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Review

A Critical Approach to Existing Management Perspectives in Scuba Diving: A Step in Defining Ecological Carrying Capacity

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Abstract: There are a considerable number of studies reporting the negative impacts of recreational diving and their causes, yet there is a gap in the information regarding the aspects of activity management. This paper presents a systematic approach to the management measures found in the literature. A large part of the measures identified address stakeholders' awareness, data on the activity, and implementing adapted management measures. Stakeholders need to be integrated into the entire process of managing the activity because they are the target for correcting actions. A knowledge gap of the evaluation of the "ecological carrying capacity" of dive sites exists, along with a lack of methods for its assessment. This study informs future steps on the development of an integrated management and monitoring model that encompasses the assessment of ecological carrying capacity in further research. It also brings a vision of sustainable management of the recreational diving activity by advancing the conceptual framework of scuba diving and tourism integrated management.

Keywords: scuba diving management; environmental impacts; management actions; sustainability

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1. Introduction

Each year, a considerable number of new divers complete a diving certification, making recreational diving one of the fastest growing coastal tourist activities [1–3]. The diver training organisation, the Professional Association of Diving Instructors (PADI), has more than 100,000 certified professionals, who in turn have certified more than 28 million divers since 1967, spread over more than 200 countries and territories [4,5]. This recreational activity is economically viable and can raise environmental awareness by allowing direct observation of the marine ecosystem [6,7]. It is also accepted in multiple-use marine protected areas (MPAs) as a source of income [7–9]. However, carrying out this activity also brings negative impacts on the marine environment, particularly through physical disturbance of species and habitats. Moreover, non-indigenous species (NIS) can be transported by diving boats from marinas and introduced into sensitive marine areas such as MPAs [10].

Scuba diving can cause localised devastation of habitats and the sensitive marine organisms that inhabit them [11–13]. Yet, the effects of this activity are simpler to control [14] compared with other local and global stressors that impair marine environments (e.g., overfishing, pollution, habitat destruction, increasing temperatures, ocean acidification). As such, a series of measures have appeared over the years with the aim of improving the management of recreational diving and minimising its impacts. They fall into the following categories: (1) providing divers with adequate marine education, (2) the use of predive briefings by operators and a mandatory introduction and orientation dive, (3) the

possibility of joining a coral reef conservation programme [14], (4) the adoption of a user-pays approach [15], (5) monitoring the effects of human pressure on marine organisms [16], (6) the alternative of using artificial reefs [17], and (7) spatial zoning strategies [18]. Despite a large and growing literature on the impact of recreational diving and, consequently, the existence of a panoply of management measures, the problems identified over the years in the management of the activity worldwide persist (e.g., limited control minimising the negative impacts on marine life and the entire marine ecosystem characteristic of each dive site, either by divers or by the diving operation). In the case of managing diving activity in MPAs, the common management framework is the carrying capacity approach, which addresses the question, "How many divers are too many?" The behaviour of divers and dive operators, which is critical to the health of dive spots, is still not enough incorporated into a management framework. With this study, the authors intend to fill the knowledge gap identified above; specifically, (i) to identify the management measures that are suggested and implemented to combat these impacts, and (ii) to understand what solutions to achieve better management of the industry activity exist. The main objective is to advance the theoretical and conceptual understanding of scuba diving and tourism management and to propose an approach to defining ecological carrying capacity.

2. Methods

Between September 2020 and April 2021, a screening of the databases "Web of Science" and "Google Scholar" and a search in the "Google Scholar" database for "grey" literature (e.g., reports, articles from newspapers, magazines, and government documents) were carried out. This set of publications is managed using the open-source EndNote Online Classic software tool (https://endnote.com/ (between September 2020 and April 2023). As the study was not immediately finished, a new screening with similar methodology in early 2023 helped to update the results, with no significant changes.

The literature was systematically examined via search topics using Boolean operators. Topics were screened in the titles, abstracts, and keywords as follows:

TS = ((dive tourism) OR (scuba-div* AND manag*) OR (scuba-div* AND carrying capacit*) OR (scuba-div* AND (behavio* OR satisfact*)) OR (scuba-div* AND (limits of acceptable change OR LAC)) OR (scuba-div* AND mang* AND value* AND MPA*) OR (scuba-div* AND MPA*) OR (scuba-div* AND impact*) OR (carrying capacity* dive tourism) OR (limits of acceptable change dive tourism) OR (ecosystem services dive tourism))

Legend: TS—Topic; *—Right and left truncation. Boolean operators: AND and OR.

This first approach returned a total of 1363 publications (i.e., not only scientific articles) that potentially included information about recreational scuba diving, management of the activity, evaluations of carrying capacity and the "limits of acceptable change (LAC)", recreational scuba diving in MPAs, identification of the impacts of diver behaviour on marine organisms, and divers' satisfaction.

In a preliminary search, each publication was analysed (title, abstract, and keywords) and selected if it had at least one of the following criteria: (i) information about diving tourism and management of the activity, (ii) information about diver behaviour in the marine environment and satisfaction with the dive experience, (iii) content about carrying capacity within diving tourism, (iv) management of the activity in MPAs, (v) evaluation of the social and ecological carrying capacities at dive destinations, and (vi) the values of marine biodiversity in areas of recreational diving and of the activity. This focused analysis reduced the number of selected publications to 192.

A second, more detailed analysis of the 192 publications reduced the set to 117 articles proposing management measures for the scuba diving industry. These management measures, here defined as "an action that improves the sustainability of the industry", have the following information collected (Figure 1).

