land

Article

Mobilizing Global Change Science for Effective Multi-Actor Governance in the Laguna San Rafael and Guayaneco Biosphere Reserve

Trace Gale [1,2,*], Andrés Adiego [1,3], Fabien Bourlon [1,4] and Alexandra Salazar [1]

1 Centro de Investigación en Ecosistemas de la Patagonia (CIEP), José de Moraleda 16, Coyhaique 5951601, Chile; andres.adiego@ciep.cl (A.A.); fabienbourlon@ciep.cl (F.B.); alexandra.salazar@ciep.cl (A.S.)
2 Cape Horn International Center (CHIC), O'Higgins 310, Cabo de Hornos 6350000, Chile
3 Department of Geography and Territorial Planning, Universidad de Zaragoza, Calle Pedro Cerbuna 52, 50009 Zaragoza, Spain
4 CNRS, Sciences Po Grenoble, School of Political Studies, PACTE Laboratory, Université Grenoble Alpes, 38000 Grenoble, France
* Correspondence: tracegale@ciep.cl; Tel.: +56-09-8955-6032

Abstract: The 1950s initiated transformative shifts in human interactions and societal behaviors, exacerbating global environmental challenges—notably, biodiversity loss. The post-2020 Kunming–Montreal Global Biodiversity Framework (GBF) addressed these challenges with ambitious plans to halt and reverse biodiversity losses. Supported by initiatives like UNESCO's Man and the Biosphere program, the GBF seeks to enhance sustainability through country-level strategies that will mainstream nature-positive policies and expand multi-actor conservation governance. This study supports the local-level implementation of the GBF through a roadmap for the initial phase of the knowledge-action network creation. Through a case study of the Laguna San Rafael and Guayaneco Biosphere Reserve (LSRGBR) in Chilean Patagonia, this research explores the potential for inexpensive, readily available methods to support local decision makers by increasing access to and the visibility of relevant sustainability research. The study analyzes two decades of global change (GC) research within LSRGBR zones to understand spatial trends and identify applied insights with the potential to inform governance and management strategies. Findings highlight where GC research has occurred, areas of GC research interest, how applied content has manifested, and how existing research can inform and support governance action plans. Ultimately, this research proposes an adaptable knowledge mobilization framework for the LSRGBR that can be applied to a variety of place-based needs and contexts to mobilize science for broader sustainability objectives and enhance the potential for multi-actor collaboration and governance.

Keywords: biosphere reserve; Chilean Patagonia; global change drivers; governance; knowledge–action network; Laguna San Rafael; post-2020 Kunming–Montreal global biodiversity framework (GBF); sustainability science; systematized literature review

check for updates

Citation: Gale, T.; Adiego, A.; Bourlon, F.; Salazar, A. Mobilizing Global Change Science for Effective Multi-Actor Governance in the Laguna San Rafael and Guayaneco Biosphere Reserve. *Land* **2024**, *13*, 1739. https://doi.org/10.3390/land13111739

Academic Editors: Vincent Ralph Clark and Ruida Pool-Stanvliet

Received: 11 September 2024
Revised: 21 October 2024
Accepted: 22 October 2024
Published: 23 October 2024

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The 1950s are widely recognized as marking the onset of an intense acceleration in the way that humans relate with one another and with the world they inhabit [1–4]. Since this pivotal moment, prevailing human values and behaviors have influenced the direction of various societal trends, including demographic, sociocultural, technological, economic, institutional, governance, conflict-related, and epidemic trajectories [1–7]. These factors are the indirect drivers of change happening in natural systems worldwide; a phenomenon known as global change. Indirect drivers orient complex systems of interrelated human activity that function and interact with one another and with the earth, along multiple scales. These activities directly impact and alter natural systems through human-induced climate, land, and sea use changes, biodiversity loss, pollution, resource exploitation, and the spread of invasive species [5–8].

Amid escalating global change, environmental degradation, and levels of human distress, the post-2020 Kunming–Montreal Global Biodiversity Framework (GBF), which was adopted by 195 countries around the world and the European Union, outlines a vision for 2050 in which biodiversity is valued, conserved, restored, and sustainably utilized, maintaining ecosystem services that sustain human well-being [9]. This vision was guided by the scientific bases and policy recommendations of decades of sustainability science, including the Millennium Ecosystem Assessment [10], the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) conceptual framework [11], and the IPBES global assessment of biodiversity and ecosystem services [5,7]. Sustainability science is an interdisciplinary field that studies the interactions between human systems and the natural environment, to better understand and promote sustainable practices that balance ecological health, economic viability, and social equity [12]. The GBF identifies priority areas related to sustainability science, evolving protected area paradigms, and the integration of conservation values within society, as well as the mainstreaming of biodiversity in governance and policy [9,13]. This framework emphasizes enhancing protected areas' effectiveness, promoting sustainable use, and fostering societal engagement in biodiversity conservation. It also advocates for incorporating biodiversity considerations into various sectors and governance frameworks to achieve sustainable development goals. These themes are central to the GBF's objectives and targets aimed at halting biodiversity loss and promoting sustainable practices globally [9].

The UNESCO Man and the Biosphere (MaB) program aligns with and supports the GBF by promoting the concept of biosphere reserves (BRs) with integrative area-based zoning that include models for sustainable development that weave together biodiversity conservation and human well-being [14–16]. Each BR features a nucleus zone focused on conventional conservation with restricted human activities, surrounded by a buffer zone that allows low-impact development. Finally, transitional zones encircle BRs, accommodating urbanization and development, provided there is a commitment to sustainability [17].

The MaB emphasizes research into and the monitoring of ecosystems, which contributes to the scientific understanding necessary for effective biodiversity management, a key aspect of the GBF [14,16]. Additionally, BRs serve as platforms for participatory multi-actor governance, engaging local communities in conservation efforts and fostering sustainable practices that reflect the GBF's goals of equity and inclusivity. By facilitating the sharing of best practices and lessons learned from BRs, the MAB program supports the GBF's objectives to enhance protected area networks and promote the sustainable use of biodiversity, thereby contributing to the overall aim of halting biodiversity loss [5,7,9,13,14,16]. The MaB program envisions a capacity for BRs to foster multi-actor governance systems capable of co-producing knowledge, effectively transferring and applying relevant findings, and providing feedback to enhance future knowledge production [18–20]. Knowledge–action (KA) networks have emerged to address these needs.

1.1. Knowledge–Action Networks: Connecting Science, Management, and Governance

In the context of environmental conservation and governance, a KA network serves as a platform for connecting scientific knowledge with practical knowledge, actions, and policy decisions aimed at addressing environmental challenges and promoting sustainability [21]. KA networks bring together diverse stakeholders, including scientists, policymakers, conservationists, local communities, Indigenous groups, and other relevant actors, to tackle challenges associated with GC through the exchange of information, ideas, and best practices, and the development of relevant actions [22]. Thus, finding ways to develop and integrate a KA network with multi-level governance approaches may help BRs develop an iterative learning loop to advance transformative change towards more sustainable pathways for their territories [5,7,23].

Developing an effective KA network can be challenging [23,24]. First, BRs (and other PAs) must identify and understand how science is occurring within their territory. Often, research occurs with little to no local contact or local-level transfer. Researchers come from around the world to conduct their work, but data, results, and recommendations do not always reach decision makers within the areas where research occurs [23,24]. Moreover, much sustainability research is still very specialized, making it difficult to understand, operationalize, and integrate within smart policy mixes and governance interventions [25,26]. GC science must increasingly be operationalized by focusing on how theories and findings can contribute to multi-actor governance levers for transformative change. This includes preemptive action, environmental law and policy, cross-sectoral cooperation and decision making, as well as incentives and capacity building. Such an approach is essential to navigate the uncertainties and ever-changing conditions of specific territorial contexts and priorities [5,7,21,24].

This paper explores these challenges and possibilities in the context of the Laguna San Rafael and Guayaneco BR (LSRGBR), located in the Aysén del General Carlos Ibáñez del Campo region (Aysén) of Chilean Patagonia. The overarching objective of this research is to demonstrate how sustainability science can be operationalized to support the creation of a KA network that can support the shared visions of the MaB program, the GBF, and the transformative change model advanced by IPBES (2019) [5,7], by helping the LSRGBR identify and understand how science is occurring within their territory. Within the place-based context of the LSRGBR, we explore a simple approach for identifying, georeferencing, and characterizing the areas of emphasis for GC science that has occurred in recent decades, including trends related to KA content (i.e., document excerpts which include recommendations, suggested management practices, strategies, and educational content). Then, we explore the ways in which existing research can strengthen and inform current action and decision making.

1.2. Case Study Context

The LSRGBR (Figure 1), officially declared in 1979, is situated in the Aysén Region of Chilean Patagonia (Figure 1). Currently, the LSRGBR protects an area of 51,304 km^2 composed of terrestrial and marine ecosystems [27]. Some of the most important geographic landmarks within the LSRGBR include the San Rafael Lagoon and Glacier, the North Patagonian Ice Field, the Exploradores Valley, and the Baker Fjord (Figure 1). The LSRGBR buffer and transition zones include a total estimated population of around 4900 inhabitants dispersed within the small city of Cochrane, a series of small urban centers, and large rural areas [28].

The nucleus zone of the LSRGBR is comprised of the Laguna San Rafael National Park (LSRNP), which has been administered by the Chilean National Forest Corporation (CONAF) since its creation in 1959. This park has been the area in which tangible protection and management action has concentrated—in large part because, historically, there has not been a legal validation of the MaB framework in Chile. Thus, for several decades, the LSRGBR has largely existed on paper. It lacked several of the basic MaB management components, including formal funding and a management action plan; thus, historically, there has been little territorial recognition or clarity regarding the LSRGBR and no strong sense of ownership by the local community, except in local conservation and socio-cultural development organizations.

Recent advances have positioned the LSRGBR to move forward in more substantive ways. Chilean Law 21600, enacted in 2023, established the Biodiversity and Protected Areas Service (SBAP) and the National System of Protected Areas after a lengthy legislative process that began in the early 2000s [29]. After several revisions and extensive public consultations, the law was finally passed in 2023, marking a significant achievement in protecting Chile's biodiversity. This aligns with global frameworks such as the GBF and UNESCO's MaB program, emphasizing the preservation, restoration, and sustainable use of ecosystems [29].

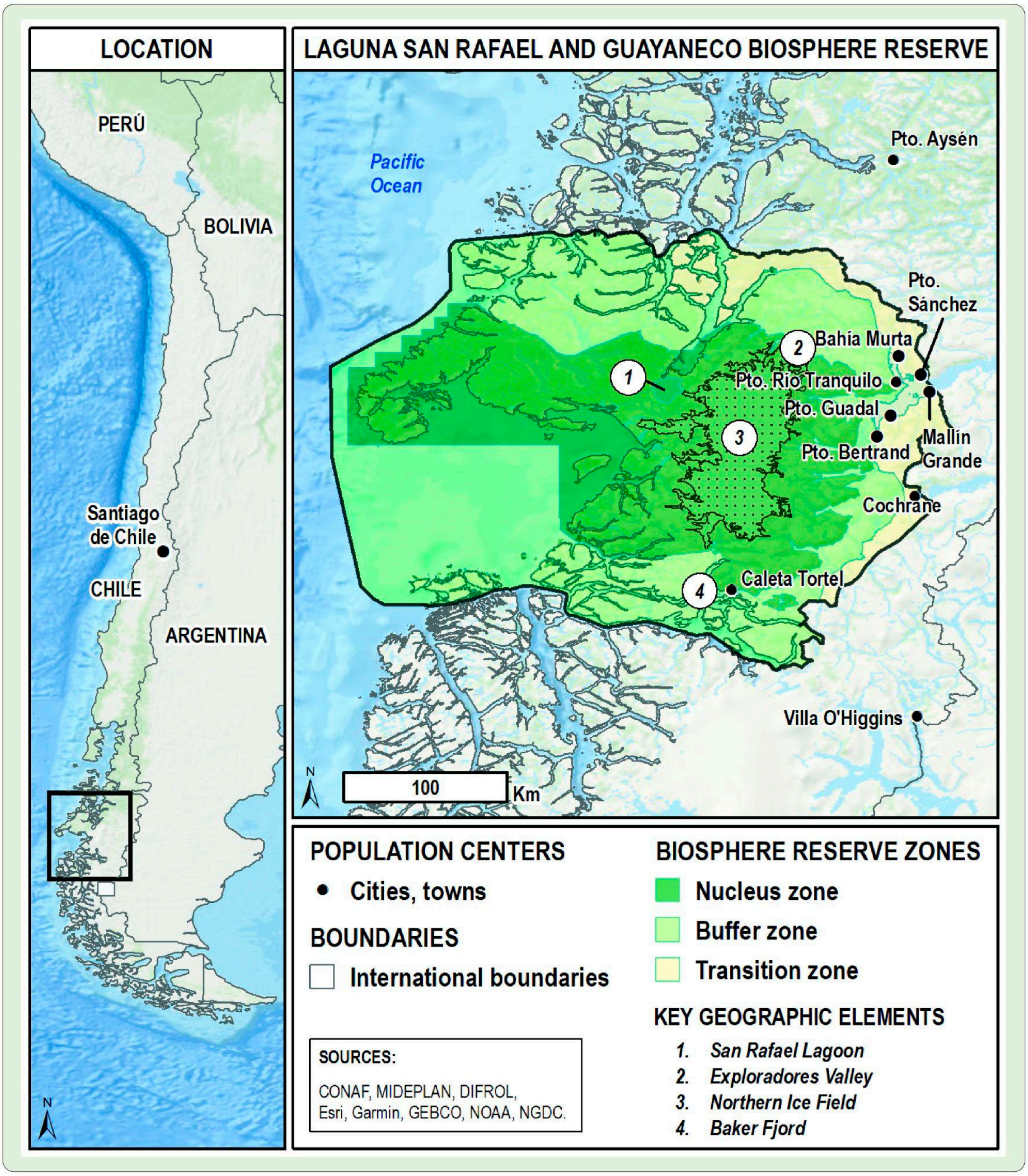

Figure 1. Study area: Laguna San Rafael and Guayaneco Biosphere Reserve.

In parallel, a series of other advances were occurring for the LSRGBR. While they vary in size and location, all BRs are governed by UNESCO guidelines, which were initially established through the Seville Strategy and Statutory Framework of the World Network of BRs in 1996 and updated in 2017 with the new global MAB Strategy and Lima Action Plan (LAP) [14,16]. The LAP underscores the role of BRs in advancing the UN Sustainable Development Goals (SDGs), the GBF, and sustainable, transformative, societal change [14,16]. BRs are expected to serve as climate change research observatories, promoting sustainable development and partnerships with educational institutions that integrate with local governance systems [14,16].

A 2017 review of the LSRGBR by the International Coordinating Council of the MaB Program (MaB-ICC) identified several deficiencies with zoning and functions that required immediate address [30]. The MaB-ICC is the main governing body of the MAB program, which operates under the guidance of UNESCO Member States. With technical support from a consultant appointed by UNESCO, the Aysén Regional government and CONAF realized a participatory process with LSRGBR stakeholders during 2018 to address these shortcomings. Process outcomes included defining the buffer and transition zones for the BR, establishing a Management Committee, and developing an initial action plan for the 2018 to 2024 timeframe. The 2017–2018 MaB-ICC update process produced a Dossier for the Update and Zoning [27], which was submitted to UNESCO for approval in 2018, and approved by the MaB-ICC in 2019 [30].

The 2018–2024 action plan produced through this process included 10 objectives for the LSRGBR territory that integrated the three main functions of the MaB: conserving and safeguarding biological and cultural diversity, sustainable development, and supporting scientific research. Moreover, the 2018–2024 action plan identified that ongoing scientific research should be used to support the development, management, and planning of the LSRGBR, through the co-creation of local strategies to guide the development, conservation, and valorization of the area's cultural and natural heritage, in conjunction with the communities and stakeholders of the territory [31].

With the formalization of the basic MaB components for the LSRGBR, the enactment of Chilean Law 21600, and the GBF's area-based strategies and objectives, the LSRGBR seems poised to assume a larger role within Chile's biodiversity and sustainable development strategy, aligning its governance with the broader mission established through the LAP and the objectives of the GBF. Nevertheless, the Management Committee governance instances that were initiated during the 2017–2018 MaB-ICC update process will require support and strengthening, especially as participants interact and advance the 2018–2024 action plan. To engage the vision of the LAP, they will require a science-informed strategy for improving LSRGBR connections between science, management, and governance.

2. Materials and Methods

2.1. Research Purpose

Through a case study of the LSRGBR, this research explored the potential for inexpensive, readily available methods to support the initial phase of KA network creation by making relevant sustainability research accessible to local decision makers. Specific objectives included:

- Characterizing the evolution of GC research over the past two decades (2000–2021), within the LSRGBR.
- Characterizing the evolution of KA content related to GC research published over the past two decades (2000–2021), within the LSRGBR.
- Exploring how LSRGBR GC science can be applied to improve governance and management goals.

By helping the newly formed LSRGBR governance group to identify and understand how science is occurring within their territory, we hope to enhance their ability to convene and develop an effective KA network that will collectively advance the shared visions of the local territory, the MaB program, the GBF, and the transformative change model advanced by IPBES [5,7,9,14,16].

2.2. Research Design and Justification

The qualitative aims of this study necessitated a research design that could facilitate a comprehensive and nuanced understanding of the unique scientific trajectory for research related to GC in the LSRGBR [32]. To achieve this, an intrinsic case study methodology was employed, recognized for its effectiveness in facilitating detailed examinations of complex issues within their real-life settings [32,33], revealing distinct characteristics and complexities that are of particular interest [32–34]. Unlike instrumental case studies that examine broader phenomena through a particular instance, intrinsic case studies prioritize the case itself, especially when it holds particular interest or relevance (i.e., supporting the development of an LSRGBR KA network aligned with the MaB reserve mission, as refined by the LAP). Intrinsic case studies are frequently utilized in fields like education, psychology, and social sciences, yielding rich insights that, while not necessarily generalizable, are crucial for understanding the particular instance under investigation [32–34].

To understand the current state of GC-related science within the LSRGBR and evaluating its potential to inform strategies to better connect science, management, and governance, the intrinsic case study methodology employed a systematized literature review enriched with a geographical component, focusing on GC research published between 2000 and 2021 (Figure 2). Then, targeted content analysis was used to identify KA excerpts within the dataset documents and match the associated documents with the objectives and activities of the LSRGBR 2018–2024 action plan.

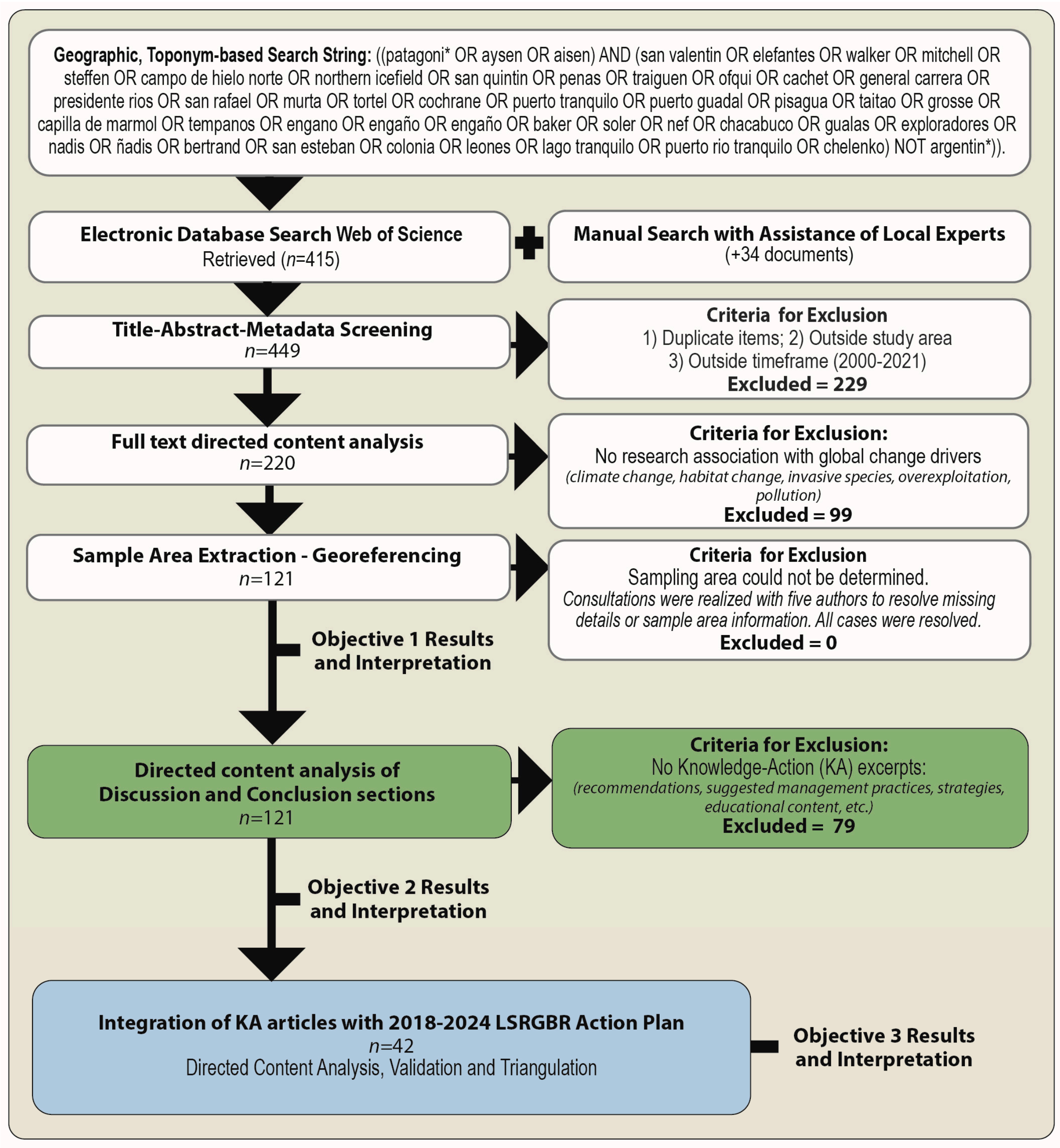

Figure 2. Study Flow Diagram.

2.2.1. Data Collection and Organization

A systematized literature review involves identifying, evaluating, and synthesizing research findings to produce a summary of current evidence that can inform evidence-based practice. It maintains scientific rigor through the use of search protocols and document selection criteria that helps to minimize biases, affording a robust, but not exhaustive revision of key research trends related to particular areas of interest [35,36]. For the LSRGBR case, it was important to also understand where research was taking place, so search parameters, coding, and analysis were enhanced with a geographic component [35–38].

The LSRGBR systematized literature review began with the Web of Science database and a query of peer-reviewed scientific literature published between 2000 and 2021. Rather than focusing on specific GC topics, the review employed a geographic focus, based on place-based toponyms [37,38]. Toponyms, or place names, are the names of geographic places: administrative areas, population centers, and landscape landmarks like rivers, volcanoes, beaches, and fjords, amongst others. Therefore, many scientific studies include them in their titles, keywords, and/or abstracts [39].

The methodology for selecting toponyms involved using a geographic layer from the Chilean National Congress Library, which includes 41,462 toponyms covering various geographic elements across the country. The research incorporated this toponym layer alongside the LSRGBR boundary layer in ArcMap (version 10.6). Toponyms were selected based on their overlap with the LSRGBR and a five-kilometer buffer, resulting in 1052 identified toponyms. Similar toponyms were consolidated into unique descriptors, leading to a provisional list of 39, which was later refined to 42 after consultations with the research team and local experts. A search string was created using these toponyms and terms related to Patagonia, excluding documents from Argentine Patagonia (Figure 2).

The Web of Science database search yielded 415 documents, reflecting the peer-reviewed research literature. Next, to further enhance the dataset, scientific actors familiar with the 2017–2018 MaB-ICC update process were invited to review the initial review list and contribute additional scientific documents related to GC and the LSRGBR, developed during the 2000–2021 timeframe. Thirty-four additional papers, books, and research reports were added, resulting in a total of 449 documents. These documents were screened to eliminate duplicates and research that did not comply with the spatial or temporal scope of the project. A full-text review of the 220 remaining documents focused on their associations with GC drivers: climate change, habitat change, invasive species, overexploitation, and pollution [5–7,10]. If a document applied to more than one GC driver, it was counted in each of them. Documents that did not mention any GC drivers were classified as "Other". This process resulted in a GC dataset of 121 documents, with a total of 184 GC driver associations that informed the first research objective.

Next, the spatial scope of each document was extracted from its methods sections, and georeferenced in a Geodatabase using ArcMap (version 10.6). Point layers were created for specific locations, while polygon layers were used for surface data. Five documents required clarification on georeferencing, which was successfully resolved with the authors' input. An overlay analysis was conducted to assess the geographic extent of each document relative to LSRGBR zones. The georeferenced sampling sites were used to generate heat maps representing sampling density in the LSRGBR. For this purpose, a grid was generated, with cells of 30 × 30 m covering the entire study area, and the number of samples contained in each cell was counted, integrating the systematized points and polygons representing the sampling sites. This integrated layer was then introduced into Global Mapper (version 19), and the density tool was used to generate heat maps. These maps were used to interpret findings for the first and second specific research objectives.

2.2.2. Identification and Analysis of the LSRGBR Knowledge–Action Context

In the second phase of the case study, we employed directed content analysis methods to investigate the application of LSRGBR GC science in enhancing governance and management objectives. Directed content analysis is a systematic approach within qualitative research that builds upon existing theories or prior studies to explore specific phenomena [40,41]. This method begins with the identification of initial coding categories and their operational definitions, which are derived from key elements of established theories. As highlighted by Hiesh and Shannon [42], this structured process allows researchers to validate and extend existing knowledge while maintaining a constructivist perspective. Directed content analysis was conducted on the abstract, discussion, and conclusion sections of the 121 GC research documents to identify KA excerpts, which were defined as content which included recommendations, suggested management practices, strategies, and educational content. The 42 documents that were found to contain relevant insights were designated as the KA subset. Next, the KA subset abstracts and applicable research content were evaluated for their potential to inform each of the 10 objectives within the 2018–2024 LSRGBR action plan. Results were coded individually and then triangulated by research team subject matter experts to improve reliability [43–45]. Finally, the GC driver coding was integrated with the 2018–2024 action plan analysis by summing the GC associations for the KA papers that were matched with the action plan objectives and graphing the driver proportions. The results of this process were incorporated within the interpretation process of the research, informing the potential for knowledge transfer and capacity building [26,46].

3. Results

3.1. Characterization of the LSRGBR Global Change Scientific Context

Figure 3 provides a dashboard of the LSRGBR scientific context, with an overview of the evolution, dynamics, and spatial trends for GC research over the study timeframe of 2000–2021 (n = 121). Figure 3A of the dashboard provides an overview of the global change drivers that were associated with articles that included sample areas within each of the three BR zones: the nucleus, buffer, and transition zones. Figure 3B demonstrates the evolution of LSRGBR research over the twenty years of the study, showing areas of emphasis according to the drivers. Figure 3C reflects the cumulative document associations for each of the driver associations. Finally, Figure 3D illustrates spatial trends for GC research within the LSRGBR through a sampling site density heat map derived from the 121 documents.

Climate change emerged as the predominant driver in LSRGBR research, appearing in a total of 96 documents (79.34%) throughout the review period (2000–21), with the exception of 2004 and 2005 (Figure 3B,C). There was a noticeable increase in climate change research between 2018 and 2021, with 38 documents (31.4% of the total) published during these years. Habitat change was the second most-discussed driver, featured in 42 documents (34.71%). Introduced in a 2002 publication, habitat change research was absent in subsequent years, reappearing in 2008, with consideration in all subsequent years of the study. There were 11 documents associated with the invasive species driver during the study period, with a concentration in recent years (e.g., five publications in 2021). Overexploitation, associated with a range of factors including mining, tourism, aquaculture, and proposed mega-hydroelectric projects, appeared in 17 documents, debuting late in the dataset in 2009, with increased attention in 2021. The 18 pollution-related documents in the sample spanned the period from 2008 to 2021, with intermittent treatment in the documents and a marked increase in 2021, with five documents attributed to this year alone.

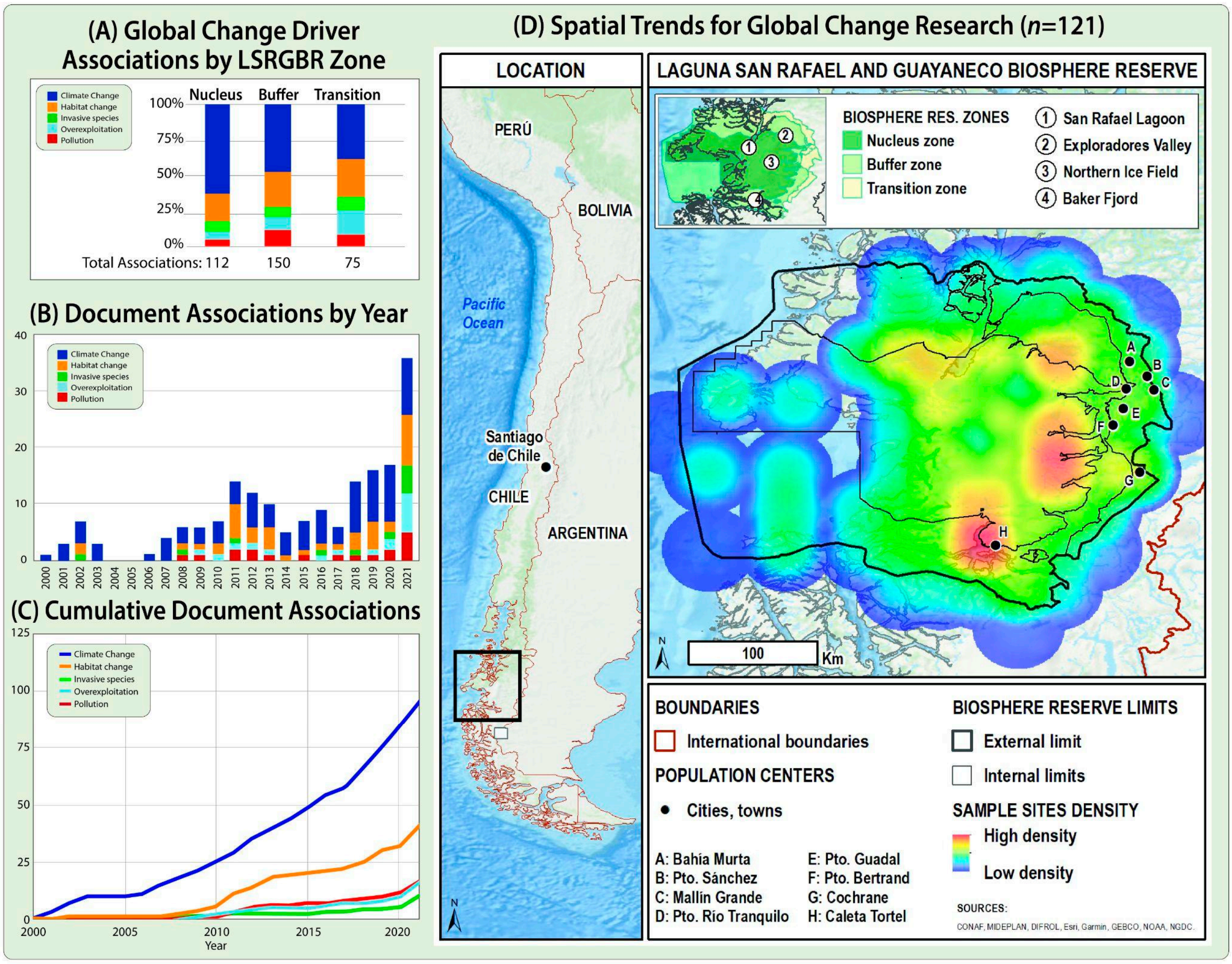

Figure 3. Temporal and spatial global change driver associations for the 121 GC subset documents: (**A**) Global change driver associations, by zone of the Laguna San Rafael and Guayaneco Biosphere Reserve (LSRGBR); (**B**) Number of document associations per year, by driver; (**C**) Cumulative number of document associations per driver; (**D**) Spatial trends within the LSRGBR.

The majority of the studies (55.37%) considered multiple BR zones in their sample areas, while the rest focused on a single zone (Figure 3A,D). To better understand the GC scientific context, we looked at how research has considered the nucleus, buffer, and/or transition zones in relation to the GC drivers. Within the 81 articles that included consideration of the BR nucleus zone, we found 112 associations with the GC drivers: 70 were related to climate change (62.5%), 22 to habitat change (19.64%), eight to invasive species (7.14%), seven to overexploitation (6.25%), and five to pollution (4.46%; Figure 3A). The buffer zone was the most prevalent study area within the literature, with 91 articles and 150 GC driver associations. Again, climate change was the most prevalent driver (70 associations; 46.67%). Nevertheless, research consideration of the other drivers increased in the buffer zone studies, especially for habitat change, which was associated with 37 of the documents (24.67%). In the 43 studies that considered the transition zone, we observed an accelerated and broader research consideration of the GC drivers. For example, beyond the 29 studies that considered climate change (38.67%), 20 studies considered habitat change (26.67%). Invasive species (seven, 9.33%) and overexploitation (13, 17.37%) documents also showed higher proportions of consideration within the transition zone, although contamination associations (six documents, 8%) decreased, as compared to the buffer.

Three high-density research "hotspots" emerged in the analysis, located along the southern and eastern edges of the Northern Patagonia Ice Field. There were also areas where the density of sampling sites was low or null, located mainly in the western portions of the LSRGBR. The largest of the high-density research hotspots was situated along the area of the park accessed between Puerto Bertrand and Cochrane, along the eastern flank of the Northern Patagonian Ice Field (33 documents). Most of these studies (11 documents) were focused on the nucleus zone of the BR, while some extended focus to the buffer and transition zones (13 and nine, respectively). The area around the town of Cochrane was the most prominent place considered within studies that included the transition zone (14 documents). The section of the park accessed through Caleta Tortel and the Baker Fjord represented another research hotspot, with 33 articles studying the dynamics occurring in the nucleus and buffer zones of the LSRGBR. The sectors around the San Rafael Lagoon formed a slightly less-dense cluster within the nucleus zone (29 documents) with an adjoining concentration of buffer zone research focused along the Exploradores Valley (27 documents), with access through Puerto Río Tranquilo.

3.2. The Potential for Global Change Knowledge to Inform LSRGBR Action, Governance, and Management Goals

To better understand the potential for mobilizing LSRGBR sustainability science, we turned to the KA subset documents, which were associated with applied content and/or recommendations (Figure 4). In total, 91 associations with the GC drivers were identified within the 42 articles that contained KA excerpts. Mirroring the broader GC subset results, the majority of KA subset documents were linked to the climate change driver (29 articles), while 25 articles featured associations with the habitat change driver. The remaining GC drivers (i.e., invasive species, overexploitation, pollution) were less prevalent within the KA subset, accounting for a combined total of 37 associations.

The series of five graphs (Figure 4A) represents the five GC drivers, showing the differences between research production for the GC dataset (n = 121) and the KA subset (n = 42). There are gaps between the GC and KA subset document trajectories for all five GC drivers, with the greatest gap appearing for climate change research. Invasive species, overexploitation, and pollution-associated documents were the lowest represented categories within the GC drivers; however, they were the most closely aligned in terms of their overall scientific production and content with KA recommendations.

Figure 4B illustrates the spatial trends for the KA subset documents (n = 42), providing a geographic perspective of the sample areas within the BR sectors and zones. In comparison with the overall GC dataset trends, KA research was much more concentrated within the buffer and transition zones of the LSRGBR, although seven of the documents were focused solely within the nucleus zone (Figure 4B). Three research hotspots emerged within the KS subset: one in the Baker Fjord area and the other two situated along the eastern and western interfaces of the Northern Patagonia Ice Field.

KA excerpts were rare within the documents published during the first decade of the study. There were a total of three KA documents with four GC associations during the period between 2002 and 2008 (Figure 4C). For the rest of the study period, KA excerpts were more frequent, with two notable periods of time in which documents tended to cluster. The first involved a series of 15 documents, with a total of 30 associations addressing all five GC drivers, that clustered between 2009 and 2015. The majority of these studies were related to dynamics within the Northern Patagonia Ice Field and the Baker River basin watershed, which drains into the Pacific fjords. A second cluster of 24 documents with KA excerpts emerged from 2017 through 2021, with 57 GC associations spread fairly evenly amongst the five GC drivers. The heaviest concentration of KA excerpts was associated with documents published in 2021, during which, 26 GC driver associations were identified, providing recommendations for all five drivers. Understanding glacial and watershed dynamics remained a prevalent theme during this period, but KA research also extended to other areas, including tourism, peatlands, microalgae, and biodiversity.

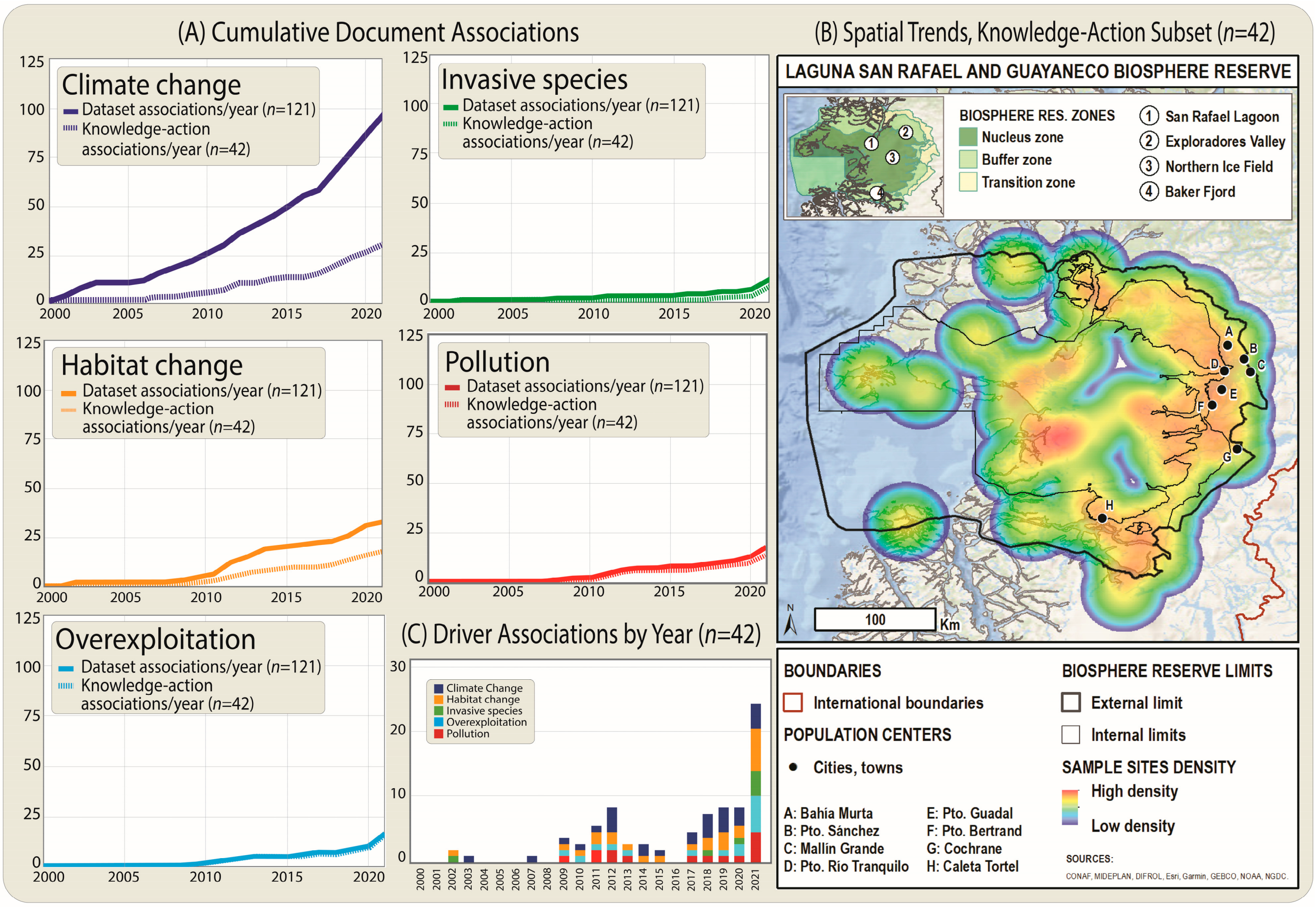

Figure 4. Temporal and spatial global change driver associations for the 42 knowledge–action subset documents: (**A**) Cumulative document associations for the five global change drivers, by zone of the Laguna San Rafael and Guayaneco Biosphere Reserve (LSRGBR); (**B**) Spatial trends within the LSRGBR; (**C**) Number of document associations per year, by driver; (**C**) Cumulative number of document associations per driver, by year.

3.3. Knowledge Mobilization Potential in the Context of the Laguna San Rafael and Guayaneco Biosphere Reserve 2018–2024 Action Plan Objectives

Directed content analysis successfully matched all 42 KA subset articles with one or more of the LSRGBR 2018–2024 action plan objectives (Figure 5). Objectives 4 and 9 were linked with the most KA subset documents; 24 and 22 documents, respectively (Figure 5). Objective 10, which sought to safeguard biodiversity and genetic variety, also had numerous articles (16) associated, as did Objective 8, which sought to support sustainable tourism (14 associated articles), and Objective 6, which sought to promote the sustainable extraction of natural resources (12 associated articles). Objectives 1, 2, and 3, which focused on waste management and agrochemical and mining regulation, were matched with the fewest articles in the 42 KA subset (four, five, and five, respectively).

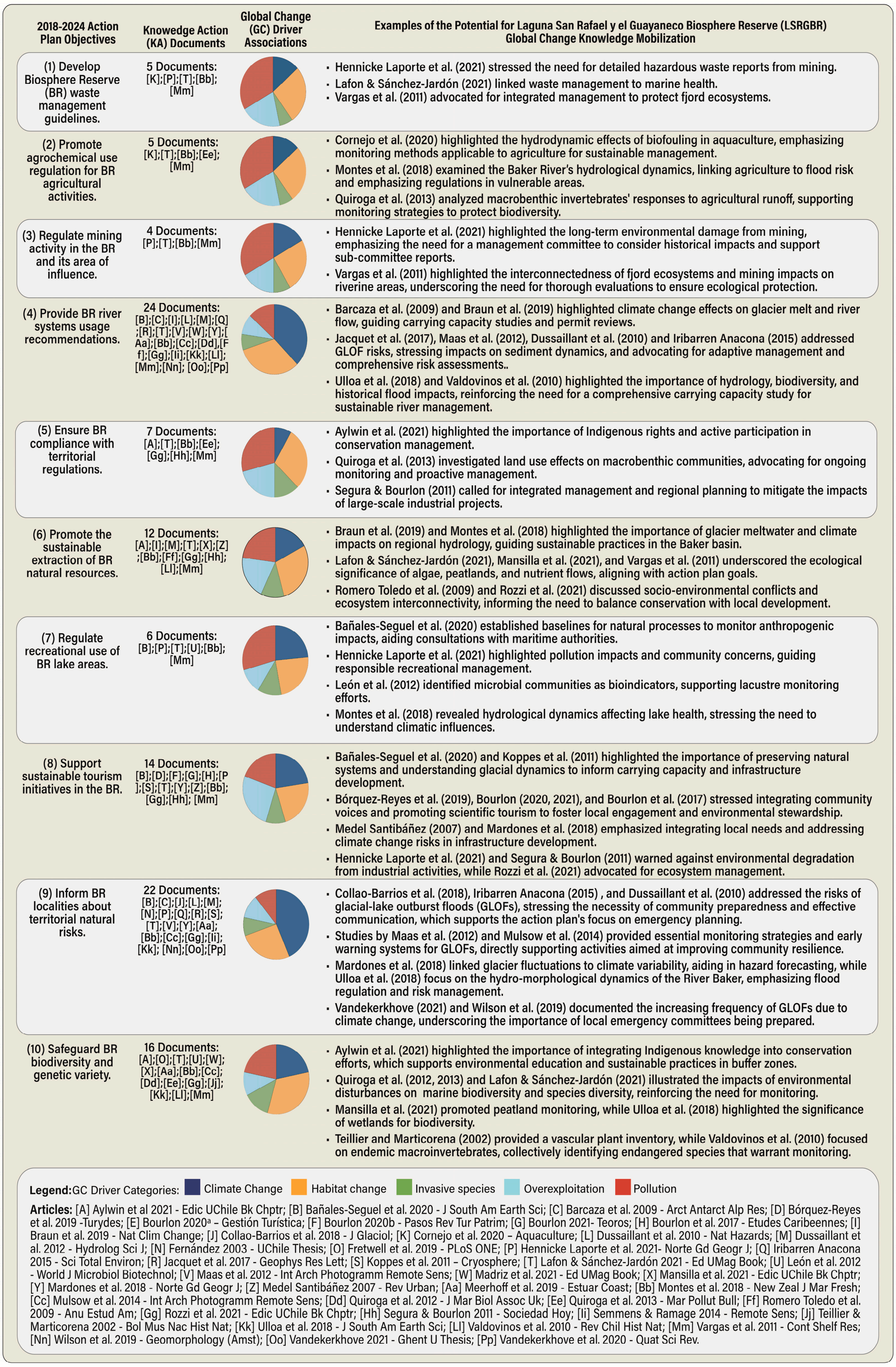

Figure 5. Knowledge Mobilization Potential Assessment for the Laguna San Rafael and Guayaneco Biosphere Reserve 2018–2024 action plan [47–79].

The first three objectives of the LSRGBR 2018–2024 action plan addressed the better management and regulation of waste, agrochemicals, and mining activities within the BR. Not surprisingly, the most frequently mentioned GC driver for related research for these objectives was pollution, followed by habitat change and overexploitation. Objectives 4 and

8 related to the use of rivers and natural risks. Most of the KA excerpts for these objectives were oriented around changing conditions in the Northern Patagonia Ice Field and natural phenomena like glacial lake outburst floods (GLOFs). The predominant driver associated with these objectives was climate change, followed by habitat change and pollution. For Objectives 5 and 6, which addressed compliance with territorial regulations and sustainable resource extraction, the dominant driver associations involved habitat change, followed by pollution and overexploitation. Objective 7 addressed recreational lake use. The most common GC driver associations for this objective involved pollution, habitat, and climate change. Objective 8 supported sustainable tourism initiatives, with GC driver associations concentrated around overexploitation, followed by climate change and habitat change. For Objective 10, which prioritized safeguards for biodiversity and genetic variety, the most mentioned driver was habitat change, followed by climate change and pollution.

4. Discussion

On its own, the systematized literature review with a geographical perspective presented in this case study provides the LSRGBR with targeted management and governance knowledge that can inform spatial planning, community engagement, monitoring, evaluation, and policy development. The 121 GC subset documents convey an ongoing and intensifying research focus on climate change within all three zones of the BR and increasing consideration of the wider set of GC drivers (Figure 3A,D). GC dataset content analysis reinforced a general alignment between research topics, territorial planning, and development priorities that may be channeled and directed through a LSRGBR KA network.

For example, during the early 2000s, a series of hydroelectric dams were proposed for the Baker River, which flows along the southern and eastern interface of the BR. Research taking place in the LSRGBR began to cluster along the Baker River watershed, forming the research hotspots we observed along the eastern flank of the Northern Patagonian Ice Field, around Puerto Bertrand and Cochrane, and around the southern reaches of the BR, accessed through Caleta Tortel and the Baker Fjord (Figure 3D). The most notable hydroelectric proposal came in 2007, when the government earmarked the Baker and Pascua rivers for significant hydroelectric projects to enhance the national grid. During the years that followed, research intensified in the zone of the proposed dams. Research focused on developing a more comprehensive understanding of natural processes, biodiversity implications, and social and hydrological dynamics. Prompted by the repeated occurrence of a series of GLOFs between April 2008 and September 2009, with direct implications for the Baker basin, one of the areas of research concentration during this period involved the understanding of GLOF dynamics and implications. Associated research concentrated on possible responses of the watershed to climate change and GLOFs, including the possible implications for habitat change and the proposed hydroelectric initiatives [72,80–83].

Over the next few years, the hydroelectric proposals underwent various stages of environmental assessments and public consultations, stirring considerable debate among local communities, environmentalists, and Indigenous groups concerned about the potential ecological impact and cultural significance of the region. These developments also appeared within the SRLGBR dataset [84,85], providing sociocultural insights that helped interpret escalating opposition, highlighted by protests and activism. Ultimately, by 2014, the idea of building hydroelectric dams in the Baker River was abandoned as the government shifted its focus towards renewable energy alternatives, alongside acknowledging the importance of preserving the unique biodiversity and cultural heritage of the Patagonian region [86].

GC dataset document trends (Figure 3A,B), published since the abandonment of the dams in 2014, show an acceleration of research in the LSRGBR (Figure 3B,C), accompanied by a broadened consideration of GC drivers [87–92]. The general alignment between GC research topics and development priorities illustrated through this example supports the potential for research to inform policy and decision making, and offers the LSRGBR valuable tools for capacity building, education, and knowledge sharing [5,7,21–25].

For example, the collection of georeferenced knowledge documents that were identified within the GC dataset can facilitate the creation of detailed spatial maps that highlight ecological features, sensitive habitats, potential natural risks, and areas of cultural importance within the BR [93]. Geoportals, or other environmental education and governance decision-making tools, could share these maps more broadly, enhancing knowledge mobilization that may help unleash sustainable values and action within BR communities, aligning the LSRGBR with the transformative change pathways identified by the 2019 IPBES Global Assessment [7,11,23,26,46].

4.1. A Closer Look at Knowledge-Action Content and Evolution

Slightly more than a third (34.7%) of the GC dataset documents contained KA excerpts. These documents tended to employ a wider geographic focus within the BR, moving beyond the nucleus zone to consider how GC dynamics within the buffer and transition zones are affecting sustainable pathways for the LSRGBR. For example, while seven of the KA subset documents were focused solely on the BR nucleus zone, the remaining 35 documents included a focus on the buffer and transition zones (Figure 4B). Similarly, the GC driver focus also broadened amongst the KA documents, with increasing consideration of habitat changes and of the interactions between GC drivers.

Comparing the annual document trends within the GC dataset and KA subset suggests an increasing interest and capacity for applied research in the LSRGBR. As shown in Figure 6, in 14 of the 22 years examined, a larger proportion of GC documents lacked KA excerpts compared to those that included them. However, this gap narrowed in the later years of the study. Notably, in 2012, 2017, and 2021, the number of documents with KA excerpts surpassed those without. Additionally, in both 2014 and 2019, the distribution was evenly split at 50% for each category. Perhaps the intentional development of a KA network and agenda within the LSRGBR could further strengthen and accelerate this positive trend in applied research moving forward.

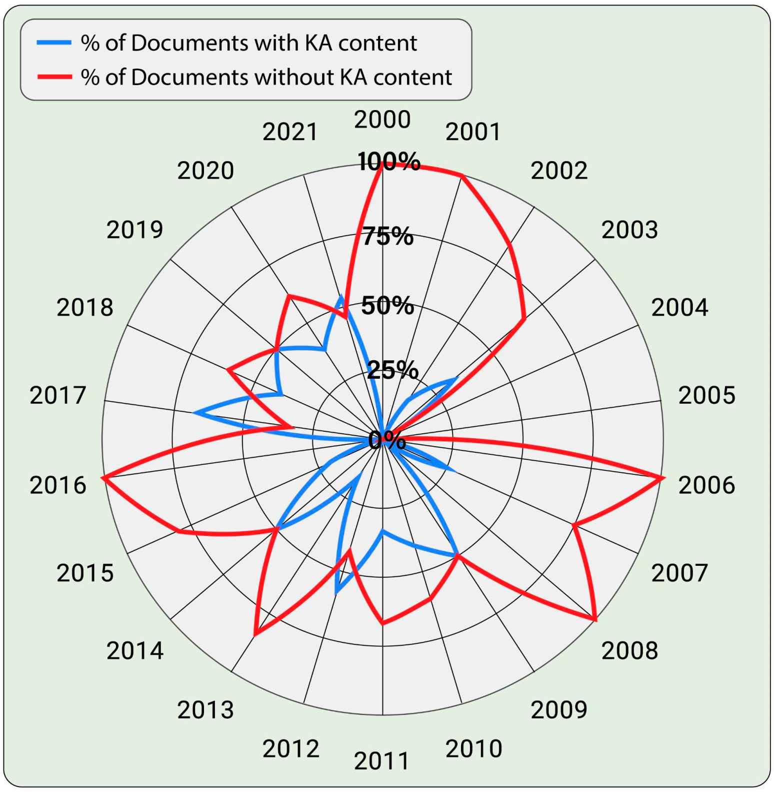

Figure 6. Comparison of Laguna San Rafael and Guayaneco Biosphere Reserve GC documents with and without knowledge–action content for the 2000–2021 timeframe.

Directed content analysis further supported the potential for mobilizing GC knowledge in the LSRGBR by identifying how the 42 KA documents could inform the 2018–2024 action plan objectives and activities. All 42 of the KA documents were matched with one or more of the 2018–2024 action plan objectives, confirming a general alignment between KA content and governance priorities. KA content aligned most frequently with objectives associated with natural systems and functions, specifically, Objective 4 (24 KA documents), which focused on river systems; Objective 9 (22 KA documents), which focused on natural risks; and Objective 10 (16 KA documents), which sought to safeguard biodiversity and genetic variety.

Climate change was the predominant GC driver associated with Objectives 4 and 9, with land use change associations playing a strong secondary role (Figure 5). The GC driver associations for Objective 10 were more evenly distributed amongst the five drivers, with land use change playing the predominant role, closely followed by climate change and pollution drivers. Overexploitation and invasive species GC drivers were also recognized with respect to Objective 10, suggesting the complexity involved in developing related sustainability paths. The LSRBGR governance group can use this information to guide their activities and understand where future research and policy should focus. Fewer KA documents were identified for action plan objectives associated with human activities like mining (four KA documents), agriculture (five documents), and waste management practices (five documents), although tourism KA research was more prevalent (14 documents). Based on the distribution of GC associations for the research linked with these objectives, it seems important to foster an additional research focus on the impacts of human activities on natural system changes within the BR.

4.2. Mobilizing Global Change Science for Effective Governance Action in the Laguna San Rafael and Guayaneco Biosphere Reserve

The effective assimilation of knowledge within a social–ecological system depends significantly on its mobilization, involving dynamic interactions between various actors [21–23,26]. By better understanding how, and where, GC-related research has evolved in the BR, the newly formed multi-level governance group can purposefully assemble scientific actors and representatives of other ways of knowing (e.g., Indigenous knowledge, craftsman, community members, public services, private sector actors, political actors) to discuss how findings might be mobilized to improve governance action and effectiveness, and strengthen research and management agendas [5,7,23,26,46]. As this practice occurs and advances, the findings and data of these studies can be blended and absorbed within the normative and political dimensions of the territory, leading to the development of an effective KA network [21,23].

This case study employed simple and inexpensive research methods to operationalize sustainability science to inform a scientific base for the creation of a KA network for the LSRGBR. Specifically, the systematized literature review helped to simplify the large volume of LSRGBR research into clear and concise summaries. The directed content analysis of the KA subset, using the 2018–2024 action plan, compiled valuable information to support effective decision making and facilitate the process of applying newly acquired knowledge to real-world practices. These outcomes help operationalize sustainability science, as inputs that can advance informational governance. However, building a successful KA network will require sustained efforts from UNESCO, the Aysén regional government, CONAF, participants in the new multi-level governance group, and other interested parties, employing strategies that enhance connectivity across the expansive LSRGBR territory. Muñoz-Erickson and Cutts [21] underscored the importance of this connectivity, along with intentional diversity, equity, and inclusion strategies, to ensure credibility and legitimacy among stakeholders. They also highlighted the necessity of creating spaces for discussing priorities, findings, and implications, which facilitate critique, negotiation, and integration in alignment with sustainability goals.

Internet access to tools like Google Scholar, Research Gate, or Academic Scholar enables a much wider access to the academic literature and rapid advancements in language translation, facilitated by advanced natural language processing (NLP), enabling the automatic translation of documents to a wide variety of languages. Thus, the systematized literature review process, used in this research, is accessible to governance groups around the world. While georeferencing study areas requires more specialized skills, attributing research to BR zones and sectors can be accomplished through simple coding and/or readily available technologies like GoogleEarth. Understanding where and how research occurs can also serve to identify relevant actors to inform and participate in KA networks and committees.

Ideally, the systematized literature review and directed content analysis that was employed in this case study would take place before BR action planning occurs to inform the BR vision and mission and then subsequently guide action plan priorities through an integrated KA research agenda. Yet, the relative speed with which the systematized literature review can be developed can also be useful for more specific challenges. In both cases, systematized literature reviews and directed content analysis can help actors identify research gaps and priorities and triangulate scientific advances with practical and technical knowledge [21–23]. The key themes and findings that surface through the review can foster discussion and focus decision making, helping to build a common understanding of the research landscape and a platform for different actors to share their related knowledge, resources, and strategies. As Muñoz-Erickson and Cutts [21] highlighted, a well-informed network can enhance its credibility and legitimacy among stakeholders, building trust in network processes and outcomes. The topics that surface through these types of studies can inform dedicated spaces for discussing priorities, findings, and implications and encourage critique, negotiation, and integration, which are vital for achieving sustainability goals.

The research and process presented in this paper have several limitations that are important to understand and consider, when evaluating the potential for research applications and/or replicability in other BR contexts. First, the dataset used in this study was primarily based on a combination of Web of Science, peer-reviewed research, and scientific documents that were added by an expert work group. This process may have overlooked valuable research published in other outlets, potentially skewing the understanding of GC drivers presented in the study. Second, by design, case study research is place-based, oriented by particular conditions and contexts. While its generalizability is naturally limited, we believe that this research offers an interesting and innovative knowledge mobilization process that should continue to be transferred, tested, and improved, in the context of sustainability research, the GBF, and the UNESCO MaB mission. While the findings of the current study accomplished our goal to help the newly formed LSRGBR governance group identify and understand how science is occurring within their territory, much work remains for them with respect to the development of an effective KA network. The following list of future research priorities can support this process:

1. Additional analysis of the existing dataset for this study could concentrate on authors and collaborators that have been involved in LSRGBR research, with the goal of identifying and prioritizing scientific contributors for a future KA network.
2. Expanding the current review beyond the traditional boundaries of academic literature to include local expert contributions, plans, strategies, and technical reports. This would enable a wider consideration of place-based knowledge and help identify ways to increase synergies across sectors.
3. Strengthening the case study we have developed with primary data collection through interviews, workshops, and a purposeful focus on understanding a wider variety of perspectives and ways of knowing.
4. Evaluating how local, national, and international policy legislates and incentivizes human activities and GC for the LSRGBR. Purposeful analysis of research–policy–action links could help transform and focus LSRGBR governance interventions to expand the potential for transformative sustainability change [5,7].

5. Directed content analysis can expand beyond the existing 2018–2024 action plan to consider other sustainability related models, like the GBF, the transformative change model advanced by IPBES [7,11], or the SDGs, which may highlight strategic considerations for future LSRGBR research agendas and action plans.

The outcomes of these studies could inform KA network composition and a strategy for capacity building, education, knowledge generation, and the next phase of multi-actor governance interventions. With better knowledge of the existing KA landscape, the CG LSRGBR governance group will be in a good position to review progress on the objectives and activities of their 2018–2024 action plan, synthesizing the advances and challenges they have encountered with current knowledge, to effectively adapt their plans for the following governance timeframe.

This paper explored these challenges and possibilities for developing an increasing connection between CG science and multi-actor governance levers for transformative change within the context of the LSRGBR. While the baseline development process we have developed was specifically tailored for the LSRGBR context, similar processes, and the future research priorities we have identified, may help BRs in other geographies, as well as other conservation initiatives and strategies, to mobilize GC science within their own multi-actor governance contexts. Our results have demonstrated the potential of a systematic, place-based approach for improving the understanding of how GC investigation has evolved and manifested within particular geographies and contexts. Nevertheless, the value of this research remains to be seen. Multi-actor governance groups, like the newly formed management group of the LSRGBR, will need to prioritize time and resources toward the review and continued evolution of this research. Thus, establishing a formal KA network and strategy for capacity building, education, and knowledge sharing seems warranted for the LSRGBR, and is likely an opportunity for other BRs and conservation initiatives [7,11].

The exchange of information, ideas, and best practices within KA networks not only advances sustainable development goals, but also plays a crucial role in protecting biodiversity, mitigating climate change, and ensuring the long-term health of ecosystems and natural resources [23]. This underscores the importance of these networks in driving positive change and fostering a more sustainable future. KA networks align and advance the BR governance guidelines that were updated in 2017 with the new global MAB Strategy and LAP [14,16]. Through effective knowledge networks, BRs can serve as critical platforms for bridging scientific knowledge and research with practical actions and policy decisions aimed at addressing environmental challenges and promoting sustainability [21,26]. By bringing together a diverse array of stakeholders, including scientists, policymakers, conservationists, local communities, and other relevant actors, these networks facilitate collaboration, knowledge sharing, and evidence-based decision making to tackle the complex and interconnected challenges associated with GC and other aspects of sustainability science and action [22].

Author Contributions: Conceptualization, T.G., A.A., F.B. and A.S.; Data curation, T.G. and A.A.; Formal analysis, T.G., A.A., F.B. and A.S.; Funding acquisition, T.G.; Investigation, T.G. and A.A.; Methodology, T.G. and A.A.; Project administration, T.G.; Resources, T.G.; Supervision, T.G.; Validation, T.G. and A.A.; Visualization, T.G. and A.A.; Writing—original draft, T.G. and A.A.; Writing—review & editing, T.G., A.A., F.B. and A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Chile's National Research and Development Agency (ANID) under ANID's Regional Program R17A10002, the FONDECYT 1230020 project, the CIEP R20F0002 project, NODO SLN 0002, and the CHIC-ANID PIA/BASAL PFB210018.

Data Availability Statement: Data supporting reported results can be found in: Adiego, Andrés; Gale, Trace (2024), "Mobilizing Global Change Science for Effective Governance Action in the Laguna San Rafael y el Guayaneco Biosphere Reserve", Mendeley Data, V1, doi: 10.17632/b7fdyyx3nr.1 [94].

Acknowledgments: The authors of this paper speak three different native languages. To facilitate effective collaboration, AI translation tools like DeepL Pro were used in early drafts of the manuscript to bridge between languages. Then, the final paper was developed by the lead author, in English, without the use of AI. This work informs the results of the Aysén Regional Government project, FIC BIP 40049360-0, "Resilience, Sustainability, and Valuation of the Laguna San Rafael y el Guayaneco Biosphere Reserve".

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Bai, X.; Van Der Leeuw, S.; O'Brien, K.; Berkhout, F.; Biermann, F.; Brondizio, E.S.; Cudennec, C.; Dearing, J.; Duraiappah, A.; Glaser, M.; et al. Plausible and Desirable Futures in the Anthropocene: A New Research Agenda. *Glob. Environ. Chang.* **2016**, *39*, 351–362. [CrossRef]
2. Steffen, W.; Broadgate, W.; Deutsch, L.; Gaffney, O.; Ludwig, C. The Trajectory of the Anthropocene: The Great Acceleration. *Anthr. Rev.* **2015**, *2*, 81–98. [CrossRef]
3. Steffen, W.; Persson, Å.; Deutsch, L.; Zalasiewicz, J.; Williams, M.; Richardson, K.; Crumley, C.; Crutzen, P.; Folke, C.; Gordon, L.; et al. The Anthropocene: From Global Change to Planetary Stewardship. *AMBIO* **2011**, *40*, 739–761. [CrossRef] [PubMed]
4. Shoshitaishvili, B. From Anthropocene to Noosphere: The Great Acceleration. *Earths Future* **2021**, *9*, e2020EF001917. [CrossRef]
5. Díaz, S.; Settele, J.; Brondizio, E.S.; Ngo, H.T.; Guèze, M.; Agard, A.; Arneth, P.; Balvanera, P.; Brauman, K.A.; Butchart, S.H.M.; et al. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Service*; IPBES Secretariat: Bonn, Germany, 2019; ISBN 978-3-947851-13-3.
6. Gale, T.; Báez Montenegro, A. Toward Understanding Research Evolution on Indirect Drivers of Ecosystem Change along the Interface of Protected and Non-Protected Lands. *Sustainability* **2024**, *16*, 7572. [CrossRef]
7. Brondízio, E.S.; Settele, J.; Díaz, S.; Ngo, H.T. (Eds.) *The Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*; Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES): Bonn, Germany, 2019; ISBN 978-3-947851-20-1.
8. Hindsley, P.; Yoskowitz, D. Global Change—Local Values: Assessing Tradeoffs for Coastal Ecosystem Services in the Face of Sea Level Rise. *Glob. Environ. Chang.* **2020**, *61*, 102039. [CrossRef]
9. Convention on Biological Diversity. *15/4. Kunming-Montreal Global Biodiversity Framework*; Secretariat of the Convention on Biological Diversity (SCBD): Montreal, QC, Canada, 2022; p. 15.
10. Millennium Ecosystem Assessment (Program) (Ed.). *Ecosystems and Human Well-Being: Synthesis*; Island Press: Washington, DC, USA, 2005; ISBN 978-1-59726-040-4.
11. Díaz, S.; Demissew, S.; Carabias, J.; Joly, C.; Lonsdale, M.; Ash, N.; Larigauderie, A.; Adhikari, J.R.; Arico, S.; Báldi, A.; et al. The IPBES Conceptual Framework—Connecting Nature and People. *Curr. Opin. Environ. Sustain.* **2015**, *14*, 1–16. [CrossRef]
12. Kates, R.W. What Kind of a Science Is Sustainability Science? *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 19449–19450. [CrossRef]
13. Convention on Biological Diversity. *15/8. Capacity-Building and Development and Technical and Scientific Cooperation*; Secretariat of the Convention on Biological Diversity (SCBD): Montreal, QC, Canada, 2022; p. 23.
14. United Nations Educational, Scientific and Cultural Organization (UNESCO). *A New Roadmap for the Man and the Biosphere (MAB) Programme and Its World Network of Biosphere Reserves: MAB Strategy (2015–2025), Lima Action Plan (2016–2025), Lima Declaration*; UNESCO Man and the Biosphere Program: Paris, France, 2017; p. 55.
15. Dudley, N.; Stolton, S. *Best Practice in Delivering the 30 × 30 Target: Protected Areas and Other Effective Area-Based Conservation Measures*; The Nature Conservancy Equilibrium Research: London, UK, 2022.
16. Pool-Stanvliet, R.; Coetzer, K. The Scientific Value of UNESCO Biosphere Reserves. *S. Afr. J. Sci.* **2020**, *116*, 1–4. [CrossRef]
17. Moreira Muñoz, A.; García, J.L.; Sagredo, E. Reserva de la Biosfera Laguna San Rafael: Sitio de importancia global para la investigación del cambio climático. In *Reservas de la Biosfera de Chile: Laboratorios para la Sustentabilidad*; Serie GEOlibros; Instituto de Geografía UC Universität Innsbruck: Santiago, Chile; Innsbruck, Austria, 2014; pp. 210–229. ISBN 978-956-14-1390-0.
18. Alonso-Yañez, G.; Davidsen, C. Conservation Science Policies Versus Scientific Practice: Evidence from a Mexican Biosphere Reserve. *Hum. Ecol. Rev.* **2014**, *20*, 3–29. [CrossRef]
19. Baumgartner, J.; Kuntner, E.; Melchert, J.; Misera, J.; Sauerwein-Schlosser, C.; Schleyer, C.; Unthan, N. Biosphere Reserves as Drivers of Regional Governance? Communication Challenges within the UNESCO Biosphere Reserves Engiadina Val Müstair (Switzerland) and Schwäbische Alb (Germany). *Ecomont J. Prot. Mt. Areas Res.* **2022**, *15*, 4–10. [CrossRef]
20. Brenner, L.; Job, H. Challenges to Actor-oriented Environmental Governance: Examples from Three Mexican Biosphere Reserves. *Tijdschr. Voor Econ. Soc. Geogr.* **2012**, *103*, 1–19. [CrossRef]
21. Muñoz-Erickson, T.A.; Cutts, B.B. Structural Dimensions of Knowledge-Action Networks for Sustainability. *Curr. Opin. Environ. Sustain.* **2016**, *18*, 56–64. [CrossRef]
22. Shrivastava, P.; Raivio, K.; Kasuga, F.; Tewksbury, J.; Haines, A.; Daszak, P. Future Earth Health Knowledge-Action Network. *Public Health Rev.* **2016**, *37*, 25. [CrossRef]

23. Barraclough, A.D.; Reed, M.G.; Coetzer, K.; Price, M.F.; Schultz, L.; Moreira-Muñoz, A.; Måren, I. Global Knowledge–Action Networks at the Frontlines of Sustainability: Insights from Five Decades of Science for Action in UNESCO 's World Network of Biosphere Reserves. *People Nat.* **2023**, *5*, 1430–1444. [CrossRef]
24. Weyland, F.; Mastrangelo, M.E.; Auer, A.D.; Barral, M.P.; Nahuelhual, L.; Larrazábal, A.; Parera, A.F.; Berrouet Cadavid, L.M.; López-Gómez, C.P.; Villegas Palacio, C. Ecosystem Services Approach in Latin America: From Theoretical Promises to Real Applications. *Ecosyst. Serv.* **2019**, *35*, 280–293. [CrossRef]
25. Dawes, S.S.; Cresswell, A.M.; Pardo, T.A. From "Need to Know" to "Need to Share": Tangled Problems, Information Boundaries, and the Building of Public Sector Knowledge Networks. *Public Adm. Rev.* **2009**, *69*, 392–402. [CrossRef]
26. Nguyen, V.M.; Young, N.; Cooke, S.J. A Roadmap for Knowledge Exchange and Mobilization Research in Conservation and Natural Resource Management. *Conserv. Biol.* **2017**, *31*, 789–798. [CrossRef]
27. Pontificia Universidad Católica de Chile. *Pontificia Universidad Católica de Chile Reserva de La Biosfera Parques Nacionales Laguna San Rafael y El Guayaneco: Expediente Para Su Actualización y Zonificación*; UNESCO Man and the Biosphere Program: Paris, France, 2018; p. 79.
28. Chilean National Statistics Institute (INE). *Ciudades, Pueblos, Aldeas y Caