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Review

Biosphere Reserves' Management Effectiveness—A Systematic Literature Review and a Research Agenda

Ana Filipa Ferreira [1,2,*], Heike Zimmermann [3], Rui Santos [1] and Henrik von Wehrden [2]

1 CENSE—Center for Environmental and Sustainability Research, NOVA College of Science and Technology, NOVA University Lisbon, 2829-516 Caparica, Portugal; rfs@fct.unl.pt
2 Institute of Ecology, Faculty of Sustainability and Center for Methods, Leuphana University, 21335 Lüneburg, Germany; henrik.von_wehrden@leuphana.de
3 Institute for Ethics and Transdisciplinary Sustainability Research, Faculty of Sustainability, Leuphana University, 21335 Lüneburg, Germany; heike.zimmermann@leuphana.de
* Correspondence: afdinisferreira@gmail.com; Tel.: +351-21-294-8397

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Abstract: Research about biosphere reserves' management effectiveness can contribute to better understanding of the existing gap between the biosphere reserve concept and its implementation. However, there is a limited understanding about where and how research about biosphere reserves' management effectiveness has been conducted, what topics are investigated, and which are the main findings. This study addresses these gaps in the field, building on a systematic literature review of scientific papers. To this end, we investigated characteristics of publications, scope, status and location of biosphere reserves, research methods and management effectiveness. The results indicate that research is conceptually and methodologically diverse, but unevenly distributed. Three groups of papers associated with different goals of biosphere reserves were identified: capacity building, biodiversity conservation and sustainable development. In general, each group is associated with different methodological approaches and different regions of the world. The results indicate the importance of scale dynamics and trade-offs between goals, which are advanced as important leverage points for the success of biosphere reserves. Building on the gaps identified in the literature, a research agenda is proposed, focusing on the need to investigate mechanisms for holistic research, outcomes and trade-offs, transformations for social-ecological fit and institutions for integrated management across scales.

Keywords: biodiversity conservation; biosphere reserve; leverage points; management effectiveness; research agenda; social-ecological systems; sustainability science; sustainable development; systematic literature review; trade-offs

1. Introduction

Biosphere reserves are privileged places to understand how to sustainably manage and govern social-ecological systems [1] and to advance sustainability science [2,3]. The World Network of Biosphere Reserves (WNBR) currently contains 701 designated sites, distributed over 124 countries [4]. The relevance and broad interest in the biosphere reserve enterprise does not translate, however, into a successful implementation, as there is a considerable gap between the concept and its practical realization [5–7]. Research about biosphere reserves' management effectiveness can provide a better understanding of why there is this gap [1,8,9], what is its extension [10] and how it can be closed [11–13]. However, there is a limited understanding about where and how the research about biosphere reserves' management effectiveness has been conducted, what topics have been investigated and which are the main findings. This study addresses these gaps in the literature.

Biosphere reserves are the means of implementation of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and Biosphere (MAB) Program [2]. The first biosphere reserves were designated in 1976 in eight countries [14] and were focused on the protection of natural and genetic diversity and in supporting ecological and environmental research and education [15]. Most of them were superimposed in already existing protected areas [6]. However, with the adoption of the Seville Strategy and the Statutory Framework [16], a more integrated approach, that remains as a cornerstone of the program, was implemented. According to the Statutory Framework [16] and the most recent MAB Strategy [2], biosphere reserves have four main goals: (1) the conservation of biodiversity, sustainable use of natural resources and restoration of ecosystem services; (2) sustainable human and economic development, and promotion of healthy and equitable societies; (3) logistic support to research and environmental education and the facilitation of sustainability science and education for sustainable development; and (4) contribution to the mitigation and adaptation to climate change. The Statutory Framework [16] also determined the criteria required for the designation of a biosphere reserve, which includes an appropriate zoning scheme with three areas, associated with different degrees of use of natural resources, and a participatory governance body that includes a diversity of actors. The periodic review process, which evaluates the conformity of biosphere reserves with the designation criteria every 10 years, was also adopted with the Statutory Framework. This is the only existing mechanism that evaluates the implementation of biosphere reserves, however, it provides limited information because it is more focused on the compliance with the designation criteria, than with effectiveness in achieving the goals [17]. Besides that, there is a high rate of non-response and delay, and periodic review reports are not widely available [17].

Following the definition adopted in the literature of protected areas [18], biosphere reserves' management effectiveness is how well biosphere reserves are being managed, i.e., the extent to which they achieve the goals for which they are designated. Management effectiveness integrates three dimensions: design, adequacy of processes and delivery of goals [18]. Existing scientific literature related with biosphere reserves' management effectiveness have mainly focused on identifying general factors that influence the success of biosphere reserves [8,19] or in determining compliance with the designation criteria, through the analysis of periodic reviews [6,10]. Only one large-scale study investigated the relationships between processes—participation in implementation and decision-making—and the achievement of the goals of biosphere reserves [20]. Therefore, most of the large-scale studies have focused more on the design and process dimensions of management effectiveness than on a more holistic analysis that also includes the delivery of goals. Moreover, the studies frequently rely on the analysis of the opinions of experts of biosphere reserves, such as managers and scientists [8,19,20], excluding other forms of determining and perceiving the effectiveness of biosphere reserves' management.

The conceptual framework developed by Ferreira et al. [1] summarizes the most important factors to be considered in biosphere reserves' management effectiveness, according to a more holistic approach. This framework highlights four main categories—context, inputs, processes and outcomes—and 53 subcategories that interact at different scales. However, it is still poorly understood how the relationship among these subcategories may reflect the success of biosphere reserves. To contribute to a better understanding, this study accesses how the current scientific literature is related according to these subcategories. The scientific literature analyzed in this study was retrieved from Ferreira et al. [1], and re-coded according to the presence/absence of each subcategory from the same framework. Further data was collected to provide a comprehensive overview of the scientific literature related with biosphere reserves' management effectiveness: information about the publications (e.g., publication year and affiliation of the author), scope, status and location of the biosphere reserves studied, and the methods used in the research. The results demonstrate the existence of bias and gaps in the field that were used to develop a research agenda about biosphere reserves' management effectiveness, in order to inspire and advance inquiry about this important topic.

2. Materials and Methods

2.1. Data Collection

2.1.1. Selection of the Papers

The selection of the papers used in this study results from the systematic literature review conducted by Ferreira et al. [1], to develop a conceptual framework that summarizes which factors are important to biosphere reserves' management effectiveness. An overview of how the papers were selected is given here, however, a more profound description can be found in Ferreira et al. [1]. A literature search was conducted in the Scopus database on 10 March 2017 (search string in Appendix A).

Only peer-reviewed papers published in English were included. Papers published before 1996 were excluded in order to focus the analysis on the more integrative approach which biosphere reserves have adopted after the Statutory Framework [16]. The abstract, title and keywords of 2286 potentially relevant papers were screened against the following inclusion criteria: (i) engagement with the biosphere reserve concept; (ii) useful to understand management and governance of biosphere reserves; and (iii) is an empirical study. Another reviewer evaluated 10% of the papers to identify disagreements in the paper selection process. From the 177 papers downloaded (9 papers were not accessible), those that performed comparative analysis [10,21] were excluded, to obtain only the studies that were developed in one biosphere reserve. Research conducted in biosphere reserves that were not present in the UNESCO databases in June 2017 [22,23] were also excluded, such as the study of Schmidt et al. [24] that was developed in a biosphere reserve yet to be designated. The references of the 66 publications obtained are disclosed in Table A1. The search string used, and the selection process, ensured a high specificity for peer-reviewed literature related to management and governance of biosphere reserves. This explains why only a small part of the existing scientific literature was included. Similar results were obtained in a bibliometric analysis of biosphere reserves' research [25]: most of the existing research is developed in the biosphere reserves, but not necessarily about them.

2.1.2. Definition of Subcategories

To analyze the literature, a set of categories and subcategories were defined, related to four main topics: (i) features of the publication; (ii) scope, status and location of the biosphere reserve where the study was developed; (iii) methods used in the research; and (iv) management effectiveness (Table 1).

Table 1. Main categories used to review the publications related to biosphere reserves' management effectiveness: features of the publication, scope, status and location of the biosphere reserve, research methods and management effectiveness. MAB—UNESCO Man and Biosphere Program; BR—Biosphere reserve. Subcategories are listed in Table A2.

Publication	Biosphere Reserve Scope, Status and Location	Research Methods	Biosphere Reserves' Management Effectiveness
Publication year Journal subject area Affiliation of the author	BR name Transboundary BR? Withdrawn BR? Designation year Location	Methods—data collection Actors enrolled Methods—data analysis	Context Inputs Process Outcomes Scale *

* Context, inputs, process and outcomes subcategories were coded for their relevance at international or national/regional scales.

A total of 147 subcategories were used to review the papers (Table A2). They were adapted from existing classifications, such as the classification of countries according to the UNESCO MAB regions [22], or inductively developed, e.g., the subcategories of research methods. To analyze the main findings concerning management effectiveness, the framework developed by Ferreira et al. [1] was used. This framework describes 53 general factors, grouped in four main categories—context,

inputs, processes and outcomes—which were identified as important for understanding biosphere reserves' management effectiveness. An overview of the framework subcategories is given in Table A3.

Data about the publication was retrieved from ELSEVIER [26], and data about the biosphere reserves was retrieved from UNESCO databases [22,23]. Data about the research and biosphere reserves' management effectiveness was coded in the 66 papers using MAXQDA Plus ver. 12 (VERBI Software, Berlin, Germany) [27]. To accommodate information that did not fit in the defined subcategories, "other" options were included. Coding was only performed in the Results section of each paper. Text from other parts of the paper was coded, if necessary, to understand the results. Multiple codes could be assigned to the same text segment. The text was interpreted in order to associate text chunks to the codes, guided by the definitions of each of the subcategories. All aspects of the social-ecological systems where biosphere reserves are implemented, and the management and governance systems in place, were coded.