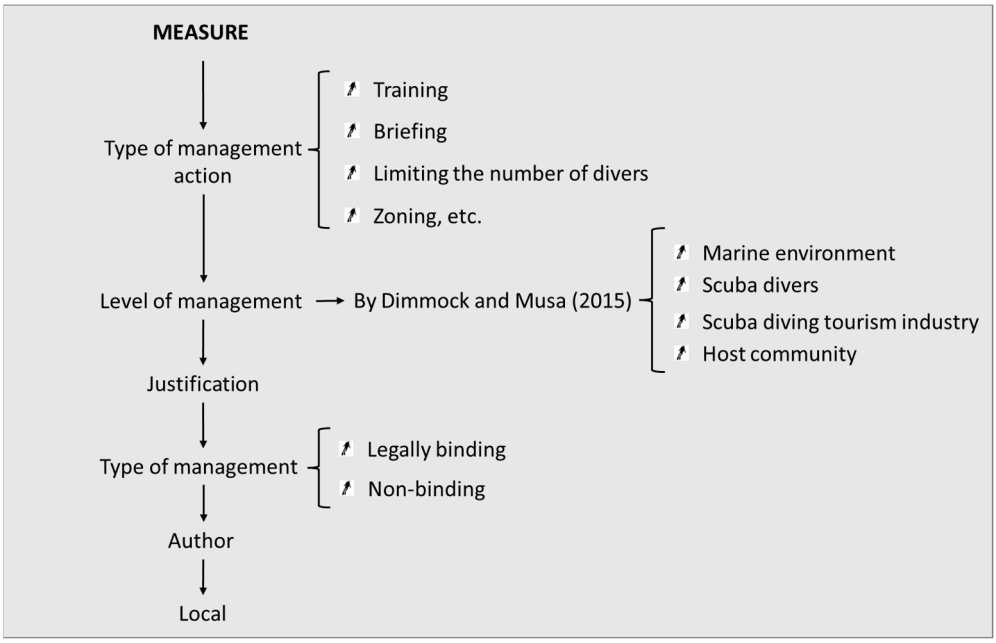

Figure 1. Information collected for the diving activity management measures identified in the literature (1993–2021) [19].

The level of management presented in Figure 1 is based on the conceptual framework of the "Scuba Diving Tourism System (SDTS)" proposed by Dimmock and Musa in 2015 [19]. This framework explains the complicated phenomena and processes in scuba diving tourism and allows key elements to be highlighted and important associations to be simplified. The core elements of the SDTS considered are the "marine environment (ME)", "scuba divers (SDs)", the "scuba diving tourism industry (DTI)", and the "host community (HC)".

The marine environment is at the centre of the SDTS system as it is the main element on which all stakeholders depend, namely, the scuba divers (demand) and the suppliers of scuba diving tourism services (e.g., operators, charter operations, as well as the associated service and tourism industries). Apart from suppliers, the host community, which grants social and cultural resources, and the governments, policymakers, and resource managers of places with valued underwater ecosystems are also part of the system.

Following the structure in Figure 1, 330 measures identified and grouped into 11 management action groups for recreational diving (Table 1) are distributed according to the criteria shown.

Table 1. Diving management action groups and the criteria used for the distribution of the identified measures.

No.	Management Action Group	Criteria
1	Briefings	Suggests introduction of briefings (e.g., predive briefings, video briefings, comprehensive briefings, environmental briefings, and educational briefings).
2	Training	Recommends improving diving skills, such as acquiring good swimming technique and buoyancy control.
3	Research/monitoring	Recommends previous research that calls for more knowledge, future work and studies, evaluation or monitoring, more information, long-term quantification, more analysis, and more surveys related to diving activity.
4	Zoning	Recommends the development of zoning plans, utilisation of spatial planning tools, and applying temporal and spatial zoning strategies.

Table 1. *Cont.*

No.	Management Action Group	Criteria
5	Governance and public policy	Proposals that promote substitution of policies, enforcement of rules and regulations, design of legal frameworks, surveillance of compliance with legislation, implementation of licence systems, and improvement of existing frameworks.
6	Economic values/mechanisms	Support of economic mechanisms, implementation of economic instruments, well-planned activities for a better local economy, creation of economic value, use of values figures and discriminatory pricing, appropriate marketing, implementation of a rating system, customer reviews, inspirational videography, sharing of positive experiences and stories, new strategies to disseminate attractions, promotion of actions, the promotion of the destination, incorporation of new services, offer of high-value services, optimisation of goods and services, dissemination of information, collection of fees for diving activity, implementation of an appropriate system of fees, and provision of new exciting information and implementation of marketing strategies.
7	Awareness	Improvement of education, awareness-raising, education programmes, reinforcement of environmental education, implementation of educational tools, development of educational frameworks, design of new messages, implementation of massive education campaigns, development of alert mechanisms, use of guidelines for responsible divers, development and implementation of code of conduct/code of diving ethics, actions to improve the behaviour of divers, increased dive guide/leader education and intervention, increased diver demand for conservation-oriented diving operations, and encouragement of continuing education.
8	Adaptive management approaches	Use of adaptive management strategies, use of management strategies considering conservation issues, redesigning existing fees, creation of sustainable dive plans and sustainable integrated coastal management plans, establishment of sustainable management approaches, implementation of quota limits or a quota system, prediction and prevention of conflicts, implementation of management plans, use of artificial reefs, and establishment of MPAs.
9	Carrying capacity approaches	Suggests limiting the numbers of divers, establishing the size of dive groups, limiting dive site access, decreasing the number of dives per dive spot, decreasing the number of persons or boats simultaneously present at the same location, "first-come-first-served" scheduling systems, carrying capacity evaluation, introduction of a system of licensing individual divers, calculation of carrying capacities and "limits of acceptable change (LAC)", establishment of a diving carrying capacity, implementation of rules to limit daily divers' visits, allocation of a maximum number of divers per dive guide, and limitation of the number of dives per reef site per year.
10	Diving industry adaptation	Recommends the use of floating buoys in dive spots, presence of a system of moorings in the dive spots, prohibition of anchoring, use of planned dive tour routes, establishment of diver entry points, maintenance of equipment associated with the diving activity (e.g., diving equipment, boats), establishment of minimum distances between dive groups at a dive spot, use of a rotational dive site system, verification of skills among divers by dive operators, maintaining the quality of the dive sites, considering diver satisfaction, and taking diver characteristics into account.
11	Stakeholder engagement	Recommends participatory processes involving key stakeholders (e.g., policymakers, dive operators); participation of stakeholders in marine spatial planning decision-making processes; expert judgement and stakeholder knowledge; transparent management rules, communicated clearly; consultation with divers and the dive industry; stakeholder perceptions; closer relationships between managers and users; and communication channels among all stakeholders. Also, it is suggested to increase interactivity and social activities, increase socialising opportunities and relationships, and improve social systems.

Certain measures may be part of more than one distinct group. In those cases, the decision was to analyse the entire article and use the global vision/main theme presented as a criterion to integrate the measure into a particular group. The distribution of the measures among the diverse groups is not watertight and was based on the authors' judgement.

