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Artificial Reef Deployment Reduces Diving Pressure from Natural Reefs—The Case of Introductory Dives in Eilat, Red Sea

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Abstract: Artificial reefs have been suggested as alternative dive sites to mitigate human pressure on natural reefs. Despite the conceptual appeal of artificial reefs, there is a paucity of empirical evidence regarding their effectiveness in achieving this objective. Here, we report that a small artificial reef deployed adjacent to a local coral marine protected area caused a shift in the routes taken by introductory dives and nearly eliminated their visitations to the natural fringing reef within the MPA. This behavioral shift among divers persisted for more than a decade following the AR deployment. These findings underscore the efficacy of well-designed and appropriately located artificial reefs as valuable instruments in the conservation of coral reefs.

Keywords: conservation; coral; scuba diving; management; marine protected areas; MPA

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1. Introduction

Scuba diving is often regarded as a form of tourism with a relatively low environmental impact. Further, as divers prefer to visit healthy coral reefs, scuba diving operators have an incentive to preserve the reefs and to keep their attractiveness. Nonetheless, adverse effects of diving on the benthic environment in general, and coral reefs in particular, have been recorded in a wide range of places [1–5]. These impacts predominantly manifest as unintentional actions of the divers, such as breaking and damaging coral structures, physical contact with coral tissue, standing on corals, resuspension of sediments upon corals, as well as potential damage caused by loose equipment such as cameras and the like, and more [2,6–10]. The repercussions of these activities are often seen in the form of harmed corals, and they particularly affect the more delicate branching coral species [5–8,11]. This sustained and localized coral damage, in turn, leads to a decline in the population of reef-associated organisms [12]. The negative impact of divers on reefs has prompted, in different locations, a range of measures such as compulsory environmental briefing before dives and during training, requiring having a certified dive guide in all recreational dives, restricting diver access to natural reefs, implementing carrying capacity limits on diver visitation, and, in some extreme cases, completely closing dive sites [10,13–16]. While the latter restricting approaches are effective, they are often considered the least favored methods. They reduce the diver's experience and may severely damage the support for conservation by the local community and the diving tourism industry. Also, legal considerations may limit the use of some of these restricting measures. Further, some measures may create resentment among the more established divers, which can lead to undesirable approaches. For example, in Israel, extensive enforcement of regulations led to the establishment of "the underwater silk (Meshi) road", in which divers deliberately cross the restricted area of the marine protected area but do so in a path that is hard to detect.

Conversely, diving tourism has a substantial economic impact on local communities and is widely regarded as a key driver in the preservation of coral reefs [17–20]. Hence, restricting diver access to coral reefs could potentially have adverse consequences for both local communities and the environment [21]. One strategy for mitigating the negative impacts of heavy diving pressure on coral reefs while maintaining an exciting diving experience is the establishment of adjacent artificial reefs [22]. The goal is that artificial reefs will become partial or full diving destinations, will attract divers away from natural reefs, and will thereby alleviate human pressure on the latter while still sustaining the economic benefits of the diving industry in the region. However, a couple of fundamental questions arise: Will this concept prove effective? Will divers shift their diving routes from natural reefs toward artificial ones? [23].

Several studies have demonstrated that scuba divers are willing to embrace artificial reefs as diving destinations, even in regions abundant with natural coral reefs [24–26]. In fact, many dive clubs and resorts create their own artificial reef to serve as an attraction and offer an additional diving adventure. Further, in Cape Verde, it was found that the deployment of artificial reefs adds economic value to the natural features of the diving area [27]. Despite this attractiveness of artificial reefs, only 49% of European divers surveyed considered them as an important form of diverting diving pressure away from natural reefs, and less than 10% chose to visit them in order to avoid damaging the natural ones [28]. Even in a non-coral reef environment, divers prefer historical destinations, natural highlights, or well-designed artificial sites over general cargo shipwrecks deployed only as diving sites [29]. Research has shown that divers exhibit different behaviors when interacting with natural and artificial reefs. This is manifested in their inflicting more severe damage on the artificial reef. Tynyakov et al. [18] suggested that in Eilat, northern Red Sea, artificial reefs take as much as 35% of the diving pressure, which represents the number of dives that may lead to coral damage, off local natural reefs. Oh et al. [30] demonstrated that although divers mostly value diving on natural reefs more than on artificial ones, artificial dive sites, properly located, may serve as potential substitutes and thus may alleviate pressures on natural reef areas for conservation purposes. Nevertheless, only a limited number of experimental studies have thus far investigated the impacts of deploying artificial reefs on the level of diving activity occurring in adjacent natural reefs following the deployment [23,31,32]. Polak and Shashar [31] examined the consequences of deploying a small artificial reef near a nature reserve, focusing on well-trained and certified divers. The findings revealed that divers who had previously allocated up to 40% of their dives to the reserve significantly reduced their dive durations in the reserve after the introduction of the artificial reef. However, no effect was found for divers who planned deep penetration into the nature reserve, and these dives continued to occur at a similar rate as prior to AR deployment. In this study, we examined the effects of the deployment of this small artificial reef on the distribution of introductory dives in the adjacent nature reserve. We have further examined the effects over a significant length of time.