2.2. Data Analysis

To access the main patterns in the data, descriptive statistics was used in R ver. 3.4.3 (R Foundation for Statistical Computing, Vienna, Austria) [28]; plots were developed using the ggplot2 package for R [29]. A cluster analysis [30] was performed to identify groups of publications that address biosphere reserves' management effectiveness in a similar way. The variables, the clustering method and the number of clusters were determined in a back-and-forward procedure. A database with the presence/absence of context, processes, inputs and outcomes subcategories (n = 53) in the 66 papers was used (Table A2). A distance matrix was developed using the Jaccard Index, as implemented in the vegdist function of the vegan package for R [31]. After testing different clustering methods, the ward.D was selected to continue the cluster analysis because of its interpretability and the strong clustering structure, as revealed by the agglomerative coefficient (Table A4).

The optimal number of clusters was determined by evaluating and interpreting different cluster solutions in relation to the generality and specificity of the results. Multidimensional scaling (MDS) was also used to determine if groups in the data can be visually identified. Vectors of external variables significantly correlated with the dissimilarities among papers were fitted in the MDS, as implemented in the envfit function of the vegan package for R, in order to explore the influence of: (i) the methods used for data analysis, (ii) the MAB region where the study took place and (iii) if the study was conducted in a biosphere reserve designated before or after the Statutory Framework.

The dissimilarities among the groups of papers obtained from the cluster analysis were investigated by conducting a permutational multivariate analysis of variance (PERMANOVA), using the Jaccard distance matrix and 999 permutations, as implemented in the adonis function of the vegan package for R [31]. The analysis was repeated for each pairwise comparison among clusters. The regression coefficients from each PERMANOVA were used to identify the subcategories that most contributed for the dissimilarities among the clusters tested.

The proportion of papers that refer each subcategory in each cluster was computed, to identify the common subcategories that are very frequently referred (in more than 70% of the papers included in each cluster).

To analyze the outcomes, the subcategories of social benefits, empowerment and learning were merged in "positive social outcomes"; and the subcategories of social impacts and inequality were merged in "negative social outcomes". Then, the number of papers that refer a given positive or negative outcome (environmental, social, cultural or economic) in each biosphere reserve was summed.

To evaluate the importance of scales in management effectiveness, the proportion of papers that refer each subcategory at international or national/regional scales was calculated, in relation to the total number of papers that refer each subcategory.

3. Results

3.1. Characteristics of the Publications

From 1998 to March 2017, the number of publications related with management and governance of biosphere reserves have generally increased, despite annual variations (Figure A1). The number of studies published in journals related to environmental or social sciences is higher than in other fields of research (Figure A2).

The first authors of the analyzed papers have affiliations in Europe and North America (57.6%), Asia and the Pacific (25.7%), and Latin America and the Caribbean (16.7%). The relationship between the author's affiliations and the region where the study was developed is represented in Figure 1. Authors from Europe and the USA and Canada have developed studies in a diversity of MAB regions. About 87% of the research from lead authors from USA or Canada is developed in the Latin America and the Caribbean, and none in their own biosphere reserves. Authors from Europe, Asia and the Pacific, and Latin America and the Caribbean have developed studies mainly in their own respective regions.

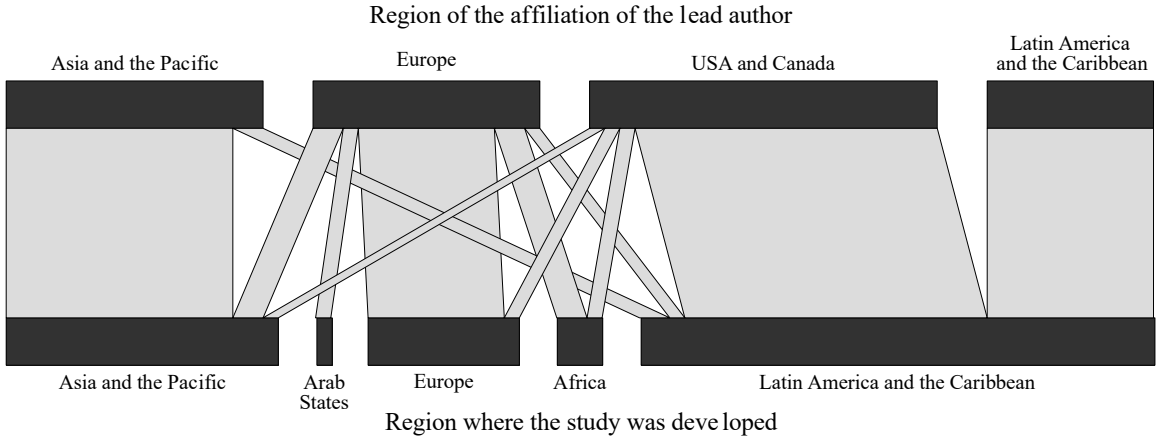

Figure 1. Network visualization of the MAB regions where the lead authors of the reviewed studies are affiliated (upper row) and the MAB regions where the studies were developed (inferior row). The MAB region "Europe and North America" is divided in "Europe" and "USA and Canada".

3.2. The Biosphere Reserves Studied

The papers analyzed performed their research in a total of 38 different biosphere reserves (Table A5). The higher number of studies was conducted in the Maya (Guatemala), Nanda Devi (India), Wolong (China), Danube Delta (Romania/Ukraine) and El Vizcaíno (Mexico) biosphere reserves. Two transboundary biosphere reserves were analyzed—Gerês/Xurés, in Portugal and Spain, and the Danube Delta, between Romania and Ukraine—however, only the study in Gerês/Xurés was performed for the entire transboundary biosphere reserve. At the time the data was analyzed, none of the investigated biosphere reserves have withdrawn the network. The biosphere reserves studied were designated between 1977 and 2012; 42% before and 68% after the adoption of the Seville Strategy.

In total, single case studies about management/governance were performed in about 6% of the designated biosphere reserves. The countries where more than three studies were performed are: Mexico (n = 21), Guatemala (n = 9), India (n = 8) and China (n = 7). Among the countries with a higher number of sites designated, only Mexico and China have studies developed in more than 10% of their biosphere reserves (Figure 2).

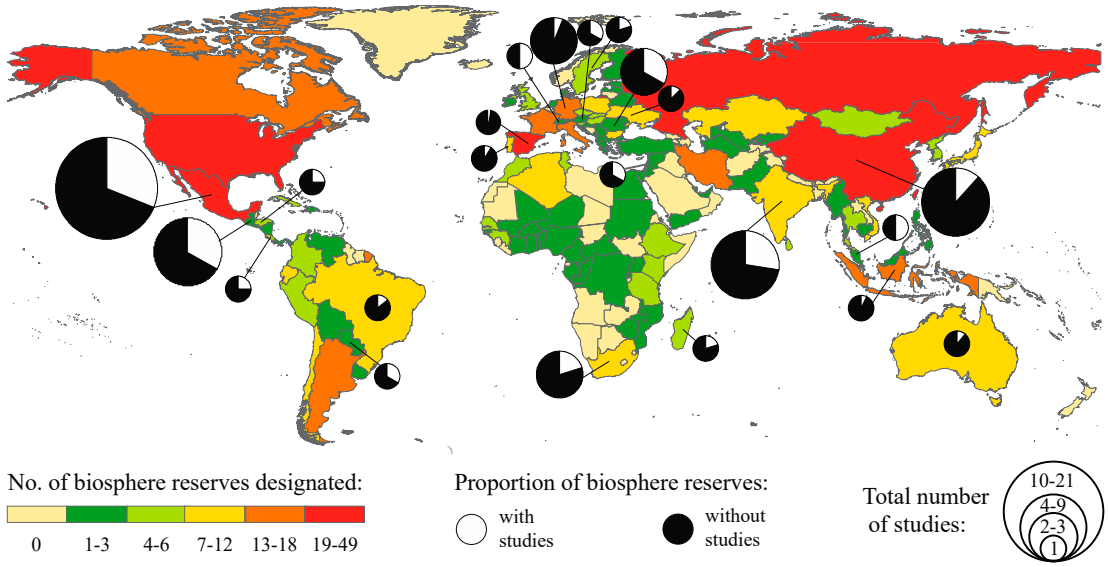

Figure 2. Number of biosphere reserves designated in relation to the number of case studies reviewed by country. The proportion of biosphere reserves with studies vs. without studies by country is represented, respectively, by the white and black fill of the circles. The size of the circle represents the total number of studies by country. Each country is colored according to the number of biosphere reserves designated.

3.3. Research Methods

Studies related to biosphere reserves' management effectiveness have used a median number of three different methods for data collection (Figure A3a), mostly interviews, document analysis and observation (Figure 3a). Almost 91% of the studies involved actors in data collection. Half of the studies involved two different actors (median, Figure A3b), mainly local communities and governmental actors (Figure 3b).

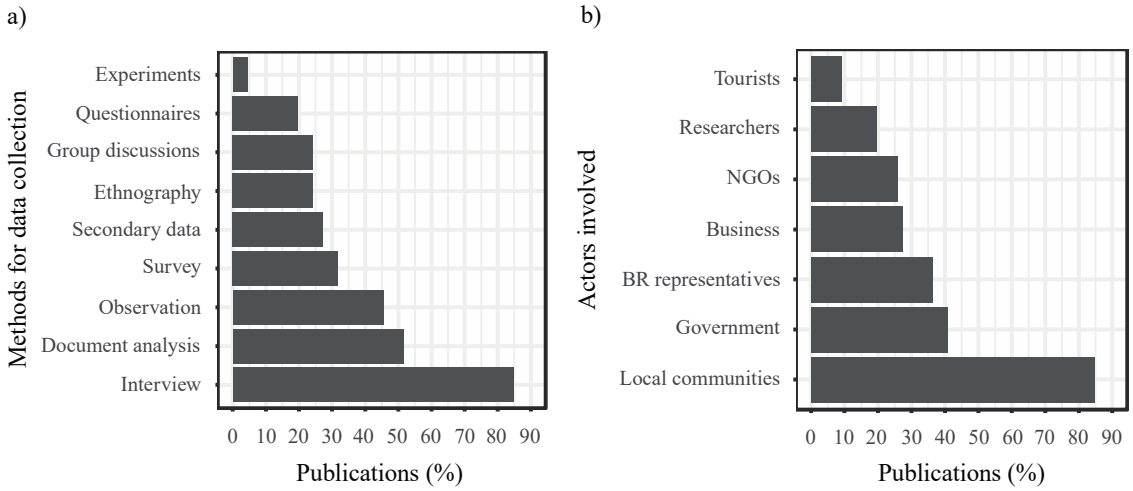

Figure 3. Proportion of the papers in relation to: (**a**) the methods used for data collection; (**b**) the actors involved in data collection. MAB—Man and Biosphere Program; NGOs—Non-governmental organizations.

