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Recreational Diving and Its Effects on the Macroalgal Communities of the Unintentional Artificial Reef *Zenobia* Shipwreck (Cyprus)

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Abstract

The ecological role of shipwrecks as artificial reefs is well established and often is prime and exclusive destinations for diving tourism. But they are also extremely delicate and sensitive environments. For this reason, the impact of recreational diving on shipwrecks should be taken in consideration since diver's experience can strongly affect their associated benthic communities. The aim of this study was to verify the impact of anthropogenic activities (scuba divers) on the macroalgal coverage, here considered as indicator of physical disturbance, on the modern shipwreck *Zenobia*, in Cyprus (east Mediterranean Sea). Divers behaviour was investigated in the wreck and the macroalgal coverage was determined (photo-quadrat method) in three areas differently exposed to physical contact of divers. Our results suggest that diving is having a significant negative effect on the macroalgae coverage of the shipwreck, especially in areas subject to high levels of use (e.g., meeting stations) when compared to control sites in the same wreck. Divers' behaviour and popular dive routes at the wreck are factors associated to the observed decrease in macroalgae benthic cover. It is important that relevant stakeholders utilizing the *Zenobia* wreck agree on basic management planning in order to protect and enhance the wreck's biodiversity. In addition, this study provides for the first time evidence of ecological deterioration of one of the most emblematic shipwreck of the Mediterranean Sea.

Keywords: Shipwrecks; Artificial reefs; Levantine Sea; Mediterranean sea; Benthic cover; Macroalgae; Recreational diving; Scuba diving impacts

Introduction

Artificial reefs are defined as submerged structures accidentally or deliberately sunk in aquatic environments [1], mimicking some features typical of natural reefs [2] and built with concrete blocks [3,4], tires, oil platforms [5], submarines, planes and vessels (e.g., shipwrecks) [6]. Common uses of artificial reefs are well documented [7-10] and are summarized in Table 1.

Shipwrecks represent a particular type of artificial reefs, not only for their ecological role but also for their value for the scuba diving industry. A particularly important scenario is represented by a shipwrecks located on a soft bottom habitat since its ecological role is further enhanced due to the diversification of the environment thanks to the introduction of hard and heterogeneous substrate in the soft-bottom habitat [11,12] representing an 'oasis' for biodiversity and abundance of local communities [13]. Furthermore, numerous shipwrecks represent definitely unique, spectacular and breath-taking diving experiences [14,15] and their recreational value has massively increased in the last 30 years [16-18] in coincidence with the development of diving activities and related safety precautions [14,19-21].

Due to their popularity for recreational activities and the consequent high frequentation, shipwrecks are ecologically sensitive sites [14] and the potentially negative impact of these activities on shipwrecks and the associated biota are well documented [22,23], especially for epibenthic or fouling organisms, which are the most exposed and consequently affected by divers [24]. For the purpose of this study, we consider "disturbance" as an unbalanced event that affect natural communities destabilizing their equilibrium and providing additional source of spatial and temporal heterogeneity compared to the undisturbed condition [25,26].

Divers' impact can be summarized into two main categories: Direct and indirect. Mechanical damage due to the direct contact of part of the divers' body (e.g., hands, knees) or gear (tanks, fins, regulators) with the bottom is very common [27-34]. This type of damage is generally caused by inexperience and/or poor buoyancy control [14,35] and the advent of underwater photography seems to contribute with an additional source of damage when divers try to remain still for taking pictures laying down to the sea bottom [36] (pers. obs.) or grabbing and anchoring themselves to irregularities that are usually biogenic substrates.

The indirect effect of diving, otherwise, is mainly due to air bubbles but consequences have usually been related to the shipwreck's structure [22,37-41] and there are only a few studies about the potential consequences of air bubbles on benthic assemblages [42]. Depending on the substrate and type of epibenthic organisms, the disturbance of a single diver can virtually be negligible but the impact on epibenthic assemblages is definitely ecologically more significant when a high number of divers are concentrated in a small area [24,43-45]. This is usually known as 'cumulative effect' [38].

Note that the distinction in "direct" and "indirect" effect is strictly dependent on the level at which the problem is analysed. In fact, considering the problem from a wider and general point of view (e.g., recreational diving worldwide) and according with general models of biodiversity conservation [26,46], the direct and indirect effects previously considered can now be joined into a new "direct" threat

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	Location	Material	Source
Research: recruitment studies, habitat variability, species interactions	Rio de Janeiro, Brazil	Concrete modules	[97]
	Rio de Janeiro, Brazil	Concrete modules	[98]
	Belgium	Shipwrecks	[6]
	Pernambuco, Brazil	Rubber and concrete modules	[99]
	Israel	Ceramic and brick fired tiles	[100]
	Sydney, Australia	Sandstone and concrete blocks	[101]
	Sydney, Australia	Sandstone blocks	[102]
	Sydney, Australia	Sandstone blocks	[103]
	Adriatic Sea, Italy	Concrete blocks	[3]
	British Columbia, Canada	Floating structures	[104]
	Sydney, Australia	Sandstone blocks	[105]
	Florida	Shipwrecks	[106]
Recruitment facilitation	Gulf of Mexico	Offshore platform	[5]
	New York Bight	Concrete	[107]
	St. Thomas, U.S. Virgin Islands	Concrete blocks	[108]
	Portugal	Concrete blocks	[109]
	Rio de Janeiro, Brazil	Rubber and concrete modules	[110]
	Rio de Janeiro, Brazil	Concrete, metal and rubber block	[111]
	Rio de Janeiro, Brazil	Concrete blocks	[112]
	Rio de Janeiro, Brazil	Concrete blocks	[113]
	South Australia	Shipwreck	[114]
Fishing enhancement	Mexico	Tires	[115]
	Adriatic Sea, Italy	Concrete blocks	[3]
	Sicily, Italy	Concrete blocks	[116]
	Gulf St. Vincent, South Australia	Tyres	[117]
	South Australia	Tyres	[118]
	Louisiana	Oil and gas platforms	[119]
Provision of sheltering, additional substrates, nursery areas, resources	Delaware Bay, New Jersey	Concrete modules	[120,121]
	Pernambuco State, Brazil	Shipwreck	[1]
	Maldives	Concrete	[4]
Tourism and recreational opportunity	South Carolina		[122]
	North-eastern Australia	Shipwreck	[123]
	Western Australia	Shipwreck	[124]
Colonization	Italy	Pulverized fuel ash (PFA)	[125]
	Tioman Island, Malaysia	Concrete blocks	[126]
	United Kingdom	Pulverized fuel ash (PFA)	[127]
Mariculture	Sicily-Malta	Floating structures	[128]

Table 1: Summary of the most common uses of artificial reefs worldwide.

concept (the general negative effects of divers) while the "indirect" threat (defined as "underlying factors, drivers or root cases" [26,46]) can be represented by management [46,47]. Based on these new definitions, direct and indirect threats are no longer two different sources of damage at small scale but a consecutive series of related steps in conservation planning (indirect effect-direct effect-impact) [48].