Introductory dives, alternatively referred to as introductory scuba experiences or trial diving, are diving opportunities designed for individuals who do not have prior diving training or diving certification. Despite involving the use of full dive equipment, these experiences are conducted with the tourist diver under the close guidance and full control of a qualified diving instructor. The instructor briefs and prepares the visitor, closely monitors and guides him/her, and, in essence, leads the visitor on an underwater tour during the dive. In Israel, such introductory dives typically last between 30 and 40 min, and they are restricted in depth, not exceeding 6 m [33]. Although the guests or tourists are controlled by the instructor, and they receive briefings on how to avoid harming the underwater wildlife, these divers sometimes exhibit unsteady behaviors. These behaviors can include inadvertently disturbing the underwater environment by kicking up sand, attempting to touch marine life, and occasionally standing on the reef or seabed. Indeed, instructional dives, including introductory dives, course dives, or refresh dives, have been identified to cause substantial damage to the natural reef [3,6]. As leading one-on-one introductory dives is a regular task for diving instructors, they frequently follow a predetermined, well-practiced route that they believe will provide a comfortable and enjoyable experience for the guests. However, this repetition of routes also concentrates and intensifies the impacts of divers to specific areas of the shallow reefs. Introductory dives are a main source of revenue for dive clubs, accounting for approximately 16% of the dives in the study area [31]. In Eilat, Israel, they constitute a significant portion of the clubs' activities, ranging from 15% to 33% (in-depth interviews with managers of three of the largest dive clubs in Eilat).

2. Methods

2.1. Study Site

An artificial reef (AR) was deployed in October 2006 at the northern tip of the Gulf of Eilat, Red Sea at 29°32′85″ N, 34°57′47″ E. (Figure 1) It was immersed at 7 m depth on a flat sandy bottom approximately 100 m from shore. The AR was set in the midst of the area with the highest density of scuba diving in Israel. The AR was positioned 10 m to the north and outside a local MPA (Eilat Coral Beach Nature Reserve), which is fenced from land. However, the MPA is open from the sea, and both swimmers and divers often bypass the short fence at its north shore and veer into the MPA. The exact location was selected by Mr. Guy Ayalon, then head of Nature and Parks Authority in Eilat. The AR is set on a sandy area so as to cater to divers having buoyancy difficulties or otherwise needing contact with the bottom. It is located between several small natural coral outcrops but no less than 10 m away from them. Noted are two coral outcrops located to its north and south (named outcrops 5 and 6 due to their depth). An area rich with garden eels, *Gorgasia sillneri*, is located further north of the AR. Artificial reef deployment and coral transplantation were performed under special permits and with cooperation and assistance of the Israeli Nature and Parks Authority.