Considering the data analysis, qualitative methods were used in about 58% of the papers alone; in about 29% of the papers, mixed qualitative and quantitative methods were used; and exclusive quantitative methods were used in only 13% of the papers.

3.4. Biosphere Reserves' Management Effectiveness

3.4.1. Cluster Analysis

A cluster analysis was developed to assess how the scientific literature is related according to the subcategories of biosphere reserves' management effectiveness [1] (Figure 4). A partitioning with three clusters provided the ideal trade-off between specificity and generality of the results (Figure A4). This solution achieved a high agglomerative coefficient (0.87; maximum of 1), however, according to the cluster evaluation statistics (Table A6), there is some uncertainty about which papers should be clustered together. The MDS (Figure 4b) also show some overlap between the groups, in particular between clusters #1 and #2.

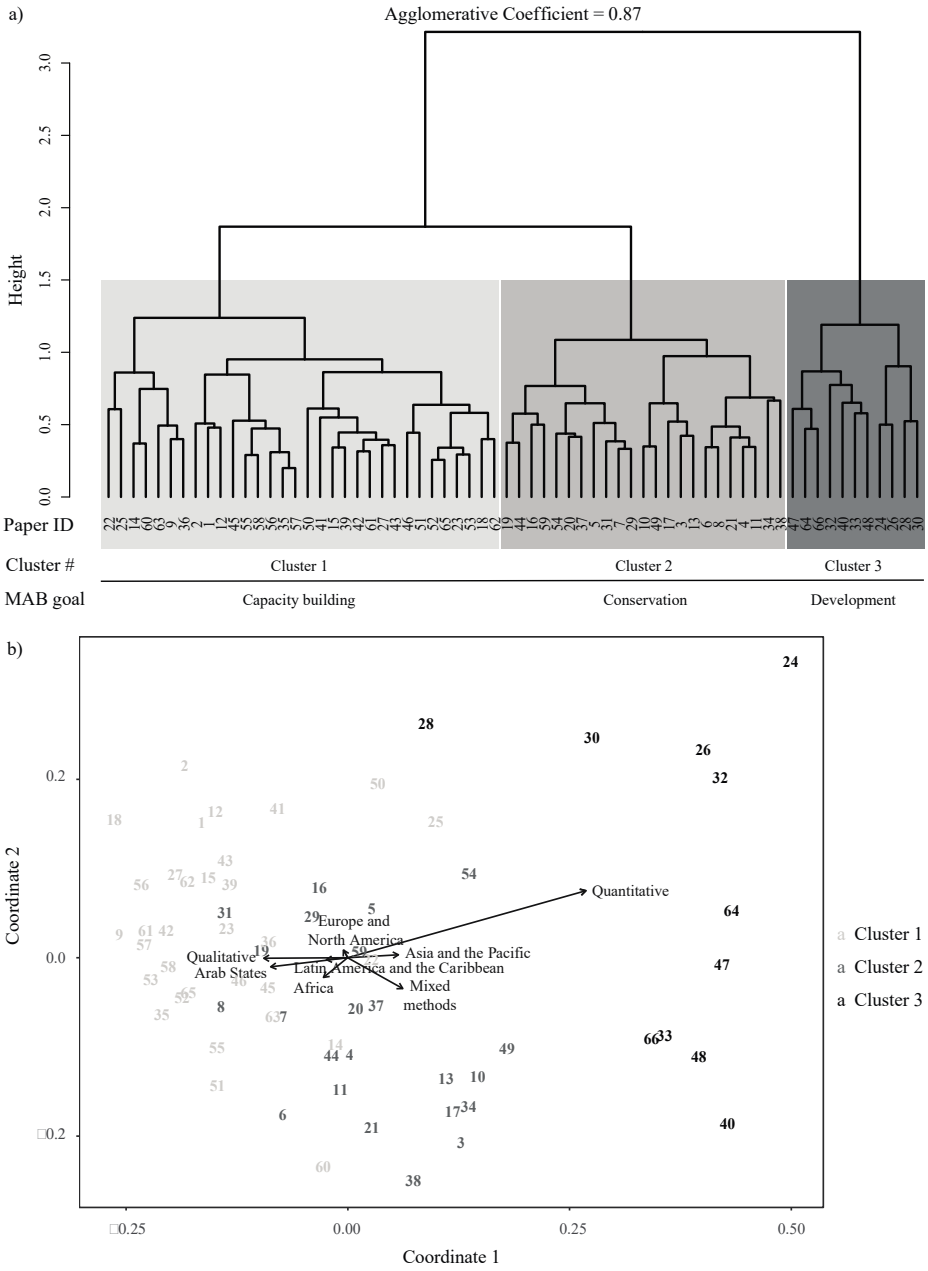

Figure 4. Cluster analysis of the scientific literature about biosphere reserves' management effectiveness: (**a**) dendrogram showing three groups of papers; (**b**) the three groups of papers in a multidimensional scaling (MDS). Only the variables that are significantly correlated with the dissimilarities among papers are represented: methods used for data analysis and MAB region.

There are, however, significant differences in the composition of the subcategories across all clusters ($P < 0.001$). The first 20 subcategories (i.e., coefficients) that most contribute to the dissimilarities between clusters are aggregated in Table 2. Comparing to the other clusters, the papers included in the cluster #1 (n = 32) are more associated with subcategories of governance (empowerment, participatory processes, management body) and learning (information, type of knowledge, learning). Papers included in the cluster #2 (n = 23) are more focused on subcategories related with biodiversity conservation (conservation and habitat management, economic and social impacts) and activities associated with it (cultural use of natural resources, material investments and infrastructure, cultural benefits). The subcategory that mostly contributes to the dissimilarities between papers included in the cluster #3 (n = 11) and the others is economic benefits. The subcategories mainly associated with the papers in each cluster are, therefore, related with three goals of the biosphere reserves: capacity building, conservation of biodiversity and sustainable development. Moreover, some of the subcategories that most contribute to the dissimilarities among the clusters are shared between cluster #1 and cluster #2 (Table 2). This suggests the existence of similar factors that influence the achievement of the goals of "capacity building" and "conservation of biodiversity", but not "sustainable development". Further analysis of the most frequent subcategories referred in each cluster revealed the existence of more similarities: socio-economic attributes of the context and the restrictions and incentives implemented in the biosphere reserve being studied are referred in more than 70% of the papers included in each cluster. The big majority of the publications in each cluster investigate the management/governance of a project in biosphere reserves.

We also assessed the contributions of other variables to the dissimilarities among papers, namely the methods used for data analysis, the MAB region where the study was conducted, and the study being developed in a biosphere reserve designated before or after the Seville Strategy. The methods used for data analysis are very strong predictors of the dissimilarities among papers ($P < 0.001$), as represented in Figure 4b. Quantitative methods are more correlated with papers in the third cluster (sustainable development), qualitative methods with papers in the first cluster (capacity building) and mixed methods with papers in the second cluster (biodiversity conservation). The MAB region where the study was performed is also correlated ($P < 0.01$), however, the predictors are weaker. Papers in cluster #3 are more correlated with studies developed in Asia and the Pacific and cluster #1 in Latin America and the Caribbean. The second cluster includes studies conducted in a diversity of regions. The study being developed in a biosphere reserve designated before or after the Seville Strategy is not significantly correlated with the dissimilarities among papers. These results are indicative of how studies developed using different methods of data analysis and in different regions of the world are also associated with different subcategories of biosphere reserves' management effectiveness.

Table 2. Subcategories that most contribute to the dissimilarities among clusters obtained from the coefficients of the PERMANOVA. Subcategories may be specific or shared between clusters.

Category/MAB Goal	Capacity Building	Biodiversity Conservation	Sustainable Development
Context	Historical factors		-
	Organizations		
	Formal rules		
	Informal institutions and culture		
	Impacts on natural resources		
	Information related	Power issues	
	Time	Economy and politics	
	-	Cultural use of natural resources	
		Extractive resource-based livelihoods	
Inputs	Non-material support/opposition		-
	Funding and material support/opposition		
	Attitudes		
	Beliefs		
	Type of knowledge	-	
Processes	Planning		-
	Public participation		
	Coordination and leadership		
	Information and capacity building		
	Institutions for management		
	Process scale BR	Material investments and infrastructure	
	Process spatial design	Conservation and habitat management	
	Process initiation	-	
	Characteristics of the management body		
	Characteristics of the participatory processes		
Outcomes	Empowerment	Cultural benefits	Economic benefits
	Social benefits	Economic impacts	-
	Learning	Social impacts	

3.4.2. Outcomes

From the 66 papers analyzed, 43 report at least one positive outcome; 49 at least one negative outcome, and 32 both positive and negative outcomes. The number of papers that report environmental, economic, cultural and social positive and negative outcomes in each biosphere reserve is represented in Figure 5. For most of the biosphere reserves, both positive and negative outcomes were reported.