The management action groups' awareness, briefings, and training interconnect because all of them have the education of divers and the use of dive guides as their focus; however, given their relevance to the industry, the authors chose to address each of them individually.

The next step was to analyse the data to understand how often management actions appear in the body of the literature and what the main ideas are behind the measures identified. Furthermore, the authors tried to understand if the measures are implemented and, if not, why not. Finally, there was an attempt to identify the major difficulties in implementing management measures and solutions to reach a better management of the industry's activity.

3. Results

Synthesis of the Management Measures Review

The results show that the largest number of identified case studies were in the United States of America (USA, e.g., Florida, California, and Hawaii), closely followed by Australia, Thailand, and Spain (Figure 2). The USA, Australian, and Thai case studies are in tropical regions, and most of the study areas in Spain are in the Mediterranean basin, with subtropical/temperate characteristics. Also, it was possible to ascertain that the largest number of scientific articles in the literature was published in the last decade, which is in line with the growth of and demand for the diving activity worldwide (Table 2). A small number of publications reviewed did not refer to any specific case study, but presented a more conceptual approach.

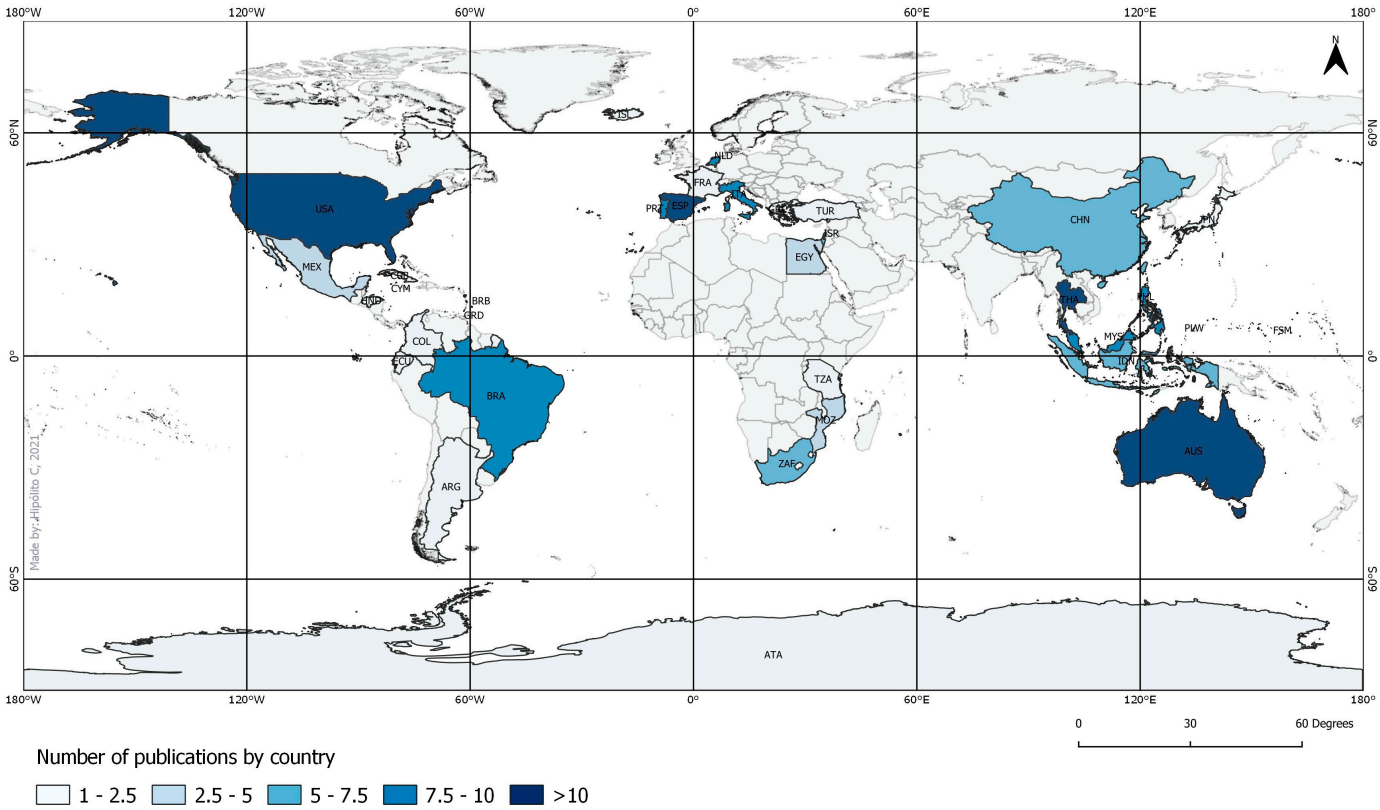

Figure 2. Distribution of the body of literature analysed, by location of case studies (data from 1993 to 2021).

Table 2. Number of publications published per year, by group of dive management actions.

	Management Actions	1993	1995	1996	1998	2000	2001	2002	2003	2004	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	**Awareness**			1			1	1		1	2	1	2	2	1	3	4	4	3	5	7	5	2	2	3	
2	**Research/monitoring**		1	1			2	1		1			1	1	4	1	1	1	4	3	6	5	3	3	4	
3	**Adaptative management approaches**	1			1	1	1	1					4		2	1		1	2	2	3	4	1	3		
4	Carrying capacity approaches			1				1		1	1		1	1	1		1	1	2	5	2	1	1	1	2	
5	Diving industry adaptation							1		1			1	1			1	1	2	6	3	1	1	2	1	
6	Stakeholder engagement										1								2	2	4	2	4	1	3	2
7	Economic values/mechanisms			1					1				2			1		2	1		3			3	3	
8	Zoning			1														1		2	3	1	1	1	2	1
9	Briefings						1								1		1	1		2	1	4			1	
10	Governance and public policy													1		1	1		4	1	1	1				
11	Training				1											1				1		1	1			1
	Number of publications																									
	Legend	1–2					3–4					>5														

In the period under review (1993 to 2021), 80% of the publications suggesting scuba diving management date from 2008 onwards. Recent studies, from 2014 onwards, reveal a growing concern with stakeholder participation in the planning and management process [3,20,21]. This growing concern about the impact of diving activity brought about increased attention to awareness-related measures and increased data collection and monitoring from the perspective of a greater focus on the preservation of marine ecosystems [1,22,23]. Management measures concerning diving carrying capacities and diving industry adaptation reveal a greater focus on limiting the number of divers and the number of dives per site [24–27] and on the prohibition of anchoring and the creation of moorings in dive sites [14,28,29]. Around 20% of the publications analysed mention the need to calculate the carrying capacities of diving sites to prevent future damage to the marine ecosystems in diving destinations [30–32]. Zoning measures are almost absent until the last decade, except for a single reference in 1996 (Table 2). Most measures related to zoning involve temporal zoning strategies in diving sites [33,34].