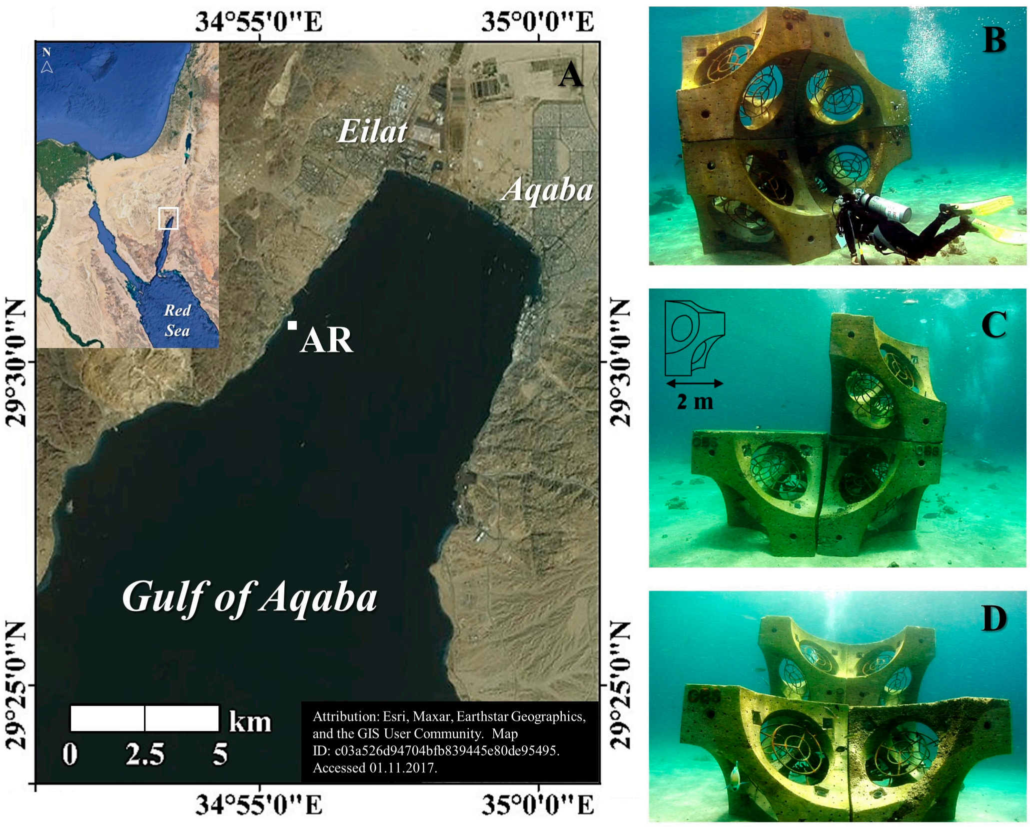

Figure 1. (**A**) Location of the artificial reef. (**B**–**D**) Artificial reef just after deployment. Photos by Ziggy Livnat. (**B**) North side of the AR; (**C**) east side of the AR; (**D**) south side of the AR. The AR is composed of 6 units (**C**), each with 2 m on its side, depth, and height.

2.2. Artificial Reef Design

A full description of the AR is provided by Polak and Shashar [31]. In short, the AR was made of six modified marine concrete units, each weighing 3.5 metric tons in the water, creating a complex structure approximately 4 × 4 × 4 m large (Figure 1). The AR's design aimed to allow high complexity, void spaces in the center of the AR, shaded areas, and high relief to allow sufficient current flow and to reduce the accumulation of sand on the AR. All these were set up in order to favor coral and fish settlement, recruitment, and growth. The design also created walls or small cliffs that allowed divers to come close to the reef without actually needing to go over it. This, in turn, along with its depth and the sandy area around it, added to the AR's appeal to instructors of diving classes and introductory dives. Holes were drilled in the artificial modules prior to deployment to serve as anchoring spots for the transplantation of corals. Starting in April 2007, five months after deployment, 230 stony coral colonies and 21 soft corals were transplanted onto the AR. The transplantation spanned over no less than four cycles and was performed in collaboration with local youth. Corals for transplantation were grown in a special underwater floating coral nursery. Natural recruitment of fishes, coral, and other marine life took over in the following years, and today, the AR is teeming with life) see video at https://youtu.be/w3PcwDPTGjc (accessed on 11 December 2023)).

2.3. Data Collection

Questioners and fact-finding interviews were conducted with 22 professional instructors/dive group leaders. All were leading introductory dives at the region of the AR, or they had done so before the AR deployment (i.e., prior to 2016). Nine worked both before and after the AR deployment, four only before, and nine worked only in the years following the AR deployment. In addition to individual experience questions (age, gender, level of certification, duration of guiding dives, dive club, etc.), interviewees were requested to describe verbally and mark on a map the paths they take during introductory dives and describe how these changed, if at all, over the years. Furthermore, in-depth interviews were conducted with the managers of three of the largest dive clubs in Eilat, all located near the area of interest. These aimed to gain additional insights and perspectives on the ways introductory dives are conducted and managed and their significance to the overall activities of the diving clubs.