Overall, anthropogenic disturbance can negatively affect distribution, abundance and taxonomic richness of one or more benthic species, remarking differences between areas exposed and not exposed to a particular disturbance source [49]. In addition, there is evidence of the suitability of benthic communities or species as indicators of human impacts [34,50,51] and, in particular, composition and abundance of benthic macroalgae can be considered as indicators of physical disturbance [24,52].

The purpose of this study is: (i) Describing the average behaviour of divers on the wreck, (ii) Verifying the presence of a potential impact due to recreational diving on the macroalgae coverage of the *Zenobia* shipwreck, and (iii) Quantifying the effect of the impact using the macroalgal coverage as indicator of stress. The photo-quadrat method was applied on three different sites of the shipwreck subject to different physical anthropogenic disturbance and their macroalgal coverage was compared.

Materials and Methods

Study site

The *Zenobia* shipwreck is a large steel ferry (172 m max length) located 800 m off Larnaca harbour (34°53'50.441''N, 33°39'28.26''E), in the oligotrophic south-eastern coast of Cyprus, on a muddy-sandy bottom environment; it sunk in 1980 and lies on its port side at -42 m (Figure 1). Recreational diving on the *Zenobia* occurs without interruptions throughout the year and reaches its peak between June and October, with about two hundred dives per day, mostly repetitive (Larnaca Sea-Cruises, pers. comm.). By some estimates, the yearly visitation to *Zenobia* is 35-45,000 divers per year [53]. *Zenobia* hosts well-developed fouling assemblages with a high benthic coverage of sponges, scleractinian corals, bryozoans that contribute to the high biodiversity associated with the wreck [53]. The survey was carried out between mid-August and mid-October 2011, along the starboard side of the shipwreck (Figure 1), which is the most exposed and almost parallel to the sea surface limiting any environmental differences in factors (such as exposure to sunlight, currents and temperature) between -17/-20 m.

Divers' behaviour

Observations on the divers' behaviour were primarily carried out on the boat, interviewing dive leaders (operators) about planned routes, depths and dive time, and on divers-customers, about their level of experience and the most attractive areas of the shipwreck. Secondarily, groups of divers were followed along the planned and most common routes, recording the areas visited and the related divers' activities. Excluded from this study were the routes normally used to penetrate the shipwreck; however, the entry and exit points were recorded.

Preliminary tests for macroalgal cover

Prior to the sampling, the minimum area, defined as the minimum area able to contain a representative number of species of the population [54], was determined creating a species/area curve [55,56]. We started counting the number of species using an initial 25 cm × 25 cm plot, then doubling the sampling area up to 1 m × 1 m. Results from this method drove us to choose an area of 50 cm × 50 cm as sampling unit, being a good compromise between information obtained and sampling effort.

Sampling areas for macroalgal cover

Preliminary observations based on the route typically undertaken by divers and their behaviour, lead us to choose three areas of interest: A control area, located along the stern (R), and two impacted areas (A and B), respectively at the top middle part and the upper part of the bow (Figure 1).

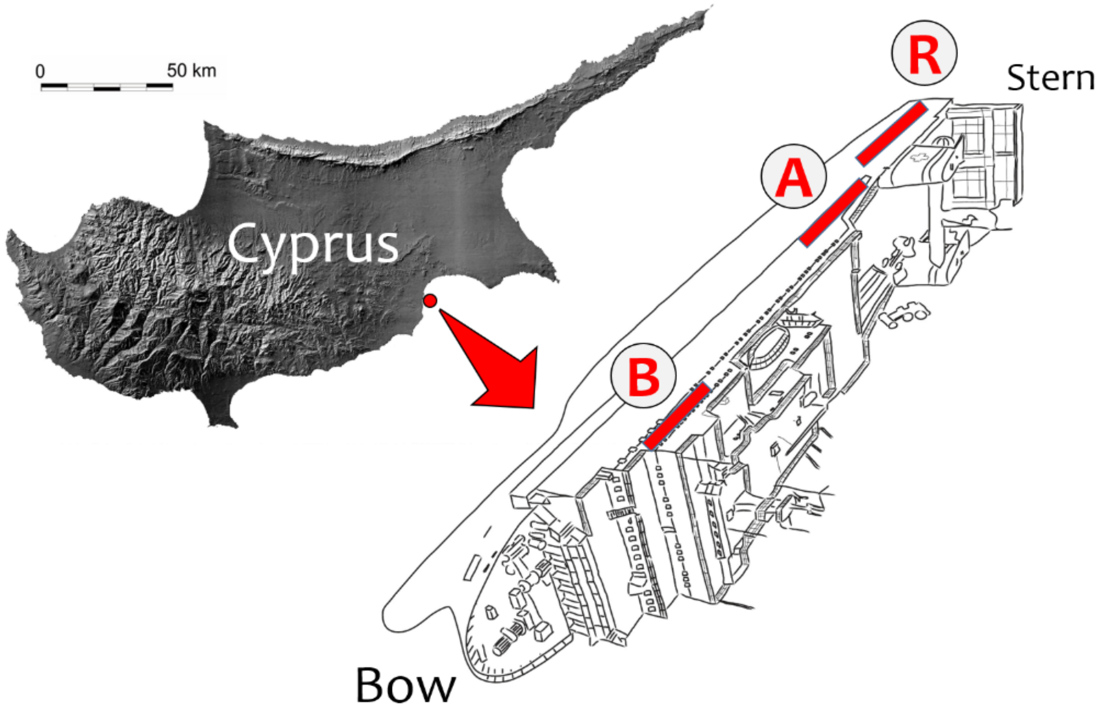

Figure 1: Position of *Zenobia* shipwreck in Cyprus and layout of transects to determine macroalgal benthic cover (R: control area; A and B: impacted areas). Transects are not drawn to scale.

Sampling procedure and data analysis

A digital camera Canon PowerShot G12 with underwater housing was mounted on a 20 mm PVC pipe framework (40 cm height) with a 25 cm × 25 cm quadrat mounted at the bottom and a plexiglass plate on the top ensured that pictures were taken perpendicular and at constant distance from the bottom. The choice of using a 25 cm × 25 cm frame, instead than 50 cm × 50 cm, was due to the manoeuvrability of a small framework compared to a larger one and the shorter distance between the lens and the substrate allowing higher resolution pictures. Then for each 50 cm × 50 cm plot, which represents our sampling area, we sub-sampled four 25 cm × 25 cm sub-plots. In each area a 15 m transect was haphazardly placed and pictures were taken continuously along the transect and replicated three times using the photo-quadrat method [24,50,57-59]. A total of 1080 photos were produced for the analysis. Using image post-processing software (e.g., Adobe Photoshop), pictures were cropped to the internal frame border, colours were adjusted, brightness and contrast were increased as well as colour saturation. Coral Point Count with Excel extensions [60] was used to analyse the macroalgal cover by replacing build-in codes according to our needs. The macroalgal coverage was estimated using 100 points randomly overlaid over each picture, according with literature [50], for a total of 400 random points for each sampling unit. At each point the presence/absence of macroalgae was assigned, and points positioned above any other substrate were discarded. The final macroalgal coverage for each sampling unit was the average of its four sub-plots.

Data were square-root transformed and ANOVA test was performed to compare the macroalgal coverage among the three areas, followed by a Tukey's pairwise post-hoc test, using the statistical package PAST v3.12 [61]. Since it was not possible to identify small-sized algal species due to image resolution, presence of suspended material (e.g. mucilage) and organic matter deposited on the macroalgae, we focused the study on three species (*Sargassum* sp., *Peyssonnelia* sp., and *Padina pavonica*) for which we calculate the specific coverage. These species were chosen because large enough to be easily identified in the pictures compared with other species and widely distributed.

Results

Divers' behaviour

Several types of diver behaviour were observed and linked to the different level of interest for the different areas of the shipwreck and in conjunction with the dynamic of the dive. The top middle part of the shipwreck represented the starting point of the majority of dives. Mooring ropes for diving boats are directly attached to the shipwreck's handrails here, making it a good spot for starting the dive following the ropes for a correct and oriented drop off. At the bottom, divers usually stationed in the area awaiting the arrival of the rest of the group and/or for general pre-dive checks. In both cases, divers usually wait lying down or kneeling on the bottom rather than maintaining a correct buoyancy control 1-2 m apart the shipwreck surface. In addition, in this area fish-feeding by divers is a common activity; divers gather from different groups into a larger group (10-15 divers simultaneously). The process is repeated several times during a period of about three hours until the first charter vessels depart the site of the wreck. In this area of the wreck the erosion of the macroalgal coverage is evident.

The upper part of the bow represented another critical area as it coincides, for the majority of divers, with the halfway through the first dive. Depending on the divers' experience level, a typical dive at the *Zenobia* comprise two immersions, a deeper one and a shallower one. Divers diving deeper during the first immersion usually performed a deep stop at -17/-19 m in this area, performing customary communication and checks within the group and before heading back to the decompression station following the starboard side of the shipwreck. The behaviour of divers along the stern side of the shipwreck differed since it is less interesting and attractive than other parts of the shipwreck. The stern side has less structural complexity and it is usually visited at the end of the second dive, when divers have to perform decompression stops or are low on air, limiting their contact with the bottom and starting the ascent to the surface.

The bow, upper decks, life boats, stackers, car deck, ramps and propellers are all areas highly visited and show signs of deterioration. Graffiti is unfortunately common as well as collection of organisms and objects from the wrecks' structure. The left side of the deck, coinciding with the deeper part of the wreck, represents the salient and most "fascinating" part of the dives. Here at -40 m depth, divers are advised to stay at a safe distance from wires, pipes and other sharp or pointed-edge structures as well as the trucks stacked at the bottom for obvious security reasons.

Macroalgal coverage

Results from the survey revealed a highly significant difference among the macroalgal coverage in the three sampled areas (ANOVA, $p<0.001$). The R transect (control area) reported the highest percentage coverage (86.1 ± 11.7) while the A and B transects (impacted areas) reported respectively a coverage of 28.4 ± 29.1 and 27.2 ± 10.1, respectively (Figure 2). Percentage of cover in transects A and B was similar (Tukey's pairwise comparison, $p<0.001$).

Specific coverage

The most common species was *Sargassum* sp. with an average coverage of 52% in the control transects, compared with *P. pavonica* (4%) and *Peyssonnelia* sp. (3.7%). In the impacted areas their specific coverage falls to less than 5% on average for all three species. While *Sargassum* sp. is absent in transect A, it showed a coverage of 3% in transect B; the species *P. pavonica* reported lower values (0.08% and 0.11% for transects A and B, respectively) as well as *Peyssonnelia* sp. (1% and 1.25% for transects A and B, respectively).

Discussion and Conclusion

The shipwreck *Zenobia* attracts every year several thousands of divers from the entire world and probably brings about €14 million a year [62] in revenue to Cyprus, thanks to the easy access and its suitability for divers with different levels of experience. For this reason, it represents a particularly vulnerable site and its associated communities of organisms are susceptible of being affected by recreational diving.

Although scuba diving is considered to be an environmental friendly form of ecotourism, several studies demonstrated the negative

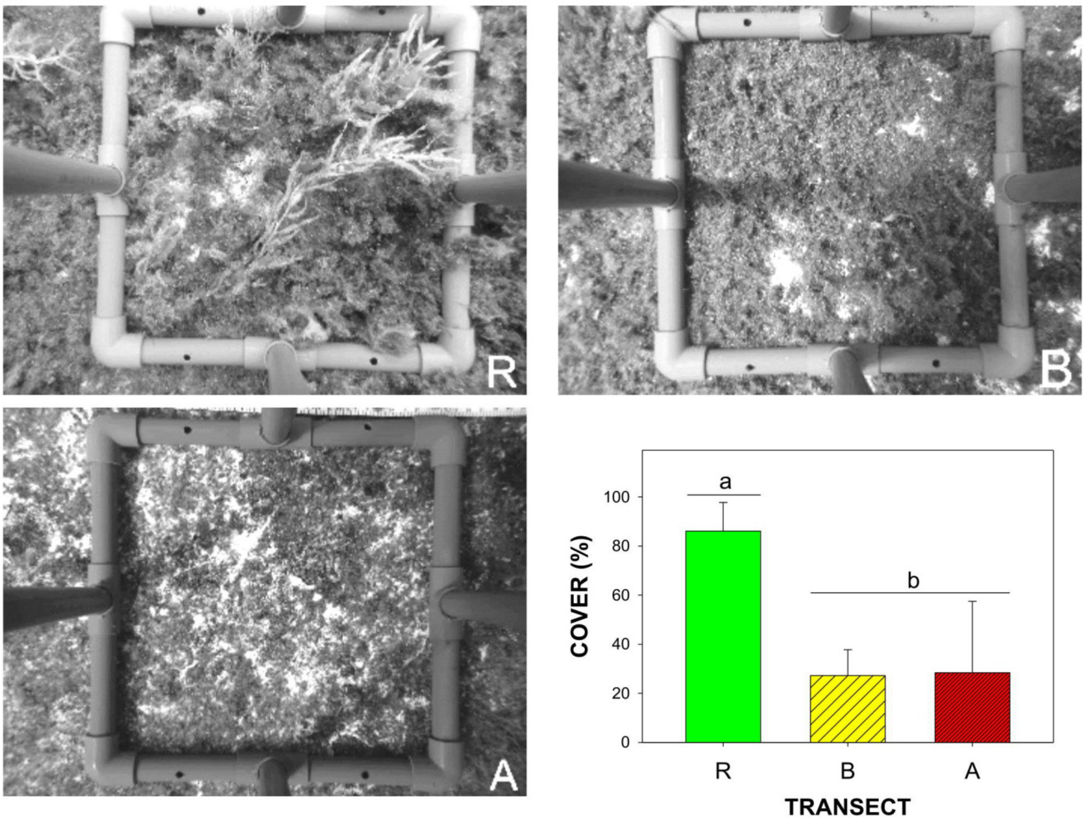

Figure 2: Comparison of macroalgal coverage representative quadrats from the control (R) and impacted areas (A, B) and corresponding bar chart (mean + SE). Letters in the bar chart indicate significant differences (Tukey's pair-wise comparison). Figure 1 shows the location of transects on the shipwreck.

impact of divers on marine ecosystems [63] damaging organisms and/or habitats regardless of whether they are accidental or deliberate actions, direct or indirect [31,36,64-69]. The damage level has often been linked to the intensity of use [44,70,71] and the level of divers' experience [72-74].

The majority of damages are usually caused by mechanical breakage [31,33,74,75] and sediments re-suspension [33,70,76]. The most prevalent type of contacts are fin kicks [65,68,75] and it has been noted that divers wearing gloves made contact with the substrate more often than divers with naked hands [65,73,77].

There is evidence that even snorkelers are known to cause effects on the marine environment [33,44,45,70] but the effects are easier to be controlled, for example using informative trails [51]. Supporting this conclusion [51], remarked that only few snorkelers practice freediving while divers can easily disturb the environment since they can stay closer to the bottom and much longer [28,31,33,35,44,67,68,78].

In the Mediterranean Sea, the negative effect of scuba diving on sub tidal communities has been studied on coralligenous communities [43], where highly frequented sites showed lower density and smaller size of bryozoans colonies [34], in marine protected areas, where several key-species are potentially threatened by recreational activities [79-81], and on submerged marine caves [80,82], where physical contacts and sediment resuspension are the main reason of sessile organisms' decline [79,82].

Due to the unique experience that shipwrecks are able to offer [14,15], they can be victims of their fame and suffer uncontrolled diving pressure. According to Kirkbride-Smith et al. [83], among the different type of artificial reefs, shipwrecks and sunken vessels are preferred compared to other artificial shapes, such as tyres, concrete modules, break walls, piers, and platforms. Nevertheless, they remark the strong difference in the preference of diving sites between new and experienced divers: while the first ones prefer to dive on artificial reefs than natural substrates, experienced divers prefer to dive on natural reefs [83,84]. According to Kirkbride-Stolk et al. [85] and Jakšić et al. [86], the issue related to negative effect of recreational activities does not concern the tourism itself but tourists' responsibility and awareness which are at the basis of long-term effects and consequences.

Our results suggest that diving is having a significant impact on the macroalgae coverage of the shipwreck, especially in areas subject to high levels of use, and those differences in coverage and biological composition may be used as an important and significant indicator of health status.

Macroalgal coverage was significantly lower in highly visited (impacted) areas, as in the middle area of the shipwreck, where the consequences of the effects of recreational diving are visible to the naked eye: the coverage in some cases was thin to the point of showing the bare wreck's hull, and it gradually becomes higher moving away from the mooring points, and relates to divers starting to dive with a correct buoyancy.

Several studies state that level of experience is directly linked to the potential damage caused to subtidal communities, attributed mainly to novice divers coming into contact with the bottom more often than the experienced ones [70,73,74,87,88] (pers. obs.) and in some cases it can play a more relevant role than the actual number of divers visiting a site [66,70,87].

From a wide point of view, the majority of conservation actions aimed to protecting biodiversity can be grouped in four categories: Direct protection and management, law and policy, education and awareness, and changing incentives [48]. In the last two decades, several ways have been introduced to handle damages due to recreational diving on artificial reefs, such as shipwrecks, aimed to preserve the structure itself and the related biodiversity. All these measures are fundamentally aimed to reducing the effects of divers, then focused directly or indirectly on the actions of divers (changing behaviour vs management strategies) [46]. They mainly consist in two different kinds of initiatives:

Directed towards changing the behaviour of divers [29] through: (i) A better environmental education [65], (ii) Promoting environmentally friendly behaviour by diving tourism operators, (iii) Briefing divers about the vulnerability of organisms attributable to visiting divers, (iv) Encouraging underwater photographers to be more aware of their actions when taking photographs [29], (v) Underwater supervision [70];

Using management strategies such as: (i) Introducing charges/transferable permits to reduce the number of dives and/or divers on sensitive sites [22,89,90], (ii) Resting some sites from all diving activity [31] or increasing the number of sites in order to avoid overcrowding of hot-spots [79], (iii) Using specific shipwrecks protection and management approaches (i.e., Commonwealth Historic Shipwrecks Act 1976, in Australia), (iv) Adoption of specific regulations for photographers [66], (v) Establishing specific trails for snorkelers and divers [20], (vi) Installing permanent and environmental friendly mooring [91].

According with the IUCN-CMP classification of direct threat to biodiversity [46], both direct and indirect effects above-mentioned fall within the area of "human intrusion and disturbance" (1st level of classification) and "recreational activities" (2nd level). This classification represents an efficient, unique and standardized way to classify potential damages and conservation measures related to any generic problem threating biodiversity worldwide, allowing an easy way to share information, experiences, successful solutions, but also improving the efficiency of conservation efforts through cross-project learning [46].

It has been demonstrated that exhaustive pre-dive briefings and underwater interventions are two of the best and easiest ways to reduce coral damage [65,92-95] reducing the number of contacts by 20-80% [70,93]. Similarly, Di Franco et al. [80] propose to start the dives in low vulnerability habitats to give divers enough time to make their comfortable and managing with their buoyancy control. Supporting this approach, it has recently been demonstrated that physical contacts are more likely during the first 10 min of dives [92].

It is interest of most of the stakeholders utilizing the *Zenobia*, one of the most emblematic shipwrecks in the Mediterranean Sea, adopting similar approaches. The conservation of the associated biodiversity as well as the wreck itself have to consider the management of the diving activities; this practice eventually has to be implemented to all sites subject to high diving tourism in Cyprus and elsewhere, in order to preserve the ecological heritage that makes them very attractive sites [96].

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References

1. Amaral F, Farrapeira C, Lira S, Ramos C, Dom R (2010) Benthic macrofauna inventory of two shipwrecks from Pernambuco coast, northeastern of Brazil. RNJ 4: 24-41.
2. Baine M (2001) Artificial reefs: a review of their design, application, management and performance. Ocean Coast Manage 44: 241-259.
3. Bombace G, Fabi G, Fiorentini L, Speranza S (1994) Analysis of the efficacy of artificial reefs located in five different areas of the Adriatic Sea. B Mar Sci 55: 559-580.
4. Clark S, Edwards AJ (1994) Use of artificial reef structures to rehabilitate reef flats degraded by coral mining in the Maldives. B Mar Sci 55: 724-744.
5. Bull AS, Kendall JJ Jr (1994) An indication of the process: offshore platforms as artificial reefs in the Gulf of Mexico. B Mar Sci 55: 1086-1098.
6. Zintzen V, Massin C, Norro A, Mallefet J (2006) Epifaunal inventory of two shipwrecks from the Belgian Continental Shelf. Hydrobiologia 555: 207-219.
7. Svane I, Petersen JK (2001) On the problems of epibioses, fouling and artificial reefs, a review. Mar Ecol 22: 169-188.
8. Claudet J, Pelletier D (2004) Marine protected areas and artificial reefs: A review of the interactions between management and scientific studies. Aquat Living Resour 17: 129-138.
9. Danovaro R, Gambi C, Mazzola A, Mirto S (2002) Influence of artificial reefs on the surrounding infauna: analysis of meiofauna. ICES J Mar Sci J Cons 59: S356-S362.
10. Pears RJ, Williams DM (2005) Potential effects of artificial reefs on the Great Barrier Reef: background paper. CRC Reef Res Centre.
11. Badalamenti F, D'Anna G (1996) Monitoring techniques for zoobenthic communities: influence of the artificial reef on surrounding infaunal community. Proceedings of the 1st Conference of the European Artificial Reef Research Network. Ancona.
12. Consoli P, Martino A, Romeo T, Sinopoli M, Perzia P, et al. (2015) The effect of shipwrecks on associated fish assemblages in the central Mediterranean Sea. J Mar Biol Assoc UK 95: 17-24.
13. Arena P, Jordan L, Gilliam D, Sherman R, Banks K, et al. (2000) Shipwrecks as artificial reefs: a comparison of fish assemblage structure on ships and their surrounding natural reef areas offshore southeast Florida. Proc. 53rd Annual Gulf and Caribbean Fisheries Institute Meeting, Biloxi, Mississippi, USA.
14. Howard JL (1999) How do scuba diving operators in Vanuatu attempt to minimize their impact on the environment? Pacific Tourism Rev 3: 61-69.
15. Murphy JW (1988) Historic shipwrecks: issues in management. The Trust.
16. Kaoru Y, Hoagland P (1994) The value of historic shipwrecks: Conflicts and management. Coast Manage 22: 195-213.
17. Nutley D (1996) Underwater cultural heritage management. Tempus-St. Lucia Queensland 5: 99-108.
18. Fabi G (2015) Practical guidelines for the use of artificial reefs in the Mediterranean and the Black Sea. FAO, Rome (Italy).
19. Van De Werfhorst LC, Pearse JS (2007) Trampling in the rocky intertidal of central California: a follow-up study. B Mar Sci 81: 245-254.
20. Hawkins JP, Roberts CM (1992) Effects of recreational SCUBA diving on fore-reef slope communities of coral reefs. Biol Conserv 62: 171-178.
21. Van Treeck P, Schuhmacher H (1999) Mass diving tourism-a new dimension calls for new management approaches. Mar Pollut B 37: 499-504.
22. Edney J (2006) Impact of recreational scuba diving on ship-wrecks in Australia and the Pacific - A review. Micrones J Hum Soc Sci 5: 201-233.
23. Kenderdine S (1997) Culture and heritage: shipwrecks and associated objects. Australia: State of the Environment Technical Paper Series (Natural and cultural heritage), Department of the Environment, Canberra Environment Australia.
24. Fernández-Márquez D, García-Charton J, Hackradt CW, Treviño-Otón J, Félix-Hackradt FC, et al. (2010) Impacts of recreational scuba diving on benthic assemblages in Cabo de Palos-Islas Hormigas Marine Reserve. in XVI Simposio Ibérico de Estudios en Biología Marina.
25. White PS (1979) Pattern, process, and natural disturbance in vegetation. Bot Rev 45: 229-299.
26. Sousa WP (1984) The role of disturbance in natural communities. Ann Rev Ecol Syst 15: 353-391.
27. Pulfrich A, Parkins CA, Branch GA (2003) The effects of shore based diamond diving on intertidal and subtidal biological communities and rock lobsters in southern Namibia. Aquat Conserv Mar Freshwater Ecosys 13: 233-255.
28. Rouphael AB, Inglis GJ (1997) Impacts of recreational scuba diving at sites with different reef topographies. Biol Conserv 82: 329-336.
29. Rouphael T, Inglis G (1995) The effects of qualified recreational SCUBA divers on coral reefs. Tech Rep CRC Reef Res Cent p: 39.
30. Talge H (1992) Impact of recreational divers on scleractinian corals at Looe Key, Florida. in Proceedings of the 7th International Coral Reef Symposium. University of Guam Press Mangilao.
31. Tratalos JA, Austin TJ (2001) Impacts of recreational SCUBA diving on coral communities of the Caribbean island of Grand Cayman. Biol Conserv 102: 67-75.
32. Uyarra MC, Côté IM (2006) The quest for cryptic creatures: impacts of species-focused recreational diving on corals. Biol Conserv 136: 77-84.
33. Zakai D, Chadwick-Furman NE (2002) Impacts of intensive recreational diving on reef corals at Eilat, northern Red Sea. Biol Conserv 105: 179-187.
34. Sala E, Garrabou J, Zabala M (1996) Effects of diver frequentation on Mediterranean sublittoral populations of the bryozoan *Pentapora fascialis*. Mar Biol 126: 451-459.
35. Luna B, Pérez CV, Sánchez-Lizaso JL (2009) Benthic impacts of recreational divers in a Mediterranean Marine Protected Area. ICES J Mar Sci 66: 517-523.
36. Harriott VJ, Davis D, Banks SA (1997) Recreational diving and its impact in marine protected areas in eastern Australia. Ambio pp: 173-179.
37. Jewell B (2004) The effectiveness on diver attitudes and awareness of underwater shipwreck values-SS Yongala, a case study. B Aust Instit Mari Arch 28: 43-62.
38. Lindemann K (1992) Hailstorm over Truk Lagoon. Pacific Press Publications, Belleville, Michigan.
39. Jeffery B (2003) War in paradise: World War II sites in Truk Lagoon, Chuuk, Federated States of Micronesia [Booklet]. Weno, Chuuk: Chuuk Historical Preservation Office.
40. Edney J (2011) A review of recreational wreck diver training programmes in Australia. AIMA B 35: 1-8.
41. McKinnon JF (2015) Memorialization, graffiti and artifact movement: a case study of cultural impacts on WWII underwater cultural heritage in the commonwealth of the Northern Mariana Islands. J Mari Arch 10: 11-27.
42. Arnott J, Wu AH, Vucko MJ, Lamb RN (2014) Marine antifouling from thin air. Biofouling 30: 1045-1054.
43. Garrabou J, Sala E, Arcas A, Zabala M (1998) The impact of diving on rocky sublittoral communities: a case study of a bryozoan population. Conserv Biol 12: 302-312.
44. Hawkins JP, Roberts CM, Van'T Hof T, De Meyer K, Tratalos J, et al. (1999) Effects of recreational scuba diving on Caribbean coral and fish communities. Conser Biol 13: 888-897.
45. Plathong S, Inglis GJ, Huber ME (2000) Effects of self-guided snorkeling trails on corals in a tropical marine park. Conserv Biol 14: 1821-1830.
46. Salafsky N, Salzer D, Stattersfield AJ, Hilton-Taylor C, Neugarten R, et al. (2008) A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conserv Biol 22: 897-911.
47. Battisti C, Poeta A, Fanelli G (2016) An Introduction to Disturbance Ecology: A Road Map for Wildlife Management and Conservation. Springer.
48. Salafsky N, Margoluis R, Redford KH, Robinson JG (2002) Improving the practice of conservation: a conceptual framework and research agenda for conservation science. Conserv Biol 16: 1469-1479.
49. Benedetti-Cecchi L, Airoldi L, Fraschetti S, Terlizzi A (2003) Metodi sperimentali per la valutazione di influenze antropiche su popolamenti ed ambienti marini costieri. In: Gambi MC, Dappiano M (eds.) Manuale di metodologia di campionamento e studio del benthos marino mediterraneo. Biol Mar Medit 10: 485-508.

50. Azevedo CA, Carneiro MA, Oliveira SR, Marinho-Soriano E (2011) Macrolgae as an indicator of the environmental health of the Pirangi reefs, Rio Grande do Norte, Brazil. Rev Bras Farmacog 21: 323-328.

51. Claudet J, Lenfant P, Schrimm M (2010) Snorkelers impact on fish communities and algae in a temperate marine protected area. Biodiver Conserv 19: 1649-1658.

52. Addessi L (1994) Human disturbance and long-term changes on a rocky intertidal community. Ecol App 4: 786-797.

53. Jimenez C, Andreu V, Evriviadou M, Munkes B, Hadjioanou L, et al. (2014) Epibenthic communities associated to unintentional artificial reefs (modern shipwrecks) under contrasting regimes of nutrients in the Levantine Sea (Cyprus and Lebanon).

54. Gambi MC, Dappiano M (eds.) (2003) Manuale di metodologie di campionamento e studio del benthos marino mediterraneo Dappiano M 10: SIBM.

55. Hallacher LE (2004) Underwater sampling technique. University of Hawaii at Hilo modified in March 2004 for QUEST.

56. Ubaldi D (1997) Geobotan e fitosociol. CLUEB.

57. Foster M, Harrold C, Hardin D (1991) Point vs. photo quadrat estimates of the cover of sessile marine organisms. J Exper Mar Biol Ecol 146: 193-203.

58. Preskitt LB, Vroom PS, Smith CM (2004) A rapid ecological assessment (REA) quantitative survey method for benthic algae using photoquadrats with scuba. Pac Sci 58: 201-209.

59. Dumas P, Bertaud A, Peignon C, Leopold M, Pelletier D (2009) A “quick and clean” photographic method for the description of coral reef habitats. J Exp Mar Biol Ecol 368: 161-168.

60. Kohler KE, Gill SM (2006) Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Comp Geosci 32: 1259-1269.

61. Hammer Ø, Harper D, Ryan P (2001) PAST-PAlaeontological STatistics, ver. 1.89. Palaeontol Electron 4: 1-9.

62. (2015) Dawn ‘Titanic of the Mediterranean’ wreck lures thousands of divers to Cyprus. Dawn.

63. Gerovassileiou V, Koutsoubas D, Sini M, Paikou K (2009) Marine protected areas and diving tourism in the Greek Seas: Practices and perspectives. Tourismos 4: 181-197.

64. Prior M, Ormond R, Hitchen R, Wormald C (1995) The impact on natural resources of activity tourism: a case study of diving in Egypt. Int J Env Stud 48: 201-209.

65. Medio D, Ormond R, Pearson M (1997) Effect of briefings on rates of damage to corals by scuba divers. Biol Conserv 79: 91-95.

66. Rouphael AB, Inglis GJ (2001) “Take only photographs and leave only footprints”?: An experimental study of the impacts of underwater photographers on coral reef dive sites. Biol Conserv 100: 281-287.

67. Rouphael AB, Inglis GJ (2002) Increased spatial and temporal variability in coral damage caused by recreational scuba diving. Ecol Appl 12: 427-440.

68. Rouphael T (1997) The temporal and spatial patterns of impact caused by SCUBA diving in coral reefs, and the human and site specific characteristics that influence these patterns: James Cook University of North Queensland.

69. Dixon JA, Fallon Scura L, van’t T (1993) Hof Meeting ecological and economic goals: marine parks in the Caribbean. Ambio (Sweden).

70. Barker NH, Roberts CM (2004) Scuba diver behaviour and the management of diving impacts on coral reefs. Biol Conserv 120: 481-489.

71. Hawkins JP, Roberts CM, Kooistra D, Buchan K, White S (2005) Sustainability of scuba diving tourism on coral reefs of Saba. Coast Manage 33: 373-387.

72. Roberts L, Harriott V (1994) Recreational scuba diving and its potential for environmental impact in a marine reserve. Rec Advan Mar Sci Technol 94: 695-704.

73. Walters R, Samways M (2001) Sustainable dive ecotourism on a South African coral reef. Biodiver Conserv 10: 2167-2179.

74. Worachananant S, Carter R, Hockings M, Reopanichkul P (2008) Managing the impacts of SCUBA divers on Thailand’s coral reefs. J Sustain Tour 16: 645-663.

75. Poonian C, Davis PZ, McNaughton CK (2010) Impacts of recreational divers on Palauan coral reefs and options for management. Paci Sci 64: 557-565.

76. Hasler H, Ott JA (2008) Diving down the reefs? Intensive diving tourism threatens the reefs of the northern Red Sea. Mar Pollu B 56: 1788-1794.

77. Schleyer MH, Tomalin BJ (2000) Damage on South African coral reefs and an assessment of their sustainable diving capacity using a fisheries approach. B Mar Sci 67: 1025-1042.

78. Di Franco, Marchini AA, Baiata P, Milazzo M, Chemello R (2009) Developing a scuba trail vulnerability index (STVI): a case study from a Mediterranean MPA. Biodiver Conserv 18: 1201-1217.

79. Milazzo M, Chemello R, Badalamenti F, Camarda R, Riggio S (2002) The impact of human recreational activities in marine protected areas: what lessons should be learnt in the Mediterranean sea? Mar Ecol 23: 280-290.

80. Di Franco A, Milazzo M, Baiata P, Tomasello A, Chemello R (2009) Scuba diver behaviour and its effects on the biota of a Mediterranean marine protected area. Env Conserv 36: 32-40.

81. Lloret J, Riera V (2008) Evolution of a Mediterranean coastal zone: human impacts on the marine environment of Cape Creus. Env Manage 42: 977-988.

82. Di Franco, Ferruzza AG, Baiata P, Chemello R, Milazzo M (2010) Can recreational scuba divers alter natural gross sedimentation rate? A case study from a Mediterranean deep cave. ICES J Mar Sci 67: 871-874.

83. Kirkbride-Smith AE, Wheeler PM, Johnson ML (2013) The relationship between diver experience levels and perceptions of attractiveness of artificial reefs-examination of a potential management tool. PloS ONE 8: e68899.

84. Edney J, Spennemann DH (2015) Can artificial reef wrecks reduce diver impacts on shipwrecks? The management dimension. J Mar Arch 10: 141-157.

85. Stolk P, Markwell K, Jenkins JM (2007) Artificial reefs as recreational scuba diving resources: a critical review of research. J Sustain Tour 15: 331-350.

86. Jakšić S, Stamenković I, Đorđević J (2013) Impacts of artificial reefs and diving tourism. Turizam 17: 155-165.

87. Davis DC (1995) Tisdell Recreational scuba-diving and carrying capacity in marine protected areas. Ocean Coast Manage 26: 19-40.

88. Abidin SZZ, Mohamed B (2014) A Review of SCUBA Diving Impacts and Implication for Coral Reefs Conservation and Tourism Management. in SHS Web of Conferences. EDP Sci.

89. Davis DC (1996) Tisdell Economic management of recreational scuba diving and the environment. J Env Manage 48: 229-248.

90. Nutley D (1998) Ten years of shipwreck access and management practices in New South Wales. B Australian Instit Mar Arch 22: 115.

91. Francour P, Ganteaume A, Poulain M (1999) Effects of boat anchoring in Posidonia oceanica seagrass beds in the Port-Cros National Park (north-western Mediterranean Sea). Aqua Conserv Mar Freshwater Ecosys 9: 391-400.

92. Lyons PJ, Arboleda E, Benkwitt CE, Davis B, Gleason M, et al. (2015) The effect of recreational SCUBA divers on the structural complexity and benthic assemblage of a Caribbean coral reef. Biodiver Conserv 24: 3491-3504.

93. Krieger JR, Chadwick NE (2013) Recreational diving impacts and the use of pre-dive briefings as a management strategy on Florida coral reefs. J Coast Conserv 17: 179-189.

94. Camp E, Fraser D (2012) Influence of conservation education dive briefings as a management tool on the timing and nature of recreational SCUBA diving impacts on coral reefs. Ocean Coast Manage 61: 30-37.

95. Townsend C (2000) The Effects of environmental education on the behaviour of SCUBA divers: a case study from the British Virgin Islands. Unpublished master’s thesis. The University of Greenwich. London, England.

96. Shani A, Polak O, Shashar N (2012) Artificial reefs and mass marine ecotourism. Tour Geogra 14: 361-382.

97. Machado PM, de Sá FS, de Rezende CE, Zalmon IR (2013) Artificial reef impact on macrobenthic community on south-eastern Brazil coast. Mar Biodiver Rec 6: e40.

98. Zalmon IR, Boina CD, Almeida TCM (2012) Artificial reef influence on the surrounding infauna-north coast of Rio de Janeiro State, Brazil. J Mar Biol Asso UK 92: 1289-1299.

99. Lira SMDA, Farrapeira CMR, Amaral FMD, Ramos CAC (2010) Sessile and sedentary macrofauna from the Pirapama Shipwreck, Pernambuco, Brazil. Biota Neotropica 10: 155-165.

100. Field S, Glassom D, Bythell J (2007) Effects of artificial settlement plate materials and methods of deployment on the sessile epibenthic community development in a tropical environment. Coral Reefs 26: 279-289.

101. Glasby T (1999) Interactive effects of shading and proximity to the seafloor on the development of subtidal epibiotic assemblages. Mar Ecol Prog Series 190: 113-124.

102. Bulleri F (2005) Role of recruitment in causing differences between intertidal assemblages on seawalls and rocky shores. Mar Ecol Prog Series 287: 53-65.

103. Bulleri F, Chapman M, Underwood A (2004) Patterns of movement of the limpet Cellana tramoserica on rocky shores and retaining seawalls. MEPS 281: 121-129.

104. Kirk MD, Esler WS (2007) Boyd Morphology and density of mussels on natural and aquaculture structure habitats: implications for sea duck predators. MEPS 346: 179-187.

105. Moreira J, Chapman M (2006) A Underwood Seawalls do not sustain viable populations of limpets. MEPS 322: 179-188.

106. Leeworthy V, Maher T, Stone E (2006) Can artificial reefs alter user pressure on adjacent natural reefs? B Mar Sci 78: 29-38.

107. Woodhead P, Jacobson M (1985) Epifaunal settlement, the processes of community development and succession over two years on an artificial reef in the New York Bight. B Mar Sci 37: 364-376.

108. Hixon MA, Beets JP (1989) Shelter characteristics and Caribbean fish assemblages: experiments with artificial reefs. B Mar Sci 44: 666-680.

109. Boaventura D, Moura A, Leitao F, Carvalho S, Curdia J, et al. (2006) Macrobenthic colonisation of artificial reefs on the southern coast of Portugal (Ancão, Algarve). Hydrobiologia 555: 335-343.

110. Zalmon IR, Gomes DCFA (2003) Comunidade incrustante em diferentes materiais de um recife artificial no litoral norte do Estado do Rio de Janeiro. Biotemas 16: 57-80.

111. Azevedo FBB, Carloni GG, Carvalheira LV (2006) Colonization of benthic organisms on different artificial substratum in Ilha Grande bay, Rio de Janeiro, Brazil. Braz Archiv Biol Technol 49: 263-275.

112. Brotto DS, Krohling W, Zalmon IR (2006) Fish community modeling agents on an artificial reef on the northern coast of Rio de Janeiro-Brazil. Braz J Oceanogra 54: 205-212.

113. Krohling W, Brotto DS, Zalmon IR (2006) Functional role of fouling community on an artificial reef at the northern coast of Rio de Janeiro State, Brazil. Braz J Oceanogra 54: 183-191.

114. Jeffery B (1990) Realising the cultural tourism potential of South Australian shipwrecks. Hist Env 7: 72.

115. Baqueiro EC, Mendez RL (1994) Artificial reefs: an alternative to enhance Mexican littoral commercial fisheries. B Mar Sci 55: 1014-1020.

116. D'Anna C, Badalamenti F, Gristina M, Pipitone C (1994) Influence of artificial reefs on coastal nekton assemblages of the Gulf of Castellammare (Northwest Sicily). B Mar Sci 55: 418-433.

117. McGlennon D, Branden KL (1994) Comparison of catch and recreational anglers fishing on artificial reefs and natural seabed in Gulf St. Vincent, South Australia. B Mar Sci 55: 510-523.

118. Branden KL, Pollard DA, Reimers HA (1994) A review of recent artificial reef developments in Australia. B Mar Sci 55: 982-994.

119. Stanley D, Wilson C (1990) A fishery-dependent based study of fish species composition and associated catch rates around oil and gas structures off Louisiana. Fish B p: 88.

120. Foster KL, Steimle FW, Muir WC, Kropp RK, Conlin BE (1994) Mitigation potential of habitat replacement: concrete artificial reef in Delaware Bay-preliminary results. B Mar Sci 55: 783-795.

121. Muir W, Steimle F, Foster K, Kropp R, Conlin B (1995) Mitigation potential of habitat replacement: Artificial reef replacement for fisheries enhancement in shallow waters of the Delaware Bay. U. S. EPA, PA, USA.

122. Rhodes R, Bell M, Pomeroy R (1994) Scuba diver expenditures associated with South Carolina's artificial reefs. B Mar Sci.

123. Cuthill M (1998) Managing the Yongala historic shipwreck. Coast Manage 26: 33-46.

124. Dowling RK, Nichol J (2001) The HMAS Swan artificial dive reef. Ann Tourism Res 28: 226-229.

125. Relini G, Dinelli G (1995) A Sampaolo Stabilised coal ash studies in Italy. Chem Ecol 10: 217-231.

126. Mohd Fauzi M, Ang S, Saiful Bahri H (2013) Colonization of marine epibiota around WABCORE artificial reef at Panuba Bay, Tioman Island, Malaysia. APCBEE Proc 5: 416-422.

127. Jensen A, Collins K (1996) The use of artificial reefs in crustacean fisheries enhancement in European Artificial Reef Research Network (EARRN) Conference.

128. Bombace G (1989) Artificial reefs in the Mediterranean Sea. B Mar Sci 44: 1023-1032.