From a total of 330 measures identified, 252 are related to the core elements of the SDTS and the DTI. As mentioned above, the DTI is heavily dependent on a considerable number of industry operators to provide adequate and suitable recreational diving experiences and therefore focuses on underwater diving service providers. Only nine measures from the total are identified as legally binding. For example, in Eilat, a popular diving destination, the annual level of visits established per dive site is well below 4000 [35]. In the island of Bonaire, divers need to have an introduction to the Bonaire National Marine Park and are required to conduct a guided dive, both conducted by the host dive company of the visitor [14]; anchoring is prohibited for vessels whose size exceeds four metres and is only allowed by fishers using rock anchors. In the island of Grand Cayman, anchoring on coral reefs has been prohibited since 1976, and since 1986, practically all boats use mooring buoys where this study was conducted [28].

When analysing the measures, the conclusion is that they are based on safeguarding the marine environment and the desire for good management of the activity. That is, the demand is for conservation-oriented diving operations to preserve the dive sites so that they retain their characteristics and can be the stage for a good diving experience. Twenty-seven percent of the measures (n = 90) are based on raising awareness, warning of the need to (i) improve the education of dive guides and divers; (ii) invest in educational environmental programmes, campaigns, tools, and frameworks; (iii) develop alert mechanisms on the environmental status; and (iv) use guidelines for responsible diving or codes of conduct/codes of diving ethics. Around 16 percent of the 330 measures (n = 52) stress the importance of research and monitoring for good development of the activity. They demonstrate the need for increased data and information on dive operations, divers' satisfaction and needs, and dive sites' biodiversity and characteristics through studies, evaluation, and monitoring. Ten percent of the measures (n = 32) suggest the use of adaptive management strategies considering conservation issues like collecting or redesigning fees or implementing an appropriate system of fees/quotas, creating sustainable dive plans and sustainable integrated coastal management plans, creating and using artificial reefs, and establishing marine reserves (e.g., marine protected areas). Eight percent of the measures (n = 26) recommend the use of carrying capacity approaches to limit the number of divers in dive sites and the number of dives per site per year. The remaining 39% (n = 128) of the measures concern all the other groups of management actions, which, despite being as important as the others, do not appear as much in the literature. Most of the management measures identified are no more than suggestions/recommendations for improving the management of the activity and minimising its impact on ecosystems.

4. Discussion

The following discussion also contains part of the results of a more comprehensive analysis. It is organised according to the structure present in Table 1.

These management measures and the proposed criteria for analysis structure are the result of a global understanding of diving impacts. It is well known that divers and the

diving industry can have a negative impact on the marine ecosystem, and the sources of impact are diverse. In the case of divers, the main cause of their negative impact on the marine environment is their behaviour [14,22,25], which can vary according to profile, objectives, and dive site characteristics [31]. The impacts normally are related to physical contact or deposition of sediments through indirect contact (e.g., hands, scuba gear, fin kicks) [12,35–38]. Although the damage induced is proven to be low, in a localised way it can be quite significant for sensitive marine species (e.g., coral colonies) [25]. The organisms can suffer breakage abrasion, tissue removal, mortality [11,17], or an excess of sediment deposition that can cover their surface, inhibiting processes such as recruitment, feeding, and photosynthesis [24]. Poor buoyancy control ability is associated with diver behaviour [39] and is strongly related to the contact rate. Novice divers have a significantly increased contact rate, while the opposite is true for experienced divers whose buoyancy control skills are superior. Thus, the group of novice divers is the group most likely to negatively affect the most sensitive dive sites [39,40]. Concern regarding this issue has been increasing since 1998 due to the growth in the number of certified divers and, consequently, the increased numbers of novice divers with poor buoyancy control causing damage to the marine environment [40].

As support for further understanding, a reminder of the major diving impacts helps to frame the action of prevention and mitigation. Among the ways to mitigate or prevent this impact are encouraging beginner divers to acquire better buoyancy skills (e.g., training sessions before participating in the activity) [22,41]; promoting greater social interaction between beginners and experienced divers; dive guides being more attentive and alert regarding this issue; and the use of dive sites with specific characteristics for this level of diver, such as lower density of corals and more abundant megafauna (e.g., large fish) [31] or with large sandy areas, allowing observation of the reef from the edges [42].

4.1. Awareness, Training, and Briefings

The development and use of training and interpretation programmes on marine habitats and marine life can be the key to greater awareness and engagement of divers underwater [43]. Skilled diving behaviour is strongly related to safety practices that reinforce relationships with diving buddies, diving masters, and diving friends but are less effective as behaviours that preserve the marine environment. Changing attitudes and behaviours involves both an awareness of the consequences and the knowledge of specific issues that can be addressed through public education programmes (e.g., incorporation of marine conservation awareness programmes in public schools). Interesting to note is that the best-known training organisations started to offer environmental awareness programmes for divers and, in collaboration with the diving industry, have developed a package for training eco-diving instructors (e.g., Scuba Schools International (SSI)), thus demonstrating concern in this regard. Diver education and buoyancy training have been a key feature in the reduction in the environmental impact of the scuba diving industry [44]. Thus, improvement of these two qualities has been shown to have a positive effect in reducing contacts made by divers in the ecosystem [14,45,46]. These are the two prerequisites for this industry, which encompasses international and national autonomous agencies (e.g., the British Sub Aqua Club (BSAC), La Confédération Mondiale Des Activités Subaquatiques (CMAS), and the Professional Association of Diving Instructors (PADI)). It is known that education is a successful tool for increasing divers' awareness, and another indirect form of intervention that can minimise the level of diver impacts is diving guides. The intervention of dive guides seems to be successful, as it seems to contribute to a reduction in diver contact with the ecosystem in the range of 20% to 80% [14]. The intervention of a dive guide reduces the likelihood of a diver contacting benthic organisms in the first 10 min of each dive. In general, the level of impact can be minor when there is continuous monitoring/intervention by the guide, thus achieving a more sustainable dive. An example is what happens in Santa Lucia (Lesser Antilles, Caribbean), where only the dive guide's intervention methods work in reducing coral damage by divers [47]. Along with novice

divers, underwater photographers may cause great destruction on the seabed, particularly on sessile organisms such as corals [37,48,49]. To photograph different scenarios and species, they often position themselves close to the substrate/bottom, leading to direct contact with marine organisms, and this is when they do not hold onto them to steady themselves [37]. Surprisingly, in [48] it was found that specialist photographers are the worst when it comes to causing impact, which reinforces the need for transversal education. Another source of impact with negative repercussions on the marine ecosystem is conflicts between divers. This is common in areas where diving becomes popular or overcrowding occurs [29]. In Molokini, minimum distances are required between participants of the same activity groups, maintaining security to avoid conflicts [29]. In certain destinations, there are reports from dive guides of disputes between divers during the dive when trying to see small emblematic species such as seahorses, which have resulted in the destruction of the seabed [50]. Therefore, for better management of the activity, codes of conduct have emerged in some regions and for some of the diving offerings (e.g., shark diving) with the aim of protecting marine species [23,51]. In developing a specific code of conduct, it is essential to integrate all stakeholders in the process [52] and to consider the reality and specificities of the site/region where it will be implemented. Moreover, this measure allows diving guides to take underwater measures if necessary.

These examples illustrate that improving the awareness of divers and dive operators through education can contribute to more divers using a particular site without causing degradation. Since 1996, the importance of education has been emphasised as having an extreme relevance in raising environmental awareness and reducing the damage caused by divers in renowned diving destinations. However, although the industry has already evolved in this sense, it still shows some resistance to investing in education as a vehicle for more sustainable management of diving activities. Still, more dive operators are improving their tools to offer a more sustainable operation with less impact on nature, such as their diving briefings. This tool, if well done with all the information about the diver's behaviour and the environmental menaces of the diving activity, can improve divers' awareness of actual and potential threats, and is a beneficial management tool for awareness and conservation of marine habitats. A dive briefing can take different forms, such as conservation education dive briefings, video briefings, or predive ecological briefings, which, based on several studies, significantly decrease the frequency of contacts made by divers [35,42,53,54]. It can also contain different content, like the ecological aspects of corals [54] and other emblematic species [54], specific alerts for scuba divers with cameras and gloves [55], basic aspects of coral biology with visual materials [39], and alerts for divers to maintain neutral buoyancy [39]. In the Florida Keys National Marine Sanctuary, a dive operator has implemented a "conservation-centred briefing" that has been shown to significantly reduce the number of touches by divers per minute compared with the results obtained by the other dive companies (0.16 ± 0.08 (mean $\pm$ SE) and 0.37 ± 0.06 (mean $\pm$ SE), respectively) [53]. In conclusion, the type of briefing offered to the divers can raise divers' awareness and sensitivity as regards their impact on the marine environment. It can be adapted to each type of diver (e.g., novice, photographer), taking into consideration the characteristics of each dive site (e.g., with a vertical wall, a cave, or the presence of sensitive species). It should be prepared by experts (e.g., biologists) to be as complete as possible.

4.2. Research/Monitoring the Marine Environment

Through scientific research, we know that in various places in the world the intensive use of dive spots may have led to differences in the distribution of benthic species abundance [11,14,26,56]. Also, it has made it possible to identify some of the behavioural sources causing the environmental impacts [12,35–38]. Evidence since 2006 indicates that for effective management and protection of the marine environment from anthropogenic activities, it is essential to have a characterisation of it, together with a delineation of its thresholds within a consistent classification [12]. Therefore, the first step in recreational

diving management is to characterise the benthic community of dive sites, as benthic species are the ones that receive mechanical damage such as breakage. Monitoring of the activity and of critical indicators of vulnerability is essential to identifying mitigating management actions before setting about calculating the "carrying capacity" of the area and limiting the number of divers [16,49,57]. All this highlights the importance of scientific research to acquire greater knowledge about the management of recreational diving activity. Through research, it was possible to ascertain that the intensive use of diving places by the diving industry may lead to several negative impacts on the marine environment. That is why long-term monitoring of this activity is crucial. In general, there has been a growing evolution in scientific research and monitoring of diving activity over the last three decades; however, there is still a lack of information and management of the activity in many of the diving destinations analysed. Thus, more information needs to be generated (e.g., recent studies with new data, studies involving monitoring and evaluation) to adapt management measures to current circumstances.

4.3. Carrying Capacity Approaches

In the analysis conducted in this study, we include, under the umbrella of the carrying capacity management action group, all management actions that focus on controlling the number of divers in a particular dive spot. Demand for a diving site is dependent on several factors, such as the marine biodiversity and the geological features of the site, but also on the wilderness experience. The benefits of the wilderness experience usually decline with the number of visitors, which generates a phenomenon of congestion or overcrowding. The overcrowding effect is also magnified by the agglomeration of diving activity in the most accessible and renowned destinations. There is a generalised consensus that limiting the number of visitors to diving sites is one of the simplest management actions and can contribute to alleviating the environmentally negative impacts of divers on the ecosystem [25,58]. Primarily, the concept of carrying capacity is developed for terrestrial sites and is the "maximum number of visitors" that a particular geographical place can carry. It was developed as a management instrument to ensure that the number of recreational visits to a wilderness area would not degrade the quality of the recreation experience and would maintain its biological and ecological functions [59]. One of the main problems of applying the concept to marine sites and scuba diving is the feasibility of excluding divers from a particular site [15]. The second problem arises from pursuing two main objectives: preserving the quality of the recreational experience and maintaining biodiversity and ecological functions. The first empirical application of the carrying capacity concept to a marine environment was used for the Bonaire Marine Park and reached the conclusion that diving had no significative effects on fish communities, but even low diving levels had an impact on coral colonies [11,60]. The majority of subsequent studies focused on the effects of divers' behaviour on coral communities and identified both short-term and cumulative effects [1]. A second group of empirical studies on non-tropical rocky reefs addressed the identification of the bio-indicators of diving impacts [13,45,56].

The development of scuba diving tourism and reef-based tourism led to a growing concern with the management of the recreation experience and a growing number of studies using the concept of social carrying capacity. The number of divers encountered, as well as the expectations about the experience, are key factors that affect the satisfaction and the quality of the diving experience. Some divers are willing to pay more to avoid encounters, while others choose specific destinations to avoid crowding.

In summary, recreational scuba diving has both ecological and social effects. The activity impacts species richness and distribution, coral reef complexity and biodiversity, and the stability of microhabitats, but also diver satisfaction. Neither of the two concepts described above can synthesise in one number a threshold that simultaneously preserves the ecological factors and guarantees a sustainable and enjoyable experience. As summarised by Zhang et al. (2016) [61], there no such thing as a magic number, and empirically, there is no generally accepted method to estimate it. The carrying capacity for diving sites depends

on a conjunction of factors that may vary between sites, namely, the presence of vulnerable species, the level of certification and environmental awareness of the practitioners involved, and the presence of various anthropogenic factors that deteriorate the ecosystem, such as suspended particulates (e.g., [17]). All this leads to the conclusion that these factors need to be considered for tropical coral reefs and subtropical reefs, as both are equally susceptible and vulnerable to diver impacts [62]. The relationship between the number of divers and measured impact is assumed to be linear in most empirical studies; however, the hypothesis that it could have a J form has been suggested [60], which may mean lower and acceptable impacts up to a critical level, after which rapid degradation sets in. The empirical evidence suggests that carrying capacity is a necessary tool in a more general management framework. With the growing tourism activity in marine environments and the growing numbers of divers concentrated in popular diving hotspots, the ecological carrying capacity is a useful tool to set a threshold for precautionary maximum levels of activity that preserve the marine environment and satisfaction with the diving experience.

In marine tourism and recreational scuba diving, the different definitions of carrying capacity may contribute to equivocal empirical applications, as different thresholds exist for biological and social carrying capacity. Seidl and Tisdell (1999) [63] argue that instead of focussing on the number of visitors, we should focus on site conditions and the impact of visitor numbers on the ecological ecosystem. The concept of ecological carrying capacity [60], interpreted as the maximum number of visitors a diving site can sustain in a specific time frame without "unacceptable damage", provides a better conceptual framework. The definition of unacceptable damage can be traced to a specific management framework, within which managers establish how much damage or how much change the social system can support [64,65]. By setting limits on damage, the managing and planning framework can define a path to a strategy for the development of a more environmental and social activity.

4.4. Adaptation of the Diving Industry

The management action group analysed, diving industry adaptation, encompasses measures whose main objective is to improve the operation of the activity and minimise its impact on the marine environment. Measures are associated with stakeholders that are part of the SDTS, such as divers, dive operators, and diving schools [19]. Interaction with other stakeholders such as local communities, recreational fishing operators, local authorities, and policymakers has been suggested [9]. All these stakeholders interact in managing the activity, adopting management measures, mitigating impacts, addressing conflicts in multi-use sea spaces, and supporting an environment that ensures economic sustainability and the wider sustainability of the industry [19,66]. These multiple stakeholders share a heterogeneity of interests, but it has been argued that scuba dive operators have a personal stake in the conservation of diverse marine life and in the conservation of small coral areas [67,68]. Borrowing from ICM methodology, it has been argued that a management strategy that takes multiple stakeholders into account must invest in proper communication and participation in the management processes [66].

A range of ad hoc measures deal with the impact of the activity on the marine environment and the preservation of quality dive sites. One example of a specific measure resulting from industry adaptation is the use of buoys so that the descent and ascent of divers have a reference in shore dives, consequently preventing the destruction of marine habitats common in this type of diving, which has a greater impact than diving from a boat. This is related to the fact that divers start and end their dive in a sand zone [47]. On the southern Caribbean island of Bonaire, only vessels over four metres are allowed to anchor, and in the case of fishers, only those using "stone anchors" are allowed [14]. Thus, a mooring system for dive operators and other boats has been installed for this purpose. Also, when divers arrive on the island, they need to take part in a briefing on the marine park, as well as participate in an orientation dive, both of which are provided by the host operator. In this case study, there is a clear adaptation of the diving industry.

As mentioned above, one of the measures that has been implemented by dive operators is entry points over sandy areas, away from coral reef areas [55,69]. This measure may have other associated measures as suggested by different authors, such as definition of the distances between entry points (e.g., 30 m apart, 12 m apart), maximum limit on the number of divers that can descend at each point at a time (e.g., 9 divers, 10 divers) [18,70], and minimum distances between those participating in the same activity groups [29]. There are other measures whose implementation could provide added value, like the planning of dive routes by operators so that sensitive habitats and species are not disturbed [71]. An example of the success of this measure is the Algarve (Portugal), where the underwater routes pleased those who visited them [72], promoting environmental awareness in situ. All the above examples show that the diving industry has been adapting and should continue to adapt to provide better and safer diving experiences with less negative impact on marine ecosystems. Only then can there be more sustainable diving activity.

4.5. Economic Values/Mechanisms

The management action group studied, economic values/mechanisms, comprises measures related to the economic value of the activity and, consequently, the local economy of diving destinations. User-pay fees for divers have been studied either for access to marine parks [73] to finance conservation [74] or simply as an instrument to manage specialist activities such as diving with sharks [15,18,75]. Access fees are suggested as an instrument to manage demand while generating revenue for park management and conservation. Most access fees are set below what divers are willing to pay [76], and in most cases, the revenue generated is not used to fund marine conservation or enforce activities. Willingness to pay for fish diversity, pristine coral, and the presence of megafauna such as sea turtles, mantas, and whale sharks is well above the values set for the majority of diving access fees [77]. The design of new fee structures, which take the value of heterogeneity into account, in studies on the willingness to pay has led to a new discussion about the use of other pricing techniques such as discriminatory pricing [78]. The potential of privately managed marine reserves and co-managed marine reserves is another example of the use of economic mechanisms at the local level in the Philippines and Malaysia [79].

While scuba diving is a market service and divers pay a competitive market price, it can be argued that this market price does not consider the use of marine public goods such as fish diversity, coral quality, and the uniqueness of the diving experience. Divers pay a price for a diversity of services provided by operators, such as accessibility to spots and equipment use, but the perceived value of a dive is greater than the price. In accordance with the research of Schoeman et al. (2016) [80], the value of tourism products can be calculated by taking tangible (e.g., marine biodiversity) and intangible (e.g., diving experience) elements into consideration. The diving tourism product is intangible; however, through the diving experience a value (e.g., emotional, functional, social, epistemic) is created that influences the satisfaction of those who practice it. Therefore, the diving industry should not underestimate the relevance of the intangible aspects of the diving experience and should focus on them in its marketing, product development, and day-to-day diving activities. In addition, they cannot neglect the aesthetic value of the dive sites because they are one of the most crucial factors in convincing visitors to come to the destination, so their maintenance should be considered a priority [81]. The diving industry can use the theme of newness in marketing strategies and keep the market up to date with product changes and new opportunities through social media, e.g., Facebook, Twitter, and Instagram [80]. Besides that, they should motivate tourists to share their positive experiences and stories with others using the same communication platforms, because satisfaction significantly influences storytelling intention [82].

The case studies analysed deal with a "very rigid economic system". In the Portofino MPA, the resident population recognises the relevance of the marine environment to their livelihoods but, antagonistically, does not want the tourism sector to be regulated. There are few employment opportunities, mainly because they do not invest in innovation and

because the local population mostly serves only high-income tourists. Moreover, the facilities of the tour operators are located outside the area in which they operate, which excludes the participation of the population in the operations and, consequently, has resulted in a decrease in the number of residents in Liguria [3,83]. But the economic benefits of recreational diving (when professionally managed) for the coastal tourism sector can translate into multiple gains for the local population. This is more significant in the case of poorly diversified, small island economies.

4.6. Stakeholder Engagement

Another, no less important management action, stakeholder engagement, includes the measures related to the involvement of all stakeholders related to the SDTS, stakeholders contributing with social and cultural resources, and government (e.g., policymakers and managers). Since 2014, the focus on the importance of effective stakeholder engagement in more sustainable management of diving activity has increased [68]. The measures analysed suggest that the work of stakeholders needs integration (e.g., managers with dive operators, scientists with policymakers) to identify the desired ecological and social states for a given region and/or dive site. This is in line with what is suggested by Augustine et al. (2016) [84]. Stakeholders like scientists and policymakers need to be open to the use of different approaches, such as empirical knowledge from stakeholders, expert judgement, policies in place, habitat and/or species mapping, and spatially explicit modelling, to demonstrate how the integrity of the marine environment is interlinked with human well-being. With the knowledge acquired, the gaps can be filled with balanced management measures at all levels, ecological, social, and economic, as suggested by [85]. In decision-making processes, with respect to marine spatial planning, dive operators should be consulted [86]. It is essential that there are effective communication channels between all stakeholders [3] and that all, especially local ones, are included through consultation and public participation during the entire planning process, as argued by Tsilimigkas and Rempis (2021) [21]. Furthermore, management rules need to be transparent, and the form of communication should be as clear as possible, as stakeholders are often concerned about corruption and mismanagement of the activity. An example of an important stakeholder contribution is when developing a code of conduct (e.g., region-specific, site-specific) [41]. In conclusion, different authors agree that there is a need for a conversation between all stakeholders in dive tourism about the steps to take to obtain a more sustainable dive industry.

4.7. Zoning

Management measures could have another field of action besides that presented above. In the research performed, the authors find that spatial zoning strategies and spatial planning tools like temporal zoning are used in diving activity management. For example, managers can rearrange the diving district/zone for each dive through spatial zoning strategies to permit divers to be visible at one time. This measure reduces the number of diver encounters without reducing the number of permitted divers in each dive site [18]. Also, it can be applied to separate divers through spatial zoning for interpersonal conflict resolution, as mentioned above and according to [87–89]. Zoning can also be used to identify dive sites that are sensitive to divers' impacts and where diving should not occur, such as shallow-water, coral-rich zones [90]. It can still contribute in another way to the activity for [91]; an appropriate zoning scheme with established criteria for the use of local ecosystem services (considering the specific environmental and socioeconomic conditions) could be a good measure for small islands with fragile ecosystems.

Temporal zoning, in conjunction with increased fees, could be implemented to decrease usage and maintain the profitability of dive sites and access for dive operators [33,89]. This measure and the staggering of visiting times are solutions that have also proved effective in resolving interpersonal conflicts at dive sites [29]. For Ha et al. (2020) [34], diving tourism destinations should implement zoning systems based on the perspective of spatial behaviour. In conclusion, the measures analysed show that it is possible to implement

zoning strategies in diving destinations and simultaneously make a profit from their implementation, for example, through the implementation of temporal zoning alongside fees. Also, zoning can be an efficient way of organising dive operations at dive sites, avoiding interpersonal conflicts between divers.

4.8. Governance and Public Policy

Under the umbrella of the management action group, governance, and public policy tools, the measures analysed have a focus on developing and redesigning appropriate policy instruments, such as policies/rules and legislation/regulation of diving activity, as well as measures that suggest surveillance of the compliance of these instruments after their implementation. Scuba diving tourism is mostly a self-regulated, market-oriented activity, with operators accepting common standards for the training and safety of participants [87]. Evidence of the negative environmental impacts of scuba diving led training organisations to develop guidelines for best practices and the Green Fins code of conduct, with the main purpose of mitigating the effects on coral reefs [92]. Enforcing marine park regulations and promoting site substitution policies was suggested by Abidin and Mohamed (2014) [25].

In a case study of the Azores scuba diving industry, the first step to manage shark diving activity is designing appropriate legal frameworks, according to Bentz et al. (2013) [23]. For these authors, laws/rules can lead to mandatory controls on the number, qualifications, and operations of shark diving businesses, but only if compliance with the law and the rules developed and implemented is subsequently monitored.

Another avenue for public policy is a regime that licenses scuba operators, considering the environmental state and the diving pressure in a particular spot [93]. Compliance with regulations and surveillance of the industry activity is another proposed avenue [31]. Conservation of marine life through the creation of MPAs and their effective management is becoming more relevant in the Caribbean Sea and the Indian and Pacific Oceans, either using regulatory public instruments, community initiatives, or private third parties. In summary, as argued by Lucrezi and Saayman (2017) [93], there is an ongoing debate on different approaches for governance, such as the self-regulatory framework [94], third-party control of the industry [67,94], and a meta-governance framework as suggested by Hunt et al. (2013) [92]. The high growth of scuba diving tourism in both protected and unprotected areas creates an urgent need for policies that address the impacts of divers and diving operations on marine biodiversity and habitats to allow preservation of diving sites. Yet caution is need when designing or reformulating policies so that they do not undermine the different key elements of the SDTS.

4.9. Adaptive Management Approaches and Economic Values/Mechanisms

The literature review also showed that there is a greater focus on adaptive management measures for diving activity. Adaptive management is an iterative process of change in management actions/measures based on continuous monitoring and new practices centred on social learning. Adaptive management benefits from stakeholder participation and addresses environmental, social, and economic concerns. That is why an increasing demand for management frameworks in the context of scuba diving and empirical studies to develop synthetic indicators [95] provides a more structured approach to assist managers and stakeholders in developing mitigating and adaptive actions. The following managing frameworks have been identified in previous studies: (i) a carrying capacity approach [8,60,96] (ii) a limits of acceptable change management framework [64,95], (iii) a percentile-based management framework [97], (iv) a discriminatory pricing framework [15], (v) a systems approach to collaborative management [19], and (vi) an adaptive management framework [98]. Also, adaptive dive management must be based on the characteristics/particularities of each dive site because each dive site has its own identity. Furthermore, it should be evaluated through scientific monitoring [99].

Integrated coastal management (ICM) plans and dive plans for diving sites are also listed in the literature as good management strategies [24,100,101]. This type of plan can

have different contents and should take into consideration certain aspects, such as the importance of beginner and occasional diving tourism [102]; the marine conditions to which divers are exposed and whether they correspond to their level of certification (e.g., training of divers and introductory dives should occur in places with no coral cover) [24,102]; and the damage of marine ecosystems by divers, which can be avoided through educational interpretative tools [101]. The implementation of artificial coral reefs is another strategy often referred to in the literature. These artificial structures can mitigate the negative impacts caused by divers on nature [25,35] and, consequently, reduce stress levels [24]. They are sometimes present at or close to dive sites (e.g., shipwrecks, anchors); however, their construction is allowed if they do not occur spontaneously. It is quite possible that in the near future it will be necessary to implement artificial reefs in MPAs to give the dive hotspots time to recover [87]. This action involves diverting divers from overloaded reef zones to artificial areas, as recommended by the authors of [61]. The list of management approaches does not end here. An adequate system of discriminatory fees and prices to attract divers could be a strategic tool to control the number of visitors, thus mitigating possible damage to the ecosystem [33,62,76,103]. It constitutes a feasible management response to decrease encounters between divers without leading to a reduction in the total number of divers simultaneously at the same dive site [18]. Fees collected from the activity can be used for the preservation and maintenance of coral reefs, including proper monitoring and awareness-raising campaigns targeting the industry for developing more sustainable activity, as is suggested by the literature [35]. Another solution to achieve better management of sensitive ecosystems is "no-take marine reserves", where fishing and diving activities are totally banned [37,104]. This policy action is fundamental to providing the basis for long-term sustainable utilisation of the coral reefs, for example, surrounding the islands of Curaçao and Bonaire and in Brazil. All these adaptive management approaches have emerged and improved over the years to protect the marine environment and to invest in a more sustainable recreational diving activity.

5. Conclusions

This paper addresses the question of how the management of recreational diving activity is considered in the literature and in studies worldwide. The bibliographical review of the last three decades shows a growing and widespread concern with the negative impacts of recreational diving on marine ecosystems. Thus, a large panoply of management measures for recreational diving activity addresses the negative impacts generated by divers' behaviour, the impact of an excessive number of divers in sensitive sites, and the dependency of the activity on a sustainable marine environment providing attractive experiences. These management proposals, scattered among different studies and documents, lack a framework in a strategy for more holistic management. By building criteria blocks to structure a systemic organisation of the management measures, a more informed vision of the existing knowledge and its gaps is provided. There are studies/publications focusing on certain criteria blocks and management actions; "awareness" is the most robust management action group of the eleven identified, with a large number of publications, especially in the pre-pandemic period (2012–2017). The results of this criteria group demonstrate the growing concern in alerting the different stakeholders involved in the scuba diving activity to its negative impact and consequences in the marine environment. The strong presence of the "research/monitoring" management block of measures indicates that a large number of studies and monitoring of the activity on the marine environment already take place, but no assessment of the effectiveness is provided. New management approaches to scuba diving are emerging, and these call for sustainable management of the activity.

Certain identified and important criteria blocks continue to be less supported by research. Only 8% of the studies analysed suggest using carrying capacity approaches to limit the number of divers in dive sites. Carrying capacity approaches, in general, address the evaluation of the social carrying capacity and, consequently, the analysis of the physical carrying capacity, for which methods already exist. Understanding the maximum

limit of visits that a dive site can have daily, considering only the visiting factors (e.g., time and length of visit), as well as the available space per diver, is not sufficient because only the social effects are considered. Thus, to synthesise in one number a threshold that simultaneously preserves the ecological factors and guarantees a sustainable and enjoyable experience, it is necessary to consider the assessment of both the social and ecological carrying capacities. Therefore, a knowledge gap associated with the evaluation of the ecological carrying capacity of dive sites is identified. This is crucial to the development of an integrated management and monitoring model that encompasses ecological carrying capacity assessment in further research. This assessment of scuba diving activity must consider setting a threshold for precautionary maximum levels of activity that preserve the marine environment and satisfaction with the diving experience.

Additionally, this study provides a vision of future challenges for the sustainable management of diving activity that includes (1) operational implemented management measures; (2) long-term monitoring of the activity and dive sites (for more than 10 years) as a means to understand the real impacts of diving and the effectiveness of the management measures applied; (3) improving training schemes in order to promote low-impact diving techniques; and (4) in the short term, establishing applicable limits on the number of divers at dive sites through carrying capacity evaluation, especially using the ecological carrying capacity method.

Finally, the perception that a comprehensive approach that leads to the recommendation of designing a governance framework that enhances regular stakeholder participation with the inclusion of all participators in the "Scuba Diving Tourism System", based on integrated and adaptive management approaches, is urgently needed.

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