Additionally, 52 introductory guided dives were tracked to examine the actual path of the dives. A snorkeling swimmer waited in the water for the guided dives to commence and then accompanied the divers while snorkeling at the surface throughout the dive until they returned to shore. The swimmer traced the dive on a pre-prepared map, where the route and duration of the time spent at each location were noted, as well as comments on divers' behavior, etc.

3. Results

Of the 22 dive guides interviewed, 3 were female and 19 male. Six were dive masters, and sixteen were diving instructors. Interestingly, the majority of these individuals viewed their employment as a temporary job, with only eight seeing their position as diving instructors as a long-term career path (two of these became managers of a dive club, one a professional UW filmmaker, and one the head of the Israeli Diving Federation).

Interviews, as well as observations, confirmed that the introductory dives follow specific paths that were repeated over time. Yet specific dive guides exhibit their own preferences regarding the route they chose, the direction they went along the route, and the amount of time spent at each of the locations of interest in it.

The frequency of dives fluctuated throughout the year and reached exceptionally high levels during Israeli holidays. For instance, during the Sukkot Jewish holidays in 2019 and 2022 (which occurred from 11 October to 22 October in 2019 and from 8 October to 17 October in 2022), the studied artificial reef saw more than 500 introductory dives per day. However, these numbers were notably reduced during the COVID-19 pandemic season, and during the 2023 Sukkot holiday (29 September–6 October 2023), they dropped to ca. 200 introductory dives per day (Figure 2). Indeed, introductory dive guides regarded their job at these times as very demanding, referring to themselves as "tea-bags".

Figure 2. Introductory dives gathered around the 4 × 4 × 4 m large artificial reef. Left—8 instructor and guest pairs. Photographed by AO on 15 October 2019. Right—4 pairs. Photographed by JT on 5 October 2023.

Overall, the paths of the introductory dives could be tracked to well-defined routes (Figure 3). Most dive guides made an effort to visit both outcrops 5 and 6 during the dive. Naturally, these routes were not set in stone and could change from dive to dive, as dive guides may have wished to shorten or increase the duration and length of the dives. Variations included going back on track from the midst of the dive, making a shortcut between points, spending time over the sandy area to let the guided diver relax and practice basic diving skills, circling any of the outcrops, exiting the water from a different place than the one from which they entered (this one was rare and occurred only if there was a problem during the dive), and the like. However, they represent the routes taken by the majority of the instructors. The direction of dives varied with guides and with the number of customers, where, in some cases, guides coordinated their path and duration to provide spacing between customers.

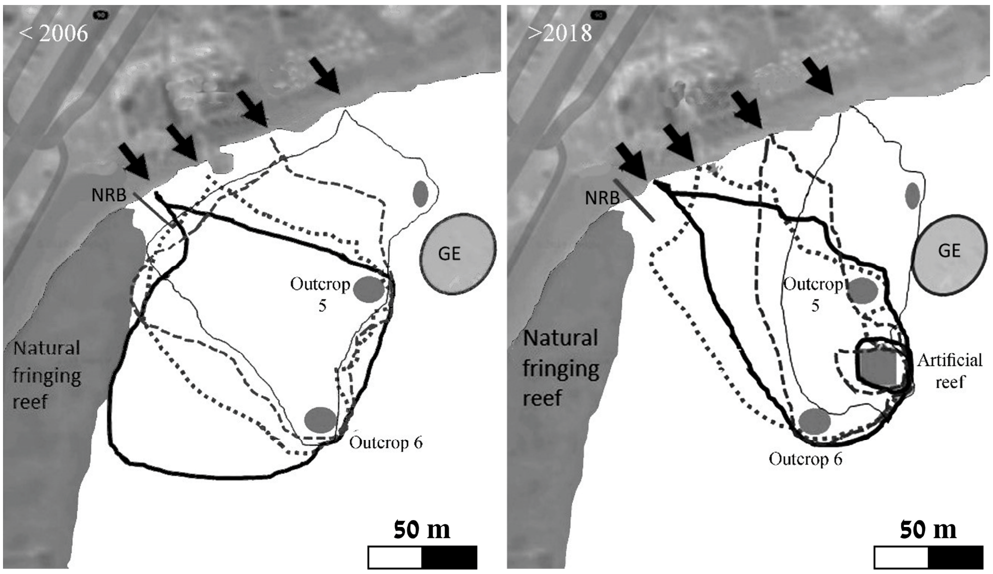

Figure 3. (**Left**): introductory dive routes prior to the deployment of an AR (prior to 2006). (**Right**): routes following the deployment of the AR (after 2018). NRB—the northern border and fence of the

local natural MPA, which is fenced from land. Arrows indicate places of entry to the water used by divers. Two coral outcrops are located in the area (named outcrops 5 and 6 due to their depth), and an area rich with garden eels, *Gorgasia sillneri*, is located further north of the AR (GE). Note the drop in visitation to the natural fringing reef, which is part of the fenced nature reserve, that occurred following AR deployment.

Questioners and tracking of dives revealed a change in the routes of the introductory dives following the deployment of the AR (Figure 3). Prior to the AR deployment, guides made an effort to include visitation to the fringing reef within the nature reserve. However, following the deployment of the AR, the dive routes changed to include visitation to it. In most cases, this included a full circle of the AR and occasionally more than one such circle. On the other hand, visitation to the fringing reef of the nature reserve was mostly eliminated. It should be noted that this diving pattern, of preferring the AR over the natural reef, continued for more than 15 years after the AR deployment (from 2006 up to 2023). This attractivity remined even when it was no longer a novel feature to the dive guides.

In interviews, dive guides explained that their preference for the AR was due to (A) its location and ease of reach, (B) its size, (C) the ease of showing things to the visitors, and (D) the opportunity of finding rare species which they find of interest.

4. Discussion

The concept of employing ARs to alleviate the strain on coral reefs due to visitor numbers has been a topic of ongoing discussion. Nonetheless, there has been a relatively restricted amount of evidence supporting the effectiveness of this strategy thus far. In the Gulf of Aqaba, ARs have emerged as a favored attraction. In Eilat, a noteworthy 35% of diving activities are conducted on ARs [18].

Here, we provide positive evidence that, indeed, ARs can serve as a conservation/pressure reduction tool. In our case, the routes of the introductory dives were altered by the deployment of the AR to the point that they no longer include the fringing reefs of the local nature reserve.

The studied artificial reef is small in its size, being $4 \times 4 \times 4$ m in dimensions. It is, therefore, too small to become a focal point of diving by itself. Further, introductory divers only rarely choose the specific location to be visited during the dive but are led by their guides. Therefore, we can safely state that the AR did not increase the overall number of dives in the area. It is recommended that if larger and more attractive ARs [24] are to be deployed, and if the intention is to alleviate pressure off the natural reefs, they should be kept at a distance from surrounding natural reefs such that one will not visit both natural and artificial reefs in a single dive.

Our study and the implications we suggest carry several caveats. (A) We did not examine nor measure any damages in the natural reserve before or following the deployment of the AR. Corals are protected in Israel, and therefore, any damage to them may lead to legal action and may cause a dive guide to lose his/her position. Therefore, we did not attempt to report such damages, nor did we interview guides regarding direct damage caused under their leadership. However, Belhassen et al. [26] report that introductory divers often make contact with the reef (and hence may damage it), doing so significantly more than certified divers. (B) Although we examined and even charted the routes introductory dives took over time, we do not have information regarding the number of dives that took place at the nature reserve prior to or following the AR deployment. Zakai and Chadwick-Furman [6] reported ca. 3000 introductory dives per 3 months within the northern nature reserve and ca. 2000 introductory dives per 3 months in the Aqua Sport area—which is what we term as the area of outcrop 5 and GE (translates to no less than 12,000 and 8000 introductory dives per year, respectively; note that dive numbers were collected from 1 January to 31 March 1996, which is not a high diving season in Eilat). The data for said study, collected in 1996 and 10 years before the AR was deployed, indicate that, indeed, a large number of introductory dives spent time within the nature reserve. During interviews, dive clubs' managers and dive guides claimed that, with the exception of outcrop 6, they do not venture into the nature reserve. However, we did not independently verify these claims.

Introductory dives and instructor-led groups are easy to follow. Yet, the potential environmental impact goes well beyond these guided divers. Other diving types, such as novice divers who have just received their certification, photographers, and adventure-seeking divers, may cause as much or even more damage to the reef [5]. This underscores the importance of considering a diverse spectrum of divers in artificial reef (AR) design. Recognizing the varied needs and skill levels within the diving community is crucial for creating ARs that not only cater to different preferences but also prioritize environmental conservation. To enhance the sustainability of these structures, careful consideration must be given to accommodating the requirements of all diver categories, ensuring that ARs effectively balance accessibility with responsible environmental stewardship.