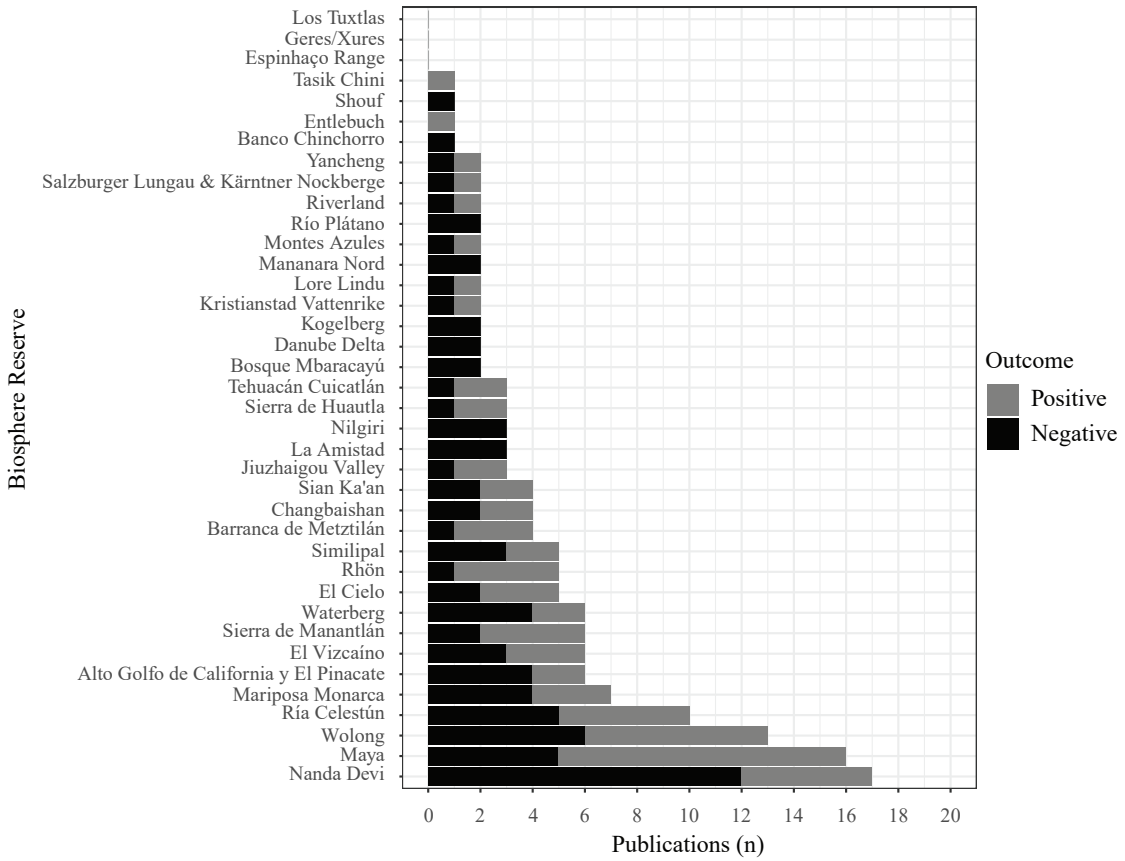

Figure 5. Sum of the number of publications that report positive and negative outcomes regarding social, economic, environmental and cultural aspects, in each biosphere reserve. Positive outcomes include, e.g., the provision of jobs, decrease of conflicts, empowerment, motivation, learning, provision of recreation opportunities or increase of the population of an endangered species. Negative outcomes include, e.g., decrease of households' income, displacement of communities, inequality, frustration, erosion of traditions or the overexploitation of natural resources.

3.4.3. Scales

The subcategories most frequently identified at international or national/regional scales are represented in Table 3. The most frequently referred subcategories are related to the context and inputs to management/governance processes, namely funding and material support/opposition. Only cultural outcomes, such as the provision of opportunities for recreation, are frequently referred at international or national/regional scales, which reflect the benefits derived by tourists.

Table 3. Most frequent referred subcategories at international or national/regional scales. The proportion of papers refers to the number of papers in which a subcategory is present.

Category	Subcategory	% of Papers
Inputs	Funding and material support/opposition	81.1
Context	Organizations	65.9
Context	Economy and politics	65
Context	Conservationist value	53.8
Outcomes	Cultural benefits	50
Context	Historical factors	45.5
Context	Power issues	44.4
Context	Socio-economic attributes	44.1
Context	Formal rules	44
Inputs	Non-material support/opposition	42.6

4. Discussion

4.1. General Patterns of the Literature

The scientific literature related to biosphere reserves' management effectiveness has increased in the last decades, following the general trend of the biosphere reserves' research [25]. However, the number of papers that conduct studies related with biosphere reserves' management effectiveness in one biosphere reserve is very limited [1]. Complementing these papers with studies that were excluded from the literature review, e.g., because they do not mention "biosphere reserve" in the abstract, title and keywords, and with gray literature, would be important to provide a more complete overview of biosphere reserves' management effectiveness. Moreover, more recent research [32–34], should also be included, since our review only includes papers published until March 2017.

As indicated by the journal subject area, environmental and social sciences are the main disciplines contributing to the research about biosphere reserves' management effectiveness. Therefore, despite the results of this study indicating a limited contribution of other disciplines, management effectiveness comprises a more heterogeneous field of study than biosphere reserves' research, which is manly related with natural and environmental sciences [25].

The results of this study also demonstrate that lead authors from Europe and North America have been responsible for a big part of the research about biosphere reserves' management effectiveness, including in other regions of the world. This result echoes the findings of other studies that examined the authors of sustainability-related research [35], demonstrating the need of greater geographic diversity.

Research about biosphere reserves' management effectiveness is methodologically diverse, using multiple methods for data collection and analysis. In contrast with large-scale studies about biosphere reserves' management effectiveness [8,19,20], local communities are the privileged actor included in the research. Most of the actors enrolled are, however, only consulted in interviews or surveys, and few studies have applied more profound methods of stakeholders' engagement.

4.2. The Biosphere Reserves Studied

According to the results, studies related with biosphere reserves' management effectiveness have been developed in only about 6% of the designated sites, and are mainly concentrated in four countries: Mexico, Guatemala, India and China. These countries are also amongst those that have developed more research, in general, in biosphere reserves [25].

In the literature analyzed, only one study covered the whole biosphere reserve—in the Gerês-Xurés between Portugal and Spain [36]. Within the WNBR, there are actually 21 transboundary biosphere reserves [4]. A better understanding of the management and governance of transboundary biosphere reserves is necessary, given their increased complexity.

Despite further information about biosphere reserves' management effectiveness which can be found in studies that compare biosphere reserves at a global scale [8,19,37–39], among countries [40,41]

or at a national scale [9,10], existing data is insufficient to provide a comprehensive understanding of the effectiveness of the WNBR. The generalized lack of research related with management effectiveness in biosphere reserves reinforces the claim that biosphere reserves have been underutilized in terms of their potential contribution to the theory and practice of sustainability science [3].

4.3. The Topics Investigated

The literature related with biosphere reserves' management effectiveness frequently addresses the implementation of restrictions to reduce environmental harms (e.g., regulation and surveillance of the use of marine resources [42]), incentives to promote more environmentally friendly behaviors (e.g., a conservation-oriented language school [43]), as well as the socio-economic characteristics of the settings where these processes are implemented (e.g., demography and sources of income in the community [44]). Moreover, three groups of papers were identified which investigate, more profoundly, topics related to: (1) governance and learning; (2) activities associated with biodiversity conservation; and (3) economic incentives to sustainable development. These groups are related to the goals of biosphere reserves: (1) capacity building, (2) biodiversity conservation and (3) sustainable development.

The literature analyzed does not cover, however, the four goals of biosphere reserves, according to the MAB Strategy 2015–2025 [2]. Some areas, in which more research seems to be important in each goal, and examples of papers found in the literature that addresses these topics are: (1) research activities, investigated in the study of Alonso-Yañez and Davidsen [45]; (2) environmental outcomes, as examined by Mehring and Stoll-Kleemann [46] and Steinberg et al. [47]; (3) equity, that was studied in the papers of Sundberg [48,49] and health, investigated in the study of Sylvester et al. [50]; and (4) climate change adaptation and mitigation, briefly addressed in Durand et al. [51].

4.4. Methods and Context

The results of this study indicate that the goals of biosphere reserves—capacity building, biodiversity conservation and sustainable development—have been mainly investigated using, respectively, qualitative, mixed and quantitative approaches. This result suggests that a holistic understanding of biosphere reserves' management effectiveness requires the use of multiple approaches. Other studies have highlighted that different lenses and perspectives are required for the understanding and management of complex [52] social-ecological systems [53]. Conceptual and methodological plurality may also increase the possibility of finding solutions for wicked problems [54]. Research about biosphere reserves' management effectiveness should, therefore, combine different methodological approaches and a diversity of actors, in order to include different perspectives about the complex social-ecological systems being managed.

The results of this study also indicate that research related with capacity building and sustainable development have been mainly conducted in, respectively, Latin America and the Caribbean, and in Asia and the Pacific; the literature related with the goal of biodiversity conservation is geographically more diverse. These results concur with previous works that underscore the importance of the context in biosphere reserves' management effectiveness [1] and in integrated conservation strategies [55]. The seminal work of Ostrom [56] highlights the need to move beyond panaceas, i.e., simple universal recipes, to resolve the problems of overuse of natural resources. Research about biosphere reserves' management effectiveness should focus, therefore, on co-creating and investigating management and governance processes that are embedded in the social-ecological contexts in which biosphere reserves are implemented. The criteria for the designation of a biosphere reserve should also be critically analyzed, in order to avoid the prescription of simple solutions (e.g., zoning or participatory management) to solve complex problems.

4.5. Main Findings Concerning Biosphere Reserves' Management Effectiveness

4.5.1. Goals

The cluster analysis conducted in this study revealed that the classification of the scientific literature according to subcategories of biosphere reserves' management effectiveness [1] reflect the goals of the MAB Program. Some of the subcategories associated with each goal are: (1) capacity building—information, knowledge, management body, participatory processes, empowerment and learning; (2) biodiversity conservation—cultural and extractive use of natural resources, conservation and habitat management, socio-economic impacts and cultural benefits; and (3) economic development-economic benefits. This pattern suggests that the goals of biosphere reserves influence which processes are developed, which inputs are needed, and, consequently, the outcomes of their management, in a given context. The goals are, therefore, of central importance to biosphere reserves' management effectiveness. This result concurs with research about complex systems that underscores the importance of the goals of the system in determining its behavior [52]. Due to this, the goals are among the most important leverage points to change systems [52,57]. This suggests that closing the gap between biosphere reserves' concept and practice [5–7] may be more effectively achieved by addressing the goals of biosphere reserves. This result provides a different perspective about key factors for the success of biosphere reserves, which have been mainly associated with the participation, designation or the availability of resources [8,10,19,20].

The focus of biosphere reserves in sustainable development [16] and in the Sustainable Development Goals (SDGs) agenda [2,58] may require, therefore, a critical analysis. These concepts have been criticized for promoting economic growth on a finite planet [59,60] and for resulting from a Western construct that ignores existing cultural alternatives and worldviews of human-nature relationships [61]. Therefore, it seems to be important to investigate alternative approaches that provide more fundamental and context-specific transformations in biosphere reserves, such as Buen Vivir (South America), Ubuntu (South Africa), Swaraj (India) and degrowth (Europe) [13,59].

4.5.2. Interdependencies between Goals and Across Scales

In this study, there were identified subcategories that are associated with specific goals of biosphere reserves and subcategories which seem to be important for multiple goals (e.g., the implementation of restrictions and incentives, and the socio-economic context). The results also indicate the presence of trade-offs among outcomes of biosphere reserves—in most of the biosphere reserves studied, both positive and negative outcomes were reported. Many factors that influence management, but which control lies outside of biosphere reserves, were reported in the literature: funding to develop its activities [62,63], goals of the organizations [45,64], economic crises [36], power issues [49] and formal rules [65]. These results are indicative of the interdependencies between goals of biosphere reserves, and between biosphere reserves and the larger systems in which they are contained. Managers of biosphere reserves, therefore, have to articulate different goals, in order to prevent that the achievement of one goal compromises others, or the purpose of the biosphere reserve, and also to consider factors that, despite originating outside of biosphere reserves, may influence its effectiveness. How biosphere reserves navigate these scale dynamics between the systems they contain and in which they are contained is, therefore, an important topic for future research.

The existence of trade-offs in biosphere reserves concurs with existing research about win-win strategies, i.e., initiatives that aim to achieve conservation and development goals. Win-win situations rarely materialize; instead, gains and losses are the norm [66,67]. While some authors suggest that the irreconcilability between conservation and development have to be recognized in order to adequately deal with trade-offs and "hard decisions" [67], others claim that the apparent incompatibility between environmental and economic activities is an artefact of neoliberal conservation approaches [68]. By not considering the unequal access to natural resources, and relying on economic growth to end poverty, neoliberal conservation instruments exacerbate the conservation-development conflicts they were

meant to resolve [68]. Given the contested nature of this topic, and the importance of trade-offs to biosphere reserves' management effectiveness, more research about the causes of trade-offs in biosphere reserves, and how to overcome them, is necessary.

4.6. A Research Agenda

Building on the topics discussed above, a research agenda, and some recommendations, are proposed to advance inquiry about biosphere reserves' management effectiveness (Table 4). The proposed research agenda is in accordance with existing suggestions to advance investigation in sustainability of social-ecological systems [69] or sustainability science [70], and also with the current action plan for biosphere reserves [58]. These similarities suggest that biosphere reserves can benefit from the advancement of these fields of research, and vice versa. Collaborative work between these research communities, and with practitioners in biosphere reserves, can, therefore, contribute to leverage theory and practice of sustainability.

Table 4. A research agenda for biosphere reserves' management effectiveness.

Main Topic	Research Question	Recommendations
Research	What mechanisms are needed in biosphere reserves to develop research programs that cover the geographic and methodological gaps found in the literature, namely, a restricted spatial coverage and the absence of a holistic research perspective with a diversity of methodological approaches and actors?	Analyze gray literature, including periodic reviews, to have a broader understanding of biosphere reserves' management effectiveness;
		Conduct research in biosphere reserves where no study about management effectiveness was performed, including transboundary biosphere reserves;
		Investigate which mechanisms may promote the development of collaborative research in biosphere reserves, including different disciplines (interdisciplinarity), methods (qualitative, mixed and quantitative) and actors (transdisciplinary);
		When studying biosphere reserves outside of Europe and North America, empower researchers from the region to lead the investigation and publications.
Outcomes	(i) How are biosphere reserves contributing their multiple goals: capacity building, biodiversity conservation, sustainable development and climate change adaptation and mitigation?	Investigate the contribution of biosphere reserves to their multiple goals, including capacity building, biodiversity conservation, sustainable development and climate change adaptation and mitigation;
		Investigate the contribution of biosphere reserves to the development of research, environmental outcomes, equity and health in the regions in which they are implemented;
	(ii) What changes are needed to assure that management/governance of biosphere reserves is orientated to achieve a more balanced mix of social, cultural, economic and environmental outcomes?	Investigate the causes of trade-offs in biosphere reserves and how to overcome them.
Social-ecological fit	What transformations are needed to assure that the goals of biosphere reserves, criteria for designation and management/governance processes, fit the social-ecological contexts in which they are implemented?	Investigate the fit between biosphere reserves' goals, criteria for designation and management/governance processes, and the social-ecological contexts in which they are implemented;
		Critically analyze the pursue of sustainable development and the SDGs in biosphere reserves;
		Investigate how context-orientated transformations can be incorporated in biosphere reserves.
Scales	What new institutional mechanisms, or changes in existing institutions, are required to facilitate the management and governance of scale dynamics in biosphere reserves?	Study what mechanisms can facilitate the integrated management of the multiple goals of biosphere reserves;
		Analyze how multi-scale and large-scale cooperation can be promoted to achieve social-ecological benefits in biosphere reserves, and the role of UNESCO in this regard.

Lastly, it is important to highlight the important role that UNESCO can play in potentiating research about biosphere reserves' management effectiveness. Existing databases containing information about biosphere reserves [22,23] should be improved, in order to provide a more complete source of data. Current shortcomings include unavailability of data (e.g., periodic reviews and spatial boundaries), data that is not updated, and lack of systematic information between biosphere reserves (e.g., information about the main ecosystems) and between both databases. Despite progress being made regarding the systematization of literature about biosphere reserves [71], further work is still necessary to disclose and better understand topics related to management effectiveness. The categories and subcategories analyzed in this study, including those of Ferreira et al. [1], could be useful in this regard. Besides providing a characterization of the context, processes, inputs and outcomes associated with biosphere reserves' management/governance, the subcategories also allow to understand how and where data was collected in the first place. The systematization of such information would be useful, not only to biosphere reserves' managers and researchers, but also, to build theory about how to sustainably manage and govern social-ecological systems on a regional scale.

5. Conclusions

Using a systematic literature review of the scientific literature, this study aimed to contribute to a better understanding about where and how the research about biosphere reserves' management effectiveness have been conducted, which topics have been investigated and what the main findings are. The results indicate that, in line with their multiple goals and complex processes of implementation, the research about biosphere reserves' management effectiveness is diverse—it investigates different topics in different locations—and plural, because it includes different conceptual perspectives and methodological approaches. Three groups of papers, that address different subcategories of the context, inputs, processes and outcomes of biosphere reserves, were identified. These groups are associated with different goals of the program: capacity building, biodiversity conservation and sustainable development. In general, the papers in each group use different methodological approaches and were developed in different regions of the world. Given the importance of the goals in structuring the scientific literature according to subcategories of management effectiveness, the goals of biosphere reserves are proposed as effective leverage points to increase their success. The results also suggest the importance of scale dynamics and interdependencies between goals in biosphere reserves' management effectiveness.

However, there were identified gaps and bias in the literature that prevent a more holistic understanding of biosphere reserves' management effectiveness. In order to advance inquiry in this important topic, a research agenda for the field, and some recommendations, are proposed, focusing on the need to investigate mechanisms for holistic research, outcomes and trade-offs, transformations for social-ecological fit and institutions for an integrated management across scales. The pursue of this research agenda may contribute to biosphere reserves becoming real laboratories for sustainable development, in all its dimensions and diversity. Moreover, collaborative work between different research communities, and practitioners in biosphere reserves, i.e., managers, local communities and other stakeholders [58], would be important to leverage theory and practice of sustainability.

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Appendix A

Search string used in the Scopus database (retrieved from Ferreira et al. [1]). TITLE-ABS-KEY ("biosphere reserve") AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO. (DOCTYPE, "ip")) AND (LIMIT-TO (LANGUAGE, "English"))

Table A1. List of the publications reviewed (retrieved from Ferreira et al. [1]).

ID#	Reference
1	Alonso-Yañez, G., and Davidsen, C. (2014). Conservation science policies versus scientific practice: evidence from a Mexican biosphere reserve. Human Ecology Review, 20(2), 3–30. http://doi.org/http://www.jstor.org/stable/24707624
2	Alonso-Yanez, G., Thumlert, K., and de Castell, S. (2016). Re-mapping integrative conservation: (Dis) coordinate participation in a biosphere reserve in Mexico. Conservation and Society, 14(2), 134–145. http://doi.org/10.4103/0972-4923.186335
3	Azcárate, M. C. (2010). Contentious hotspots: ecotourism and the restructuring of place at the Biosphere Reserve Ria Celestun (Yucatan, Mexico). Tourist Studies, 10(2), 99–116. http://doi.org/10.1177/1468797611403033
4	Behnen, T. (2011). The man from the biosphere - exploring the interaction between a protected cultural landscape and its residents by quantitative interviews: the case of the UNESCO Biosphere Reserve Rhön, Germany. Eco.Mont, 3(1), 5–10. http://doi.org/10.1553/eco.mont-3-1s5
5	Boja, V., and Popescu, I. (2000). Social ecology in the Danube Delta: theory and practice. Lakes and Reservoirs: Research and Management, 5(2), 125–131. http://doi.org/10.1046/j.1440-1770.2000.00107.x
6	Brenner, L., and Job, H. (2006). Actor-oriented management of protected areas and ecotourism in Mexico. Journal of Latin American Geography, 5(2), 7–27. http://doi.org/10.1353/lag.2006.0019
7	Catalán, A. K. R. (2015). The Monarch Butterfly Biosphere Reserve: an exemplary participative approach? Environmental Development, 16, 90–103. http://doi.org/10.1016/j.envdev.2015.04.005
8	Constantin, M. (2012). On the ethnographic categorization of biodiversity in the Danube Delta "Biosphere Reserve." Eastern European Countryside, 18(1), 49–60. http://doi.org/10.2478/v10130-012-0003-x
9	Devine, J. (2014). Counterinsurgency ecotourism in Guatemala's Maya Biosphere Reserve. Environment and Planning D: Society and Space, 32(6), 984–1001. http://doi.org/10.1068/d13043p
10	Durand, L., Figueroa, F., and Trench, T. (2014). Inclusion and exclusion in participation strategies in the Montes Azules Biosphere Reserve, Chiapas, Mexico. Conservation and Society, 12(2), 175–189. http://doi.org/10.4103/0972-4923.138420
11	Durand, L., and Lazos, E. (2008). The local perception of tropical deforestation and its relation to conservation policies in Los Tuxtlas Biosphere Reserve, Mexico. Human Ecology, 36(3), 383–394. http://doi.org/10.1007/s10745-008-9172-7
12	Elgert, L. (2014). Governing portable conservation and development landscapes: reconsidering evidence in the context of the Mbaracayú Biosphere Reserve. Evidence and Policy, 10(2), 205–222. http://doi.org/10.1332/174426514X13990327720607
13	Fazito, M., Scott, M., and Russell, P. (2016). The dynamics of tourism discourses and policy in Brazil. Annals of Tourism Research, 57, 1–17. http://doi.org/10.1016/j.annals.2015.11.013
14	Fu, B., Wang, K., Lu, Y., Liu, S., Ma, K., Chen, L., and Liu, G. (2004). Entangling the complexity of protected area management: the case of Wolong Biosphere Reserve, Southwestern China. Environmental Management, 33(6), 788–798. http://doi.org/10.1007/s00267-004-0043-8
15	Gerritsen, P., and Wiersum, F. (2005). Farmer and conventional perspectives on conservation in Western Mexico. Mountain Research and Development, 25(1), 30–36. http://doi.org/10.1659/0276-4741(2005)025{[}0030:FACPOC{]}2.0.CO;2
16	Grandia, L. (2009). Raw hides: hegemony and cattle in Guatemala's northern lowlands. Geoforum, 40(5), 720–731. http://doi.org/10.1016/j.geoforum.2009.01.004
17	Habibah, A., Er, A. C., Mushrifah, I., Hamzah, J., Sivapalan, S., Buang, A., … Sharifah Mastura, S. A. (2013). Revitalizing ecotourism for a sustainable Tasik Chini Biosphere Reserve. Asian Social Science, 9(14), 70–85. http://doi.org/10.5539/ass.v9n14p70

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ID#	Reference
18	Hagan, K., and Williams, S. (2016). Oceans of discourses: utilizing Q methodology for analyzing perceptions on marine biodiversity conservation in the Kogelberg Biosphere Reserve, South Africa. Frontiers in Marine Science, 3, 188. http://doi.org/10.3389/fmars.2016.00188
19	Hahn, T. (2011). Self-organized governance networks for ecosystem management: Who is accountable? Ecology and Society, 16(2), 18. http://doi.org/10.5751/ES-04043-160218
20	Hill, W., Byrne, J., and Pegas, F. de V. (2016). The ecotourism-extraction nexus and its implications for the long-term sustainability of protected areas: what is being sustained and who decides? Journal of Political Ecology, 23(1), 307–327. http://dx.doi.org/10.2458/v23i1.20219
21	Hill, W., Byrne, J., and Pickering, C. (2015). The 'hollow-middle': why positive community perceptions do not translate into pro-conservation behavior in El Vizcaíno Biosphere Reserve, Mexico. International Journal of Biodiversity Science, Ecosystem Services and Management, 11(2), 168–183. http://doi.org/10.1080/21513732.2015.1036924
22	Hoffman, D. M. (2014). Conch, cooperatives, and conflict: conservation and resistance in the Banco Chinchorro Biosphere Reserve. Conservation and Society, 12(2), 120–132. http://doi.org/10.4103/0972-4923.138408
23	Humer-Gruber, A. (2016). Farmers' perceptions of a mountain biosphere reserve in Austria. Mountain Research and Development, 36(2), 153–161. http://doi.org/10.1659/MRD-JOURNAL-D-15-00054.1
24	Kent, K., Sinclair, A. J., and Diduck, A. (2012). Stakeholder engagement in sustainable adventure tourism development in the Nanda Devi Biosphere Reserve, India. International Journal of Sustainable Development and World Ecology, 19(1), 89–100. http://doi.org/10.1080/13504509.2011.595544
25	Knaus, F., Bonnelame, L. K., and Siegrist, D. (2017). The economic impact of labeled regional products: the experience of the UNESCO Biosphere Reserve Entlebuch. Mountain Research and Development, 37(1), 121–130. http://doi.org/10.1659/MRD-JOURNAL-D-16-00067.1
26	Kraus, F., Merlin, C., and Würzburg, H. J. (2014). Biosphere reserves and their contribution to sustainable development. Zeitschrift Für Wirtschaftsgeographie, 58(2–3), 164–180.
27	Langholz, J. (1999). Exploring the effects of alternative income opportunities on rainforest use: insights from Guatemala's Maya Biosphere Reserve. Society and Natural Resources, 12(2), 139–149. http://doi.org/10.1080/089419299279803
28	Lee, A. E. (2014). Territorialisation, conservation, and neoliberalism in the Tehuacán-Cuicatlán Biosphere Reserve, Mexico. Conservation and Society, 12(2), 147–161. http://doi.org/10.4103/0972-4923.138413
29	Li, W. (2006). Community decision making—participation in development. Annals of Tourism Research, 33(1), 132–143. http://doi.org/10.1016/j.annals.2005.07.003
30	Liu, W., Vogt, C. A., Lupi, F., He, G., Ouyang, Z., and Liu, J. (2016). Evolution of tourism in a flagship protected area of China. Journal of Sustainable Tourism, 24(2), 203–226. http://doi.org/10.1080/09669582.2015.1071380
31	Lu, Y., Fu, B., Chen, L., Xu, J., and Qi, X. (2006). The effectiveness of incentives in protected area management: an empirical analysis. International Journal of Sustainable Development and World Ecology, 13(5), 409–417. http://doi.org/10.1080/13504500609469690
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35	Maikhuri, R. K., Nautiyal, S., Rao, K. S., Chandrasekhar, K., Gavali, R., and Saxena, K. G. (2000). Analysis and resolution of protected area-people conflicts in Nanda Devi Biosphere Reserve, India. Environmental Conservation, 27(1), 43–53. http://doi.org/10.1017/S0376892900000060
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ID#	Reference
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39	Mollett, S. (2010). Está listo (Are you ready)? Gender, race and land registration in the Río Plátano Biosphere Reserve. Gender, Place and Culture, 17(3), 357–375. http://doi.org/10.1080/09663691003737629
40	Monterroso, I., and Barry, D. (2012). Legitimacy of forest rights: the underpinnings of the forest tenure reform in the protected areas of Petén, Guatemala. Conservation and Society, 10(2), 136–150. http://doi.org/10.4103/0972-4923.97486
41	Nautiyal, S., and Nidamanuri, R. R. (2010). Conserving biodiversity in protected area of biodiversity hotspot in India: a case study. International Journal of Ecology and Environmental Sciences, 36(2–3), 195–200.
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43	Pfueller, S. L. (2008). Role of bioregionalism in Bookmark Biosphere Reserve, Australia. Environmental Conservation, 35(2), 173–186. http://doi.org/10.1017/S0376892908004839
44	Pulido, M. T., and Cuevas-Cardona, C. (2013). Cactus nurseries and conservation in a biosphere reserve in Mexico. Ethnobiology Letters, 4, 96–104. http://dx.doi.org/10.14237/ebl.4.2013.58
45	Rao, K. S., Nautiyal, S., Maikhuri, R. K., and Saxena, K. G. (2003). Local peoples' knowledge, aptitude and perceptions of planning and management issues in Nanda Devi Biosphere Reserve, India. Environmental Management, 31(2), 168–181. http://doi.org/10.1007/s00267-002-2830-4
46	Richardson, T. (2015). On the limits of liberalism in participatory environmental governance: conflict and conservation in Ukraine's Danube Delta. Development and Change, 46(3), 415–441. http://doi.org/10.1111/dech.12156
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49	Silori, C. S. (2007). Perception of local people towards conservation of forest resources in Nanda Devi Biosphere Reserve, north-western Himalaya, India. Biodiversity and Conservation, 16(1), 211–222. http://doi.org/10.1007/s10531-006-9116-8
50	Singh, R. B., Mal, S., and Kala, C. P. (2009). Community responses to mountain tourism: a case in Bhyundar Valley, Indian Himalaya. Journal of Mountain Science, 6(4), 394–404. http://doi.org/10.1007/s11629-009-1054-y
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58	Sundberg, J. (2004). Identities in the making: conservation, gender and race in the Maya Biosphere Reserve, Guatemala. Gender, Place and Culture, 11(1), 43–66. http://doi.org/10.1080/0966369042000188549

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ID#	Reference
59	Sundberg, J. (2006). Conservation encounters: transculturation in the "contact zones" of empire. Cultural Geographies, 13(2), 239–265. http://doi.org/10.1191/1474474005eu337oa
60	Sylvester, O., Segura, A. G., and Davidson-Hunt, I. J. (2016). The protection of forest biodiversity can conflict with food access for indigenous people. Conservation and Society, 14(3), 279–290. http://doi.org/10.4103/0972-4923.191157
61	Trillo-Santamaría, J.-M., and Paül, V. (2016). Transboundary protected areas as ideal tools? Analyzing the Gerês-Xurés Transboundary Biosphere Reserve. Land Use Policy, 52, 454–463. http://doi.org/10.1016/j.landusepol.2015.12.019
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63	Velez, M., Adlerstein, S., and Wondolleck, J. (2014). Fishers' perceptions, facilitating factors and challenges of community-based no-take zones in the Sian Ka'an Biosphere Reserve, Quintana Roo, Mexico. Marine Policy, 45, 171–181. http://doi.org/10.1016/j.marpol.2013.12.003
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65	Young, E. (1999). Local people and conservation in Mexico's El Vizcaino Biosphere Reserve. The Geographical Review, 89(3), 364–390. http://doi.org/10.2307/216156
66	Yuan, J., Dai, L., and Wang, Q. (2008). State-led ecotourism development and nature conservation: a case study of the Changbai Mountain Biosphere Reserve, China. Ecology and Society, 13(2), 55. http://doi.org/10.5751/ES-02645-130255

Table A2. Categories and subcategories used to review the publications. Subcategories used in the cluster analysis are identified with "1" in the last column ("C"). The subcategory "health benefits" was not used in the cluster analysis because it was not coded in any paper. NA—Not applicable; BR—Biosphere reserve; MAB—UNESCO Man and Biosphere Program; NGO—Non-governmental organizations.

#	Category	Subcategory	Value	C
1	Publication year	NA	Year	0
2	Journal subject area [1]	Earth and Planetary Sciences	0/1	0
3		Environmental Science	0/1	0
4		Agricultural and Biological Sciences	0/1	0
5		Economics, Econometrics and Finance	0/1	0
6		Business, Management and Accounting	0/1	0
7		Social Sciences	0/1	0
8		Arts and Humanities	0/1	0
9		Other subject area	0/1	0
10	Affiliation of the author [2]	NA	Africa; Arab States; Asia and the Pacific; Europe and North America; Latin America and the Caribbean	0
11	Name of the BR [2]	NA	BR name	0
12	Transboundary BR? [3]	NA	0/1	0
13	Withdrawn BR? [4]	NA	0/1	0
14	BR year of designation [2]	NA	Year	0
15	Research location [2]	Country	Country name	0
16		Region	Africa; Arab States; Asia and the Pacific; Europe and North America; Latin America and the Caribbean	0
17	Methods for data collection	Experiments	0/1	0
18		Questionnaires	0/1	0
19		Survey	0/1	0
20		Secondary data	0/1	0
21		Document analysis	0/1	0
22		Interview	0/1	0
23		Group discussions	0/1	0
24		Observation	0/1	0
25		Ethnography	0/1	0
26		Other	0/1	0

Table A2. *Cont.*

#	Category	Subcategory	Value	C
27	Actors enrolled	Local communities	0/1	0
28		Government	0/1	0
29		NGOs	0/1	0
30		Researchers	0/1	0
31		Tourists	0/1	0
32		Business	0/1	0
33		MAB representatives	0/1	0
34		Other	0/1	0
35	Methods for data analysis	NA	Qualitative; quantitative; mixed methods	0
36	Context	Historical factors	0/1	1
37		Organizations	0/1	1
38		Formal rules	0/1	1
39		Informal institutions and culture	0/1	1
40		Power issues	0/1	1
41		Socio-economic attributes	0/1	1
42		Economy and politics	0/1	1
43		Information-related	0/1	1
44		Time	0/1	1
45		Impacts on natural resources	0/1	1
46		Extractive resource-based livelihoods	0/1	1
47		Cultural use of natural resources	0/1	1
48		Human-wildlife conflicts	0/1	1
49		Cultural landscape	0/1	1
50		Bio-physical attributes	0/1	1
51		Conservationist value	0/1	1
52		Resource mobility	0/1	1
53		Other	0/1	0

Table A2. *Cont.*

#	Category	Subcategory	Value	C
54	Inputs	Attitudes	0/1	1
55		Beliefs	0/1	1
56		Funding and material support/opposition	0/1	1
57		Non-material support/opposition	0/1	1
58		Knowledge	0/1	1
59		Other	0/1	0
60	Process	Process scale BR	0/1	1
61		Process scale task	0/1	1
62		Process spatial design	0/1	1
63		Process initiation	0/1	1
64		Public participation	0/1	1
65		Participatory processes characteristics	0/1	1
66		Management body characteristics	0/1	1
67		Coordination and leadership	0/1	1
68		Human resources-related	0/1	1
69		Material investments and infrastructure	0/1	1
70		Conservation and habitat management	0/1	1
71		Restrictions	0/1	1
72		Enforcement and control	0/1	1
73		Incentives	0/1	1
74		Economic development	0/1	1
75		Research and monitoring	0/1	1
76		Information and capacity building	0/1	1
77		Planning	0/1	1
78		Institutions for management	0/1	1
79		Other	0/1	0

Table A2. *Cont.*

#	Category	Subcategory	Value	C
80	Outcomes	Economic benefits	0/1	1
81		Social benefits	0/1	1
82		Empowerment	0/1	1
83		Health benefits	0/1	1
84		Learning	0/1	1
85		Cultural benefits	0/1	1
86		Environmental benefits	0/1	1
87		Economic impacts	0/1	1
88		Social impacts	0/1	1
89		Inequality	0/1	1
90		Health impacts	0/1	0
91		Cultural impacts	0/1	1
92		Environmental impacts	0/1	1
93		Other	0/1	0
94–110	Scale	Context subcategories (#36 to #52)	National/regional; international; not local	0
111–115		Inputs subcategories (#54 to #58)	National/regional; international; not local	0
116–134		Process subcategories (#60 to #78)	National/regional; international; not local	0
135–147		Outcomes subcategories (#80 to #92)	National/regional; international; not local	0

1—Retrieved from ELSEVIER [26]; 2—Retrieved from UNESCO [22]; 3—Retrieved from UNESCO [72]; 4—Retrieved from UNESCO [73].

Table A3. Examples of factors included in each subcategory used to evaluate biosphere reserves' management effectiveness. Detailed descriptions of each subcategory can be found in Ferreira et al. [1].

Category	Subcategory	Examples
Context	Historical factors	Previous communist regime, colonization
	Organizations	Structure, goals, capacity, inter-organization relationships, corruption
	Formal rules	Legislation, land tenure
	Informal institutions and culture	Social norms, culture, trust
	Power issues	Race, class, gender
	Socio-economic attributes	Migrations, conflicts, unemployment and education rates, infrastructure
	Economy and politics	Markets, financial crises, democratic regimes, liberalism
	Information-related	Availability of internet or phones; media
	Time	Time restrictions
	Impacts on natural resources	Less fish, less trees, pollution
	Extractive resource-based livelihoods	Fishing, logging, harvest of medicinal plants, agriculture
	Cultural use of natural resources	Recreation, religion
	Human-wildlife conflicts	Predators attacks on livestock or humans
	Cultural landscape	Landscapes that result from the traditional use of the land
	Conservationist value	Highly endangered species or habitats
	Bio-physical attributes	Altitude, climate, pests
	Resource mobility	Migratory species
Inputs	Attitudes	Positive/negative evaluations about the process
	Beliefs	Perceived benefits or impacts, values, worldviews
	Funding and material support/ opposition	Financial resources
	Non-material support/opposition	Provision of emotional support, information or lobbying.
	Knowledge	Scientific knowledge, traditional knowledge

Table A3. *Cont.*

Category	Subcategory	Examples
Process	Process scale BR	Management/governance of the biosphere reserve
	Process scale task	Management/governance of a task, e.g., park monitoring
	Process spatial design	Zoning, total area, location
	Process initiation	Aspects related to how were processes initiated, e.g., if local communities were enrolled
	Public participation	Participation of civil society in process implementation or management
	Participatory processes characteristics	Who created the agenda for the meeting? How and when were communities invited? Was the information given to the participants clear?
	Management body characteristics	Degree of centralization of the management body. Who is included/excluded? Power balance
	Coordination and leadership	Coordination of activities inside the biosphere reserve. Leadership, cooperation
	Human resources-related	Availability of staff and working conditions—wages, seasonality, part-time vs. full-time
	Material investments and infrastructure	Development of new infrastructure (e.g., visitor center), or acquisition of new equipment, e.g., vehicles
	Conservation and habitat management	Habitat restauration, invasive species control, species reintroduction
	Restrictions	Prohibitions of natural resource use, park fees, fisheries quotas, biodiversity offsets
	Enforcement and control	Park patrols, fines
	Incentives	Payments for ecosystem services, compensation for wildlife damage, certification schemes
	Economic development	Mining, tourism infrastructure (hotels, restaurants), aquaculture
	Research and monitoring	Species surveys, scientific research projects
	Information and capacity building	Training, networking opportunities, partnerships, information materials
	Planning	Management plan
	Institutions for management	Use/production of legislation and/or existing informal rules
Outcomes	Economic benefits	Provision of jobs, increase number of businesses
	Social benefits	Decrease of conflicts, increase of cooperation
	Empowerment	Women are given project management functions in a culture where only men usually have decision-making powers
	Health benefits	Happiness, motivation, satisfaction
	Learning	Change in strategies, actions, or values
	Cultural benefits	Cultural revitalization, recreation opportunities
	Environmental benefits	Increase of species populations, decrease of overexploitation of natural resources
	Economic impacts	Decrease of jobs available, decrease of households' income
	Social impacts	Displacement of people, conflicts
	Inequality	Economic benefits are only available for some social groups
	Health impacts	Stress, frustration, insecurity
	Cultural impacts	Erosion of traditions, lack of access to cultural important sites or activities
	Environmental impacts	Overexploitation of natural resources, decrease of species numbers or distribution

Table A4. Criteria used to select the clustering method. The interpretability was considered hard when the dendrograms form long chains or reversals [74]. The cluster analysis was performed using the hclust function of the stats package for R.

Clustering Method	Interpretability	Agglomerative Coefficient	Decision
single average mcquitty median centroid	Hard	Not evaluated	Not used
ward.D2	Simple	0.78	
complete		0.56	
ward.D		0.87	Used

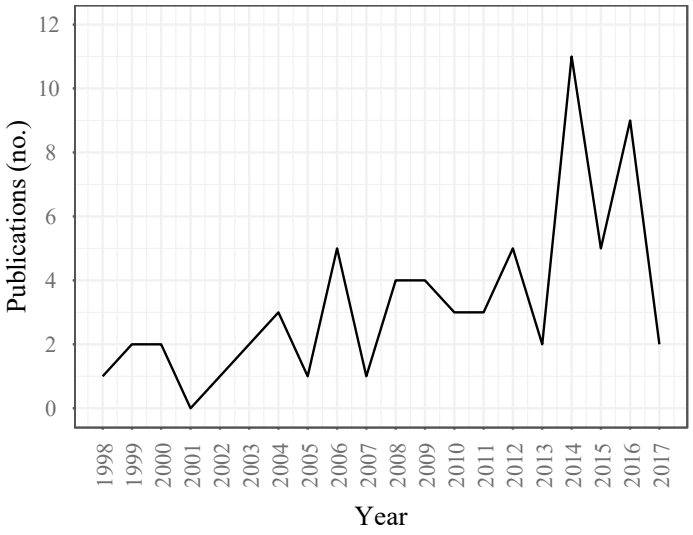

Figure A1. Temporal evolution of the number of studies about biosphere reserves' management effectiveness. Only English, peer-reviewed papers, which are developed in one biosphere reserve, and published between 1996 and March 2017 in the Scopus database were included.

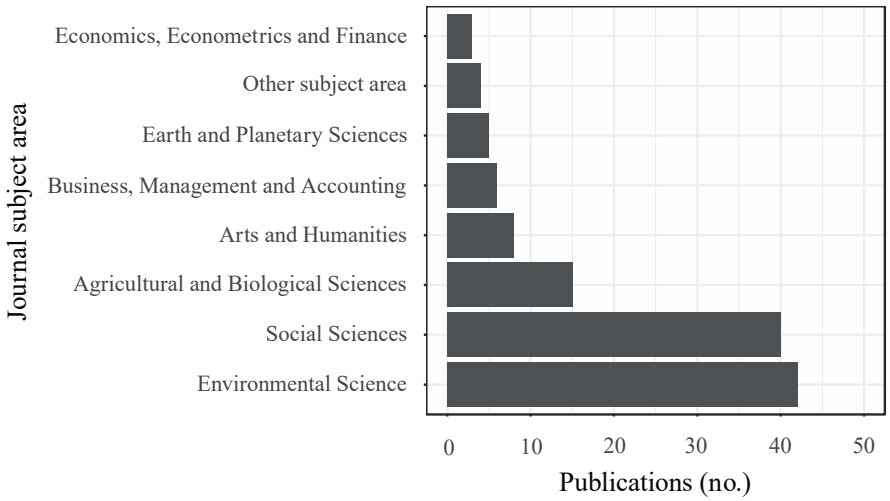

Figure A2. Subject area of the journals where the studies about biosphere reserves' management effectiveness were published, according to ELSEVIER [26]. Journals can belong to more than one subject area.

Table A5. Information about the location of the biosphere reserves (MAB region and country), number of studies performed in each biosphere reserve (n), and if the biosphere reserve is transboundary (T = 1) or not (T = 0). Information about transboundary biosphere reserves was retrieved from UNESCO [72].

BR Name	MAB Region	Country	n	T
Mananara Nord	Africa	Madagascar	1	0
Kogelberg	Africa	South Africa	1	0
Waterberg	Africa	South Africa	1	0
Shouf	Arab States	Lebanon	1	0
Wolong	Asia and the Pacific	China	4	0
Jiuzhaigou Valley	Asia and the Pacific	China	1	0
Yancheng	Asia and the Pacific	China	1	0
Changbaishan	Asia and the Pacific	China	1	0
Nanda Devi	Asia and the Pacific	India	6	0
Similipal	Asia and the Pacific	India	1	0
Nilgiri	Asia and the Pacific	India	1	0
Lore Lindu	Asia and the Pacific	Indonesia	1	0
Tasik Chini	Asia and the Pacific	Malaysia	1	0
Salzburger Lungauand Kärntner Nockberge	Europe and North America	Austria	1	0
Rhön	Europe and North America	Germany	2	0
Geres/Xures	Europe and North America	Portugal/Spain	1	1
Danube Delta	Europe and North America	Romania/Ukraine	4	1
Kristianstad Vattenrike	Europe and North America	Sweden	1	0
Entlebuch	Europe and North America	Switzerland	1	0
La Amistad	Latin America and the Caribbean	Costa Rica	1	0
Maya	Latin America and the Caribbean	Guatemala	9	0
Río Plátano	Latin America and the Caribbean	Honduras	1	0
Sierra de Huautla	Latin America and the Caribbean	Mexico	2	0
Mariposa Monarca	Latin America and the Caribbean	Mexico	2	0
Ría Celestún	Latin America and the Caribbean	Mexico	2	0
Montes Azules	Latin America and the Caribbean	Mexico	1	0
Los Tuxtlas	Latin America and the Caribbean	Mexico	1	0
Sierra de Manantlán	Latin America and the Caribbean	Mexico	2	0
El Vizcaíno	Latin America and the Caribbean	Mexico	3	0
Banco Chinchorro	Latin America and the Caribbean	Mexico	1	0
Tehuacán-Cuicatlán	Latin America and the Caribbean	Mexico	1	0
Sian Ka'an	Latin America and the Caribbean	Mexico	2	0
Barranca de Metztilán	Latin America and the Caribbean	Mexico	1	0
Alto Golfo de California y El Pinacate	Latin America and the Caribbean	Mexico	2	0
El Cielo	Latin America and the Caribbean	Mexico	1	0
Riverland	Latin America and the Caribbean	Australia	1	0
Espinhaço Range	Latin America and the Caribbean	Brazil	1	0
Bosque Mbaracayú	Latin America and the Caribbean	Paraguay	1	0

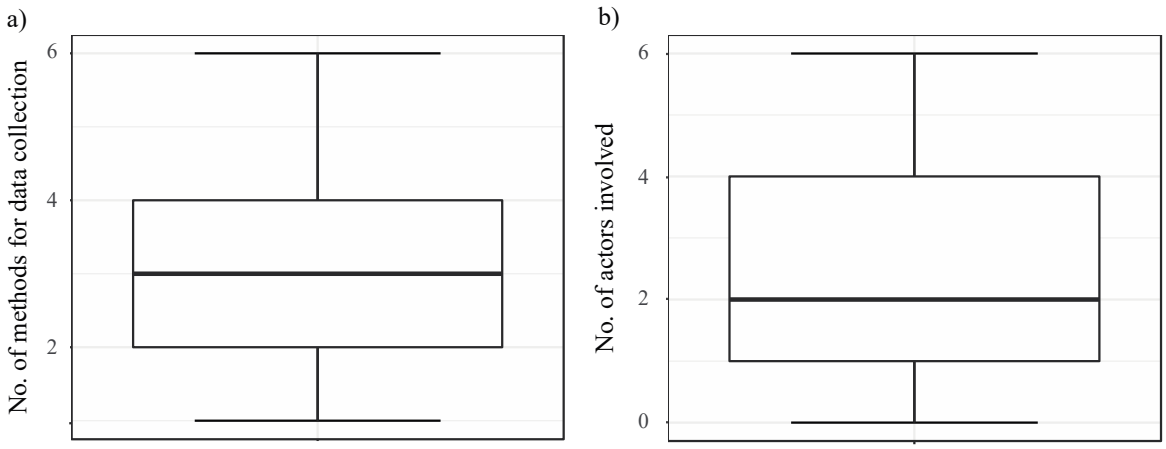

Figure A3. Methods for data collection used in the literature analyzed: (**a**) boxplot displaying the number of different methods used in the data collection; (**b**) boxplot displaying the number of different actors involved in the data collection.

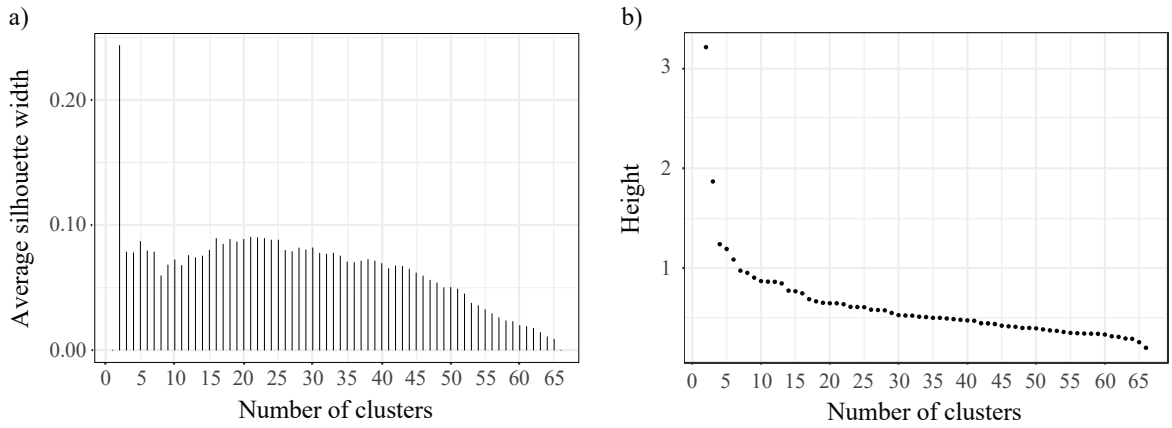

Figure A4. Definition of the optimal number of clusters according to: (**a**) the silhouette index [74] and (**b**) a scree plot. The different solutions were also interpreted to decide which one provides a better relationship between the specificity and generality of the results.

Table A6. Cluster evaluation statistics. To evaluate the internal quality of the clustering, the average silhouette width—s(i)—was used, as computed in the silhouette function of the cluster package for R. Values around 0 indicate that observations lie between two clusters; well-clustered solutions have an average s(i) close to 1. To evaluate the robustness of the clustering, the clusterwise Jaccard bootstrap mean was used, as computed in the clusterboot function of the fpc package for R with 100 resampling runs. Following Zumel and Mount [75], clusters with stability values lower than 0.6 are unstable and values of stability between 0.6 and 0.85 indicate patterns in the data, but there is a high uncertainty about which observations should be clustered together.

Cluster Validity Type	Cluster Validity Measure	Cluster 1	Cluster 2	Cluster 3
Internal quality	Average silhouette width s(i)	0.1	0.07	0.03
Robustness	Clusterwise Jaccard bootstrap mean	0.69	0.57	0.79

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