RECREATIONAL DIVING OASIS WITH ARTIFICIAL HABITATS

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Abstract
A new type of artificial habitat for recreational diving that fully retains or even exceeds the functionality of natural reefs has been developed by the Hellenic Centre for Marine Research (HCMR). The deployment of these innovative artificial structures made of concrete provides enhanced availability and diversity of microhabitats and structural refugia for reef-dwelling benthic and benthopelagic organisms while at the same time simulating the form and the aesthetics of natural reefs. By using this new technology, a network of artificial underwater "oases" suitable for recreational diving can be installed on designated small parts of the seabed, at relatively shallow depths, in the proximity of the main urban and touristic centres and in coastal areas that do not show any specific ecological, archaeological or fishing interest.

Keywords: Artificial reefs, Marine parks, Cretan Sea

The growth of marine ecotourism has resulted in ever-increasing environmental pressure and a concomitant decrease in biodiversity mainly revealed in destinations with a particular diving interest [1]. These effects are mostly due to the presence of the divers themselves. The documentation made after the taking of direct observations has shown that in almost every recreational diving activity, many incidents of unintentional or deliberate contact with marine organisms have occurred, resulting in the injury or killing of many of them [2]. The degradation of many underwater diving destinations because of massive tourism necessitates the adoption of management measures aiming at decongesting visits, such as the reduction of divers and the diverting of a proportion of visitors away from sensitive natural areas of high ecological and aesthetic value [3, 4]. One solution is the creation of artificial underwater ecotourism attractions using specially constructed artificial habitats (reefs) in an attempt to simulate the functional and morphological characteristics of the sublittoral rocky substrata, known as natural reefs. Given the documented lack of artificial reefs capable of satisfying modern recreational diving requirements [3], the main objective of the research carried out by HCMR was to overcome the drawbacks and deficiencies of the designs that exist up to now, with the development, construction and deployment of a new type of artificial reef dedicated to recreational diving. The innovative type of HCMR artificial habitat mimics the form and aesthetics of natural reefs while fully retaining or even exceeding their functionality. These artificial habitats provide an enhanced availability and heterogeneity of many microhabitats and structural refugia suitable for the attraction and final settlement of various benthic and benthopelagic organisms. Twelve experimental reef units were deployed in May 2015 at 20 m depth on a silty-sand bottom covered by scarce patches of *Caulerpa prolifera* at the Underwater Biotechnological Park of Crete (UBPCrete), a marine protected area located on the north coast of Crete. Made of concrete, they had the general form of an upright elongate monolith ranging in size between 2 m width at the base and 2.0 to 2.3 m height. They are characterized by an extensive structural complexity as they provide extensive vertically or almost vertically delimited surface at the exterior; in this way they comprise a plurality of irregular corrugations in the form of successive recesses and overhangs emulating the micro-texture of underwater rock. Irregularly-sized blind holes of varying diameter and depth were created at selected locations of the exterior surface. Furthermore, inwardly-oriented through or blind crevices of varying sizes and thickness have been formed that perpendicularly, obliquely or transversely pass through large parts of the main structure. Special wider chambers that communicate with the external environment through these crevices are constructed in the interior of the units. All these configurations have provided microhabitats and refugia to a wide size range of reef-dwelling fish (e.g. goldblotch and dusky groupers, white and common two-banded seabreams, etc.). These organisms found permanent shelter within the structures of the experimental HCMR artificial habitats only a few weeks after their deployment in the UBPCrete. According to preliminary results from a visual fish census survey the external surface of all experimental reef units were occupied by dense populations of damselfishes (*Chromis chromis*) even from the first week of reef deployment. Within three weeks the external holes of the reefs were inhabited by eleven individuals of goldblotch groupers (*Epinephelus costae*) of various sizes while in less than two months six individuals of dusky groupers (*Epinephelus marginatus*) were encountered. Furthermore, many individuals of Sparidae (*Diplodus sargus sargus* and *Diplodus vulgaris*) were also recorded in the crevices and the inner canals and chambers of the reef units. It should be noted that throughout the period of visual observations no macroalgae or other fouling organisms were visible to the naked eye on the external surface of the experimental reefs, most probably due to the extreme summer oligotrophic conditions which prevailed locally. Furthermore, the north coasts of Crete are characterized by a scarcity of sublittoral natural reefs suitable for crevice-dependent fish which are rare in the study area. This innovative technology mimics the natural rocky reef habitat to such a degree that it can substitute or even avert to some extent the modern trend of establishing recreational diving parks in remote and environmentally sensitive natural reef areas of outstanding ecological and conservation importance. By using this new technology, a large number of artificial underwater oases suitable for recreational diving could be installed on small areas of the seabed (e.g. 20,000-30,000 m²), at relatively shallow depths (from 15 to 30 metres), near main urban and touristic centres and in coastal areas of no specific ecological, archaeological or fishing interest. The development of a network of such recreational diving oases may offer many advantages. Their installation even in environmentally degraded coastal areas is expected to contribute to the protection and upgrading of the local environment. Recent research has shown a significant and in many cases irreversible environmental degradation in numerous natural diving destinations characterized by mass ecotourism. Also, their installation near large tourist and urban centres may offer easy access and efficient control of diving activities, while it may provide protection and upgrading of the neighbouring marine ecosystem supporting biodiversity and increasing local fish stocks. As management tools, they could ensure acceptance and coexistence with other end-users of the coastal zone. Finally they may offer opportunities for marine education and training activities, exercise and entertainment.

References
1 - Hasler H., Ott J.A., 2008. Diving down the reefs? Intensive diving tourism threatens the reefs of the northern Red Sea. Marine Pollution Bulletin, 56 (10), 1788–1794.
2 - Di Franco A., Millazo M., Pasquale B., Tomasello A., Chemello R., 2009. SCUBA diver behaviour and its effects on the biota of a Mediterranean marine protected area. Environmental Conservation, 36, 32-40.
3 - Stolk P., Markwell K., Jenkins J., 2007. Artificial reefs as recreational scuba diving resources: A critical review of research. Journal of Sustainable Tourism, 15 (4): 331-350.
4 - Van Treeck P., Schuhmacher H., 1998. Mass diving tourism – A new dimension calls for new management approaches. Marine Pollution Bulletin 37 (8–12), 499–504.