The strategic deployment of artificial reefs necessitates the consideration of the needs of local stakeholders and the community. In our specific case, the chosen location was characterized by intense diving activity coming from several dive clubs on one side, addressing the recreational demands of the local diving community. Simultaneously, the decision to place the artificial reef in proximity to a nature reserve was made by the Israeli Nature Reserve Authority due to a well-documented issue of uncontrolled diving activity within it. The use of an artificial reef was a deliberate effort to address and mitigate conservation concerns without negatively affecting the diving community and the local stakeholders.

Artificial reefs are deployed for a wide range of purposes, including fisheries improvement, ecological restoration of marine habitats, coastal protection, and scientific research [25,26]. Further, many of the most attractive dive sites are ships and warplanes that were sunk during wars, accidents, and the like. In recent years, there has been a growing trend of developing artificial reefs and even whole underwater parks for the diving industry [34]. These underwater tourist attractions have raised concerns regarding potential declines in their allure over time, analogous to conventional attractions. However, our study challenges this assumption by providing evidence that a carefully designed and strategically located artificial reef (AR) continues to captivate divers even 15 years post-deployment. The long-term examination underscores that provided the AR maintains structural and biological stability, it continues to function as both a sustainable diving attraction and a conservation tool. This resilience over an extended period highlights the enduring potential of well-maintained artificial reefs to simultaneously serve recreational and ecological purposes over time.

5. Conclusions

In conclusion, long-term studies emerge once again as crucial components in shaping sustainable marine conservation strategies. The establishment of well-designed artificial reefs (ARs) serves as an effective means to divert human pressure, particularly guided divers, away from natural coral reefs, thereby aiding in the preservation of these vulnerable ecosystems [25,28–39]. The emphasis on meticulous design becomes imperative, ensuring that ARs remain not only visually appealing but also biologically vibrant over extended periods. Strategic placement of ARs as alternative dive sites further reinforces their utility in alleviating stress on natural reefs. Further, such ARs can boost the local economy and produce commitment and resources for marine conservation [40]. Recognizing the diving industry as an ally rather than a disturbance is imperative, considering its role as an economic driving force for reef preservation. Embracing these principles fosters a sustainable synergy between artificial reef initiatives, reef managers, and the diving industry, which can successfully harmonize ecological preservation with economic interests, contributing to the long-term health and sustainability of marine ecosystems.

6. Future Directions and Open Questions

Our study demonstrated the applicability of AR deployment as a tool for reef conservation and as a means of diverting tourist pressure away from a natural reef while maintaining their interest. Indeed, Firth et al. [28] advocate a general call to shift much of the diving industry to manmade UW attractions. However, when planning the use of this tool in other locations or on different scales, one should bear in mind some of the questions that remain open. The current study focused on a well-defined and easy-to-study class of divers—the introductory dives. The effects of AR deployment on the choices made by other classes of divers remain to be examined. Kirkbride-Smith et al. [25] demonstrated a clear difference in AR preferences between novice and experienced divers, with the latter preferring natural habitats. Since it is assumed that experienced divers are less prone to accidents, one option is that ARs could be developed as dedicated training grounds. Other questions that should be addressed in AR design and use include the following: What will happen if a large AR is constructed? Or a whole park? Will it reduce pressure on the natural reefs, or will it increase the number of dives in the region and cause a diver's spillover effect for the natural reefs? How far from an MPA should an AR be deployed? Should it enable visitation in the same dive to the MPA, or should it force the diver to make a choice between destinations? Considering the positive effect an AR has on reducing human pressure, one should ask, what should be a proper AR deployment scheme around a marine protected area? Should they surround the MPA and be part of its buffer zone? Should they be positioned near entry points or focal points of visitors and have them as part of the visitation experience? How should small ARs be spread? Should they be placed right close to the MPA, such as in our case, or should they be positioned further away? All these come under the wide umbrella of landscape ecological design [29] and require further exploration, examination, and practical testing.

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Informed Consent Statement: The regulations in Israel do not require individual consent forms for collection of opinions and anonymous inclusion in published studies. Further, individual signed forms might have violated the point of anonymity in the data collection. Each person interviewed was made aware that the data they provided would be kept anonymous, used for research and potentially published, and by agreeing to continue the interview /answering a questioner agreed to the inclusion of their information in this study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest: The authors declare no conflicts of interest.

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