas where public access to the surrounding territory is restricted, either to ensure public safety or for operational security reasons (García-Gómez et al., 2015). Therefore, these areas can potentially provide refuge for heavily exploited species. Yet, the ecosystems that develop over time around these infrastructures are rarely monitored as part of biodiversity assessment programmes for marine conservation purposes (e.g. European Commission, 2010; Helsinki Commission (HELCOM), 2009), and are typically ignored by conservationists. Here, two infrastructure areas that limit unauthorized access to the surrounding territory were surveyed along the Israeli Mediterranean coast, as well as two rocky reef areas nearby. The goal of this study was to supply preliminary data comparing species abundance and distribution within areas of infrastructure and in unprotected rocky habitats. We aim to evaluate opportunities to expand marine conservation beyond the boundaries of marine protected areas to include even areas of intense and dominant human activity.

2 | METHODS

The surveys focused on epifaunal invertebrates (hereafter invertebrates) and fish, which are the two most identifiable species-rich taxa in eastern Mediterranean rocky habitats (Rilov, 2014). In order to survey invertebrates in infrastructure areas, the invertebrate surveying protocol of HaMaarag Nature Assessment Program (HaMaarag, 2016) was used. This programme monitors unprotected rocky marine habitats along the Israeli Mediterranean. For fish surveys the HaMaarag protocol for video-surveying was followed. A non-baited video survey was chosen, however, as opposed to the baited survey method used in the assessment programme, because although the focus of the programme is on carnivorous species this study aimed to survey all fish species. All surveys were performed in two infrastructure areas that limit unauthorized access to the surrounding territory and two reference sites during spring (April–May) 2016.

2.1 | Study sites

Two infrastructure sites were selected, in Hadera (Orot Rabin Power Station) and in Tel Aviv (the Reading Power Station). Two undeveloped and unprotected rocky habitats, in geographic proximity to each infrastructure site, were chosen as reference sites. The infrastructure sites are similar to the reference sites in terms of habitat type, with the main difference between them being the presence of the infrastructure. Thus, if not for the infrastructures, we would expect similar communities of fish and invertebrates in the infrastructure sites to those of the rocky habitat in the reference sites. Comparison with an MPA area was not performed because there are no MPAs anywhere within 80 km of the infrastructure sites. In addition, the common choice of planners in a marine spatial planning process is to rely on undeveloped unprotected habitats to achieve connectivity between MPAs, and marine infrastructure activity is likely to be seen as conflicting with marine conservation goals (Blæsbjerg et al., 2009; Ehler, 2011; SEYMSP, 2014).

In Hadera, the Orot Rabin Power Station is operated by the Israel Electric Company (IEC), and is located in the Hadera Port, on the coast of the Mediterranean Sea near the city of Hadera (32°47′391″N, 34°87′952″E). It encompasses a marine area of about 1.5 km^2 and includes submerged and above-water facilities (Figure 1). The power station coastal infrastructures include: a jetty, where ships unload coal for the power station; a coal conveyor from the pier to the station; breakwaters; an intake basin, from which sea water is pumped to cool the power station turbines; tugboat harbours; a military boat dock; and a dock for other small maintenance and security boats. The coal jetty differs from the conveyor area, as there are some artificial structures on the sea floor in that area, and in addition there are twice as many piles under the pier compared with under the rest of the bridge (Figure 2). The intake basin reaches a depth of about 4 m at its shallowest point, and a depth of about 30 m in proximity to the coal jetty. The sediment in the site is mostly sand with scattered rock. Artificial substrates found at the site include mainly concrete, steel, and rock (Figure 3a). The site is bordered by popular recreation beaches on both sides. Although the power station is operated by the IEC, the marine area is managed by the Israel Ports Authority. Israel Ports Authority limits vessel traffic and general public access to territories within its jurisdiction, usually up to a distance of 100 m from the port structures.

In Tel Aviv, the Reading Power Station is also operated by the IEC and is located on the northern border of Tel Aviv (32°10′759″N, 34°77′340″E). Unlike the Orot Rabin Power Station, it uses gas for power instead of coal, and its area of about 0.5 km^2 includes intake basins, breakwaters, boat docks, and other small artificial structures

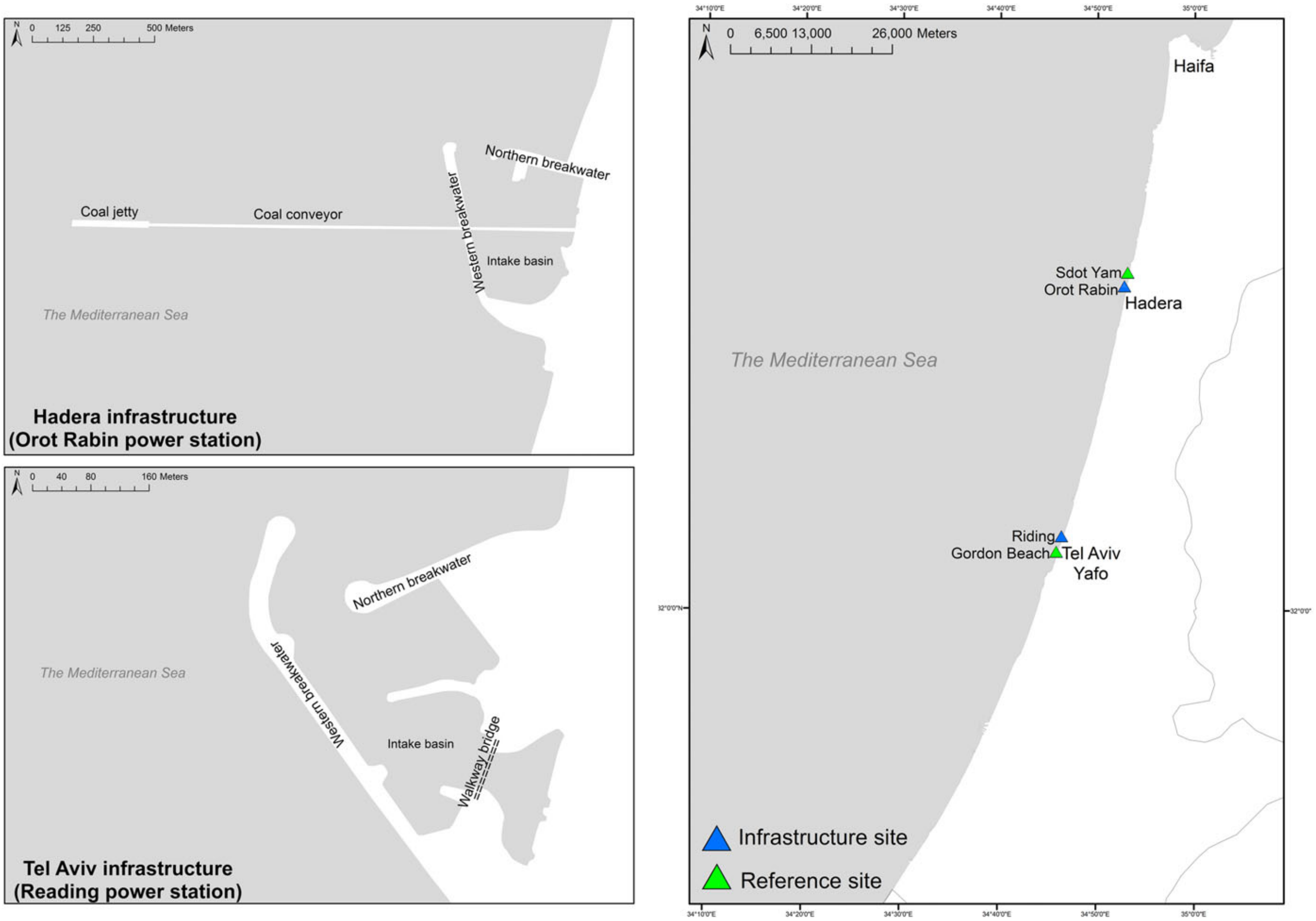

FIGURE 1 Study sites along the Israeli Mediterranean coast

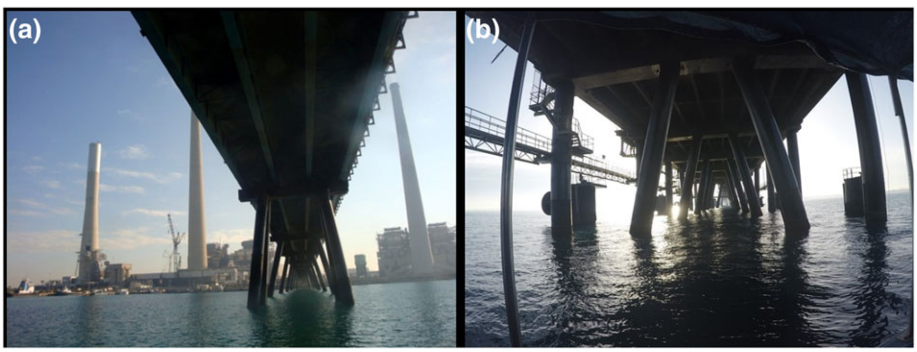

FIGURE 2 Hadera infrastructure site: Orot Rabin Power Station coal conveyor and jetty infrastructure above water and under the conveyor. (a) Coal conveyor piles. (b) Coal jetty piles

(Figure 1). Similar to the Orot Rabin Power Station, the sediment in the site is mostly sand, with scattered rock and artificial substrates comprising mainly concrete, steel, and rock. For safety reasons, the IEC does not allow any access to the area.

For each infrastructure site, a single reference site was selected. For the Hadera area, the reference site was an area of rocky bottom with Kurkar rocks, which are generally considered as unique habitats composed of sandstone, often covered with biogenic encrustations inhabited with rich and diverse marine communities (Figure 3b). The Hadera reference site is located off the Sdot Yam Beach, 2.3 km from the infrastructure site (32°49′008″N, 34°88′492″E), at a depth of 5–45 m. Similarly, in the Tel Aviv area, the reference site was an area of Kurkar rock bottom located off Gordon Beach (32°08′509″N, 34°76′442″E), at a distance of 2.6 km from the infrastructure site and at a depth of 5–7 m.

2.2 | Data collection

Surveys were conducted using scuba-diving, recording invertebrates and fish along and around artificial elements of the infrastructure sites, and along the rocks of the reference sites. The invertebrate survey was conducted using 25-m transects. Every 3 m, a quadrat of

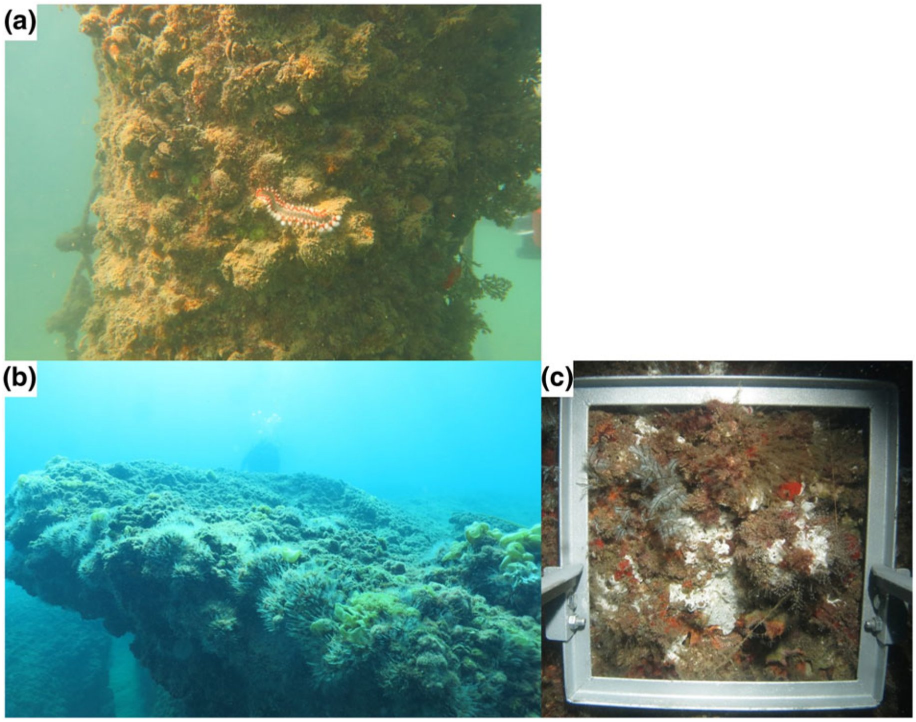

FIGURE 3 Representative images of the underwater sites, and of the sampling quadrate: (a) epifaunal community on an artificial structure at the Hadera infrastructure site; (b) unprotected rocky habitat at the Tel Aviv reference site; and (c) sampling quadrat (25 cm × 25 cm), positioned on an artificial structure at the Tel Aviv infrastructure site

25 cm × 25 cm was photographed using a Canon PowerShot S110 camera (Canon, Tokyo, Japan) equipped with Ikelite housing and flash (AF 35; Ikelite, Indianapolis, IN, USA), attached to the quadrat. Transects were positioned as follows: (i) in rocky habitats, bottom of Hadera infrastructure coal jetty, and intake basins, the transects were performed in two sets of an X-shape, starting from the centre point and stretching approximately north, south, east, and west from the centre; (ii) in breakwaters, transects were stretched at approximately 20-m intervals along the breakwater in the middle depth between the bottom of the breakwater and the sea surface; (iii) Hadera infrastructure coal conveyor piles (Figure 2) were surveyed by photographing the quadrat from four aspects of the 4-m perimeter pile (north, south, east, and west). Further details of the survey scheme are provided in Table 1.

Fish video surveys were conducted using a GoPro Hero 4 camera (GoPro, San Mateo, CA, USA) mounted on a 50-cm high tetrapod. The camera was positioned at the sites by a scuba-diver, who then retreated while video data were collected for a period of 45–60 minutes (Table 1). Fish surveys performed by the HaMaarag monitoring programme (HaMaarag, 2016) at a depth of 10, 25, and 45 m off Sdot Yam beach were also used as reference data for the Hadera infrastructure site (see Appendix S1).

2.3 | Data analysis

For comparison between infrastructure and reference sites, the same number of transects was randomly selected from all data collected in the surveys (n = 5 and n = 6 in the Hadera and Tel Aviv sites,

TABLE 1 Location of survey sites and number of replicates in all sites

Geographic area	Site	Location in site	Number of replicates (and depth in m)	
			Invertebrate transects	Fish Videos
Hadera	Infrastructure	Intake basin and eastern side of western breakwater	5 (5)	10 (5)
		Western side of western breakwater	5 (5)	10 (5)
		Coal conveyor outside intake basin	10 (5) 10 (15)	10 (10)
		Coal jetty	2 (5) 2 (15) 6 (26)	10 (26)
	Reference	Rock (vertical and horizontal)	5 (5)	10 (5) 10 (10)[a] 10 (45)[a]
Tel Aviv	Infrastructure	Artificial structures within intake basin (including the small boats dock)[b]	5 (3)	0
		Western side of western breakwater	6 (6)	11 (6)
	Reference	Rock (vertical and horizontal)	5 (6)	11 (6)

[a]Baited video survey.

[b]Poor visibility in the cooling basin did not allow for an accurate analysis of the video surveys performed in that area.

respectively). For comparison between different locations within the Hadera infrastructure site, the same number of transects was selected for each location (Table 1). Transects were analysed using CORALNET (Beijbom, 2015; Beijbom, Edmunds, Kline, Mitchell, & Kriegman, 2012; Beijbom et al., 2015). Sixteen points were randomly selected in each photo, and species-specific surface cover was recorded. Species were identified to the lowest possible taxonomic level. In cases of species layering, where more than one layer is identifiable, the bottom-most identifiable species was recorded.

To analyse the video surveys, the number of individuals per species were counted, recorded, and analysed in 60-second segments of video. For each location, non-sequential 10- and 11-segment sets for Hadera and Tel Aviv sites, respectively, were randomly selected for the analysis, with at least a 3-minute interval between the selected segments.

Species richness and Shannon's diversity index were calculated for each sampling unit (i.e. a transect or 1 minute of video), and statistical comparison of these measures between sites was based on an equal number of sampling units from each site.

The uniqueness of a given site is the degree to which its species are uncommon in other sites (Stohlgren, Guenther, Evangelista, & Alley, 2005). The uniqueness U of each site was modified from Stohlgren et al. (2005), and calculated as:

$$U_k = \frac{\Sigma \frac{n_{jk}}{N_j}}{N_t}$$

where $n_{j,k}$ is the number of observations (presence/absence) of species j at site k. N_j is the total number of observations of the species j at all sites in the area of site k (infrastructure and reference sites of Hadera or Tel Aviv), and N_t is the number of species observed in the site. Fish vulnerability was calculated by the summation of the intrinsic vulnerability index values, described by Cheung, Watson, Morato, Pitcher, and Pauly (2007), for the species present at each site. This index ranges from 1 to 100 (where 100 is the most vulnerable), and is based on life history and ecological characteristics of the species, including maximum length, age at initial maturity, longevity, von Bertalanffy growth parameter, natural mortality, spatial behaviour, and geographic range (Cheung et al., 2007). Analysis of variance (ANOVA) was performed to test for significant differences between the infrastructure and reference sites of each area. In addition, analysis of similarities (ANOSIM) was performed for each area, using the Bray–Curtis similarity index, in order to examine whether the similarity between sites or the similarity within sites better explains the total similarity. Multidimensional scaling (MDS) plots were used to graphically represent distances between sites in the multidimensional space of community composition. All analyses were performed in VEGAN (Oksanen et al., 2007) for R (R Core Team, 2014). All analyses were repeated after excluding alien species of invertebrates and fish, in order to determine whether the presence of alien species was the source of the differences observed between the infrastructure sites and the reference sites (Appendix S2).

3 | RESULTS

The diversity of both invertebrate and fish species was higher in the infrastructure sites compared with the reference sites in all cases. Also, the vulnerability of fish species was higher in the infrastructure sites. All of the comparisons between the Hadera infrastructure site findings and the Hadera reference site findings rendered statistically significantly higher values in the infrastructure site. Comparing the Tel Aviv infrastructure site findings with its reference site findings rendered significantly higher values in the infrastructure site only for invertebrate richness and diversity, but not for fish species richness, diversity, or vulnerability (Table 2).

Within the Hadera infrastructure site, fish species richness, diversity, and vulnerability were higher in the coal jetty than in any of the other locations, whereas no significant differences were found between the different locations within the Hadera infrastructure site in terms of invertebrate species richness or diversity (Appendix S2). The ANOSIM results suggest that the between-site similarity is lower than the within-site similarity of invertebrate and fish species at both infrastructure sites, however, compared with their respective reference sites (Table 2).

Nearly all fish and invertebrate species found in the reference sites of Hadera and Tel Aviv were also present in the respective infrastructure sites (Figure 4; Tables 3 and 4). Conversely, approximately two-thirds of the fish and invertebrate species found at the Hadera infrastructure site were not present at the Hadera reference site, and half of the species found at the Tel Aviv infrastructure site were not found at the Tel Aviv reference site (Figure 4; Tables 3 and 4). In addition, the total number of fish individuals was higher in the infrastructure sites compared with their reference sites. In Hadera, fish species that were found in both the infrastructure and the reference sites had 1.5–34.0 times more individuals in the infrastructure site. In Tel Aviv, fish species that were found in both the infrastructure and the reference sites had 1.6–6.6 times more individuals in the infrastructure site (Table 3). Overall, the total number of fish individuals was 7.8 and 3.0 times higher in Hadera and Tel Aviv infrastructure sites, respectively, compared with their reference sites. The invertebrate coverage percentage was 4.5 and 2.0 times higher in Hadera and Tel Aviv infrastructure sites, respectively, compared with their reference sites (Table 4). In both areas, uniqueness at the infrastructure site was higher than at the respective reference site, for both invertebrates and fish (Table 5). In addition, the uniqueness of fish species in the coal jetty at the Hadera infrastructure site was exceptionally high,

TABLE 2 ANOVA F values for all fish and invertebrate measures in the infrastructure sites, compared with their reference sites. In all cases where F was significant, the value of the measure was higher in the infrastructure site compared with the reference site

		Infrastructure vs Reference	
	Measure	Hadera	Tel Aviv
Invertebrates	Species richness	9.94**	0.57
	Species diversity (H')	4.28*	10.18**
	ANOSIM (R^2)	0.57**	0.38**
Fish	Species richness	8.97**	4.09
	Species diversity (H')	4.6**	0.02
	Species vulnerability	8.80**	2.42
	ANOSIM (R^2)	0.52**	0.58**

Statistical significance:
*P < 0.05. **P < 0.01.

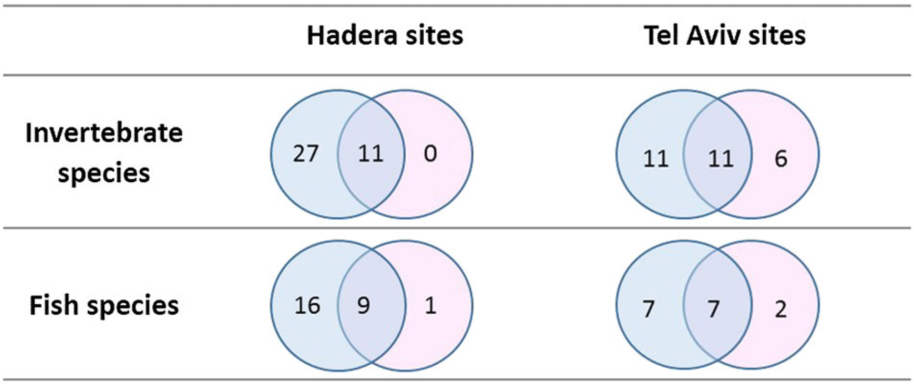

FIGURE 4 Number of species observed within infrastructure and reference sites: blue, infrastructure site; pink, reference site

TABLE 3 Number of individuals from each fish species found in Orot Rabin and Riding power stations, and in the natural rocky habitats of Sdot Yam Beach and Gordon Beach

Taxa	Species	Orot Rabin	Sdot Yam	Riding	Gordon
Balistidae	*Balistes carolinesis*	1			
Carangidae	*Caranx crysos*	19		2	
	Pseudocaranx dentex			7	
	Seriola damerili	18			
Dasyatidae	*Dasyatis pastinaca*	2			
Fistulariidae	*Fistularia commersonii*[a]	15	1		
Haemulidae	*Pomadysis incicus*				2
Holocentridae	*Sargocentron rubrum*[a]	35			
Labridae	*Coris julis*	53	29		3
	Thalassoma pavo	31	11	56	29
Monacanthidae	*Stephanolepis diaspros*[a]	3			
Mugilidae	*Liza aurata*	3	2	34	
Mullidae	*Mullus surmuletus*			1	
Pomacentridae	*Chromis chromis*	106	16		
Pomatomidae	*Pomatomus saltator*	3		2	
Sciaenidae	*Sciaena umbra*	14			
Serranidae	*Epinephelus costae*	17			
	Epinephelus marginatus	53			
	Mycteroperca rubra	143		5	3
Siganidae	*Siganus luridus*[a]	1			
	Siganus rivulatus[a]	109	26	53	8
Sparidae	*Dentex dentex*			7	
	Diplodus cervinus	34	1	22	13
	Diplodus puntazzo	2		10	
	Diplodus sargus	166	19	66	25
	Diplodus vulgaris	128	19	34	21
	Oblada melanura	7		45	8
	Pagrus caeruleostictus	2			
Sphyraenidae	*Sphyraena viridensis*	17			
Tetraodontidae	*Lagocephalus spadiceus*[a]		1		
Total number of individuals		**982**	**125**	**344**	**112**

[a]Alien species.

being at least 4.5 times greater than that found in any of the other locations in that site.

The MDS plots of fish and invertebrates in Hadera reveal that the reference sampling points are clustered together, in contrast to the broad dispersion of the infrastructure sampling points, indicating a high degree of similarity in species composition among the reference sampling points and a high degree of variability among the infrastructure sampling points. A similar trend was also found for invertebrates in Tel Aviv (Figures 5a–c). For fish in Tel Aviv, the infrastructure and reference site sampling points occupied different regions within the MDS plot; however, for both invertebrates and fish in Tel Aviv, the reference sampling points formed distinct clusters within the MDS plots, indicating the disparate species composition of the samples at the reference and infrastructure sites (Figure 5d).

TABLE 4 Percentage substrate coverage of invertebrate species found in Orot Rabin and Riding power stations, and in the natural rocky habitats of Sdot Yam Beach and Gordon Beach

Taxa	Species	Orot Rabin	Sdot Yam	Riding	Gordon
Anemones	*Anemonia viridis*	0.06		0.27	
Barnacles	*Balanus* sp.	0.64	0.44	2.88	
Bivalves	*Alectryonella plicatula*	0.56		0.39	
	Brachidontes pharaonic[a]	0.65	4.8	22.27	3.72
	Chama pacifica[a]	0.94	0.29	0.53	0.8
	Lithophaga lithophaga	0.21			
	Malleus regula[a]	0.3			
	Ostrea sp.[a]	0.51			0.13
	Pinctada radiate[a]	1.52			0.93
	Spondylus spinosus[a]	3.42	2.03		3.86
Bryozoans	*Bugula* sp.	0.86			
	Schizoporella errata	7.43	1.6	2.59	0.53
Corals	*Oculina patagonica*[a]	0.02		2.66	
Gastropods	*Conomurex persicus*[a]	0.37		0.07	
	Dendropoma petraeum	2.53			2.13
	Patella sp.	0.07			
	*Unidentified snail***	0.82	0.15		0.8
Hydrozoans	*Aglaophenia* spp.	10.42	0.29	0.14	1.2
	Pennaria disticha[a]	0.97			
Polichaeta	*Branchiomma bairdi*[a]	0.34			0.13
Serpulidae	*Unidentified serpulid*[b]	0.03	0.15		
Sponges	*Chondrilla nucula*	0.22		0.57	0.8
	Chondrosia reniphormis	0.51		0.11	0.13
	Crambe Crambe	3.07		2.01	
	Dysidea sp.	0.79		0.46	
	Ircinia sp.	0.62		0.07	0.13
	Phorbas sp.	0.69			
	Sarcotragus sp.	0.49	0.29	0.25	0.4
	Spirastrella sp.	1.07	0.15	0.04	
	Unidentified red sponge[b]	3.63	0.87	0.9	2.26
	Unidentified yellow sponge[b]	1.09			
Tunicates	*Botrylloides* sp.	2.19			
	Didemnum sp.	0.73		0.21	0.13
	Herdmania momus[a]	0.06		0.04	
	Microcosmus sp.[a]	0.26		0.18	
	Phallusia nigra[a]	0.39		0.07	0.13
	Pycnoclavella sp.	0.37			
	Symplegma brakenhielmi[a]	0.3		0.14	
Total coverage by invertebrates[c]		**49.15**	**11.06**	**36.85**	**18.21**

[a]Alien species.

[b]Unidentified species were counted as a single species each.

[c]The remaining coverage (up to 100%) was turf, algae, and bare substrate.

3.1 | Alien species

There were more native than alien species in both fish and invertebrate groups at all sites. Interestingly, in most cases, the reference sites had a smaller number of alien species yet a larger proportion of alien species than the infrastructure sites (Table 6). Besides fish species in Tel Aviv, which had one alien species in the infrastructure site and one alien species in the reference site, all other cases had 1.1–4.6 times more alien species in the infrastructure site compared with the reference site. The alien-to-native ratio tended to be higher for invertebrate species compared with fish species. In the majority of cases, excluding alien species from the analyses had a minor effect on the results (Appendix S2). Exceptions to this general trend were: (i) the invertebrate diversity was significantly higher in the Tel Aviv infrastructure site compared with the Tel Aviv reference site when alien species were included in the analysis, but not when alien species were excluded; (ii) the ANOSIM test of Tel Aviv invertebrates indicated that between-site variability was not significantly higher than within-site variability, only when alien invertebrates were excluded from the analysis.

4 | DISCUSSION

4.1 | Incorporating infrastructure value for conservation in marine spatial planning

In contrast to the common view of marine infrastructures in a marine planning process, which assumes that infrastructure activity is in conflict with the marine environment (e.g. Blæsbjerg et al., 2009; Ehler, 2011; IMSPP, 2016; Israel Marine Plan, 2016; SEYMSP, 2014; Vallega, 1995), the results show that infrastructure areas, for which access is limited, support marine ecosystems that are often more diverse, and host more vulnerable species (Cheung et al., 2007; Table 2), than unprotected rocky reef habitats. To further understand the contribution of infrastructure areas to marine conservation, additional comparisons between infrastructure areas and MPAs should be performed. The selection of reference sites in this study, however, reflects the common view of planners on marine infrastructures and on unprotected, yet undeveloped rocky habitats along the coast (e.g. Israel Marine Plan, 2016). This view, held by planners and other decision makers and marine managers, generally perceives marine infrastructures as a threat to the marine environment, whereas undeveloped rocky habitats are perceived as areas that contribute to connectivity between MPAs along the coast. The results of this study reveal a gap between the perception of marine infrastructures by planners and the actual value of these areas for promoting marine conservation. That said, a comparison between infrastructure areas and MPAs that

TABLE 5 Site uniqueness for fish and invertebrate species. Invertebrates were surveyed only at a depth of 5 m at the Sdot Yam reference site. Abbreviations: *I*, alien species included; *E*, alien species excluded; Be, eastern side of western breakwater; Bw, western side of western breakwater; Cc, coal conveyor; Cj, coal jetty

		Hadera							Tel Aviv	
		Infrastructure				Reference			Infrastructure	Reference
		Be	Bw	Cc	Cj	5 m	10 m	45 m		
Invertebrates	*I*	0.32	0.13	0.12	0.40	0.02	–	–	0.83	0.17
	E	0.32	0.10	0.12	0.40	0.01	–	–	0.84	0.16
Fish	*I*	0.16	0.12	0.04	0.58	0.04	0.01	0.05	0.75	0.25
	E	0.14	0.10	0.05	0.64	0.04	0.02	0.01	0.74	0.26

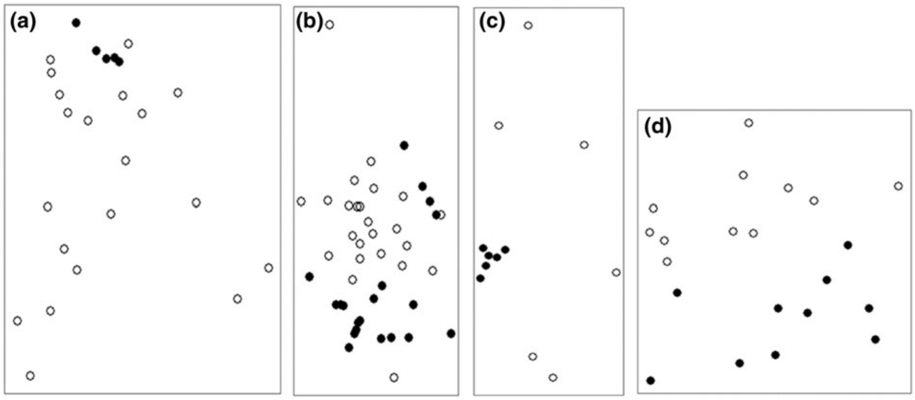

FIGURE 5 Multidimensional scaling (MDS) plots of the infrastructure and reference sites: (a) Hadera invertebrates; (b) Hadera fish; (c) Tel Aviv invertebrates; (d) Tel Aviv fish. ○, infrastructure site; ●, reference site

TABLE 6 Number of, and ratio between, the native and alien invertebrate and fish species in each area. Abbreviations: *I*, infrastructure; *R*, Reference

	Hadera				Tel Aviv			
	Invertebrates		Fish		Invertebrates		Fish	
	I	*R*	*I*	*R*	*I*	*R*	*I*	*R*
Native	24	8	20	7	14	10	13	8
Alien	14	3	5	3	8	7	1	1
Total	38	11	25	10	22	17	14	9
Proportion of alien species	37%	27%	20%	30%	36%	41%	7%	11%

limit fishing and harvesting within them might distinguish between the contributions of the infrastructure itself, versus the contribution of its management, to sustaining marine populations needing protection.

An additional aspect that should be considered when examining the contribution of marine infrastructure to marine conservation is the possible damage to the marine environment that may result from the operation of the infrastructure. Although the management of infrastructure areas might contribute to marine conservation, intentionally or unintentionally, the various modes of operation have a great potential of damaging the marine environment and should be recognized and avoided (Heery et al., 2017). Therefore, as part of the marine spatial planning process, planners should consider the potential benefits and threats to marine populations derived from various operations and conditions imposed on infrastructure areas, through the use of ecological modelling (see Shabtay, Portman, & Carmel, 2017).

4.2 | Contribution of marine infrastructures to marine conservation goals

The results of this study shows that some species exist only or mainly within the infrastructure areas, and not in the rocky habitats. Populations of these species were once common in rocky reef habitats and were degraded as a result of overexploitation (Edelist et al., 2013). These findings may be caused by heavy disturbance in unprotected rocky habitats, or by preferred and unique conditions within the infrastructure area, or by both factors. In any case, it was found that marine infrastructures that limit unauthorized access to the surrounding territory supply refuge areas for some heavily exploited species.

As an example, 70 individuals of two species of the genus *Epinephelus* were observed in the Hadera infrastructure site and were not observed in the reference site. *Epinephelus marginatus* is listed as endangered according to the International Union for Conservation of Nature (IUCN), and is ranked 72 out of 100 on the intrinsic vulnerability index (Cheung et al., 2007; Cornish & Harmelin-Vivien, 2004). *Epinephelus costae* is ranked 66 out of 100 on the intrinsic vulnerability index (IUCN status is 'data deficient'; Cheung, Pitcher, & Pauly, 2005). *Epinephelus* species are considered key species in marine conservation in Israel; hence, the observation of these species is an indication of the importance of the infrastructure site to marine conservation.

Another interesting finding is the disparate species composition when comparing the Tel Aviv infrastructure site with the Tel Aviv reference site. The lack of overlap between the sampling units as observed in the MDS suggests that species compositions that are found within the infrastructure site are missing from the unprotected rocky habitat. We suggest that these findings are an additional aspect of the value that infrastructures have for marine conservation.

Among all of the locations surveyed, the coal jetty at the Hadera infrastructure site was exceptional, for having significantly higher values in all measures (richness, diversity, vulnerability, and uniqueness) pertaining to both fish and invertebrates when compared with the reference site, and in all measures pertaining to fish when compared with other locations within the infrastructure site. The IEC (2017) environmental report suggests no difference in environmental conditions between the area of the jetty and the surrounding water (e.g. water temperature, depth, primary productivity). Therefore, we suggest that this wealth is a result of the structure, management, and strict enforcement of the limitation of access to the area. The structure is different because the density of the piles that support the coal conveyor is more than double that of the pier. Also, at the bottom of the pier there are multiple artificial structures made mainly of steel, which were illegally left in the water after the construction of the bridge in the 1980s. As a consequence, the area is structurally sheltered and complex. In addition, although public access to the whole area is restricted, some fishermen illegally enter the area of the bridge, where enforcement is relatively lax; however, access to the coal jetty is strictly enforced, because it would constitute a severe safety and security threat. García-Gómez et al. (2015) demonstrated that structure and prohibited access to infrastructure areas could be favourable for heavily exploited species. Therefore, we suggest that the sheltered and complex habitat, and the strict prohibition against access to the coal jetty, at the Hadera infrastructure site result in higher species diversity, especially for species with high commercial value.

Alien species are known to inhabit artificial structures in the marine environment (Airoldi et al., 2015; Glasby, Connell, Holloway, & Hewitt, 2007; Langhamer, 2012; Ruiz, Fofonoff, Steves, & Carlton, 2015). In the present study, the number of alien species was lower than the number of native species in all cases; however, the number of alien species was identical or higher in the infrastructure site compared with the reference site. Yet, in most cases (fish in Hadera, and fish and invertebrates in Tel Aviv), the proportion of alien species in the infrastructure sites was lower than in the reference sites. The exclusion of alien species from all analyses had minor effects on the results. This suggests that the effect of alien species on species composition in the infrastructure enclosures is similar to their effect in unprotected rocky reef habitats. This finding may reflect the great disturbances to which unprotected rocky habitats are exposed, which led to a high ratio of alien species, or it may be that the particular structure and management of the infrastructures studied here do not encourage the presence of alien species typically observed in similar sites. In addition, the diverse communities that have evolved at the infrastructure sites, during the four or more decades since their construction, might increase the resistance of the area to the establishment of alien species. Further research on the dynamics of the communities in relation to the engineering aspect and operations occuring within the infrastructure sites is required in order to understand the precise causes of the relatively low ratios of alien species within the infrastructure areas. In addition, studying the dynamics of the communities might reveal the causes for the smaller numbers, yet higher proportions, of alien species found in the infrastructure sites.

The results suggest that infrastructure enclosures have an ecological value that should be acknowledged by conservationists and marine planners. These areas could be considered artificial marine microreserves (García-Gómez et al., 2011, 2015), and could increase species diversity and the connectivity of populations along the coast. Accordingly, such areas should be managed with respect to their environmental value. Furthermore, including such sites in a monitoring programme would allow for more accurate assessments of biodiversity, upon which informed decisions could be made regarding their inclusion in a network of conservation sites or as elements that contribute to conservation in marine spatial plans. In addition, the contribution of these infrastructure sites to connectivity along the coast might already be important; however, more research is needed on specific populations to better understand the effect of the infrastructures on the connectivity of the populations. Infrastructure operators should be aware of the existence of ecologically valuable habitats within enclosed marine infrastructure areas. As a result, both the required short-term adjustments and long-term management of the area could prevent possible damage to this habitat, and could enhance marine protection and species conservation in the area. This is an opportunity to reconcile human activity and conservation needs, and to contribute to the efforts to protect wildlife in heavily impacted marine environments.

ACKNOWLEDGMENTS

We would like to thank R. Tzadok, M. Grossowicz, E. Maharam, R. Shirazi, and E. Rozen for their assistance with the scuba-diving surveys. In addition, we would like to thank the IEC, and especially K. Avramzon, G. Levy, A. Glazer, and Fuel Administration Unit members for their cooperation, assistance with the fieldwork, and with administrative processes, and to the Ministry of Infrastructures, Energy and Water Resources for the funding of this study. Finally, we would like to thank the anonymous reviewer and the Editor of the journal for their constructive comments.

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How to cite this article: Shabtay A, Portman ME, Carmel Y. Contributions of marine infrastructures to marine planning and protected area networking. *Aquatic Conserv: Mar Freshw Ecosyst*. 2018;28:830–839. https://doi.org/10.1002/aqc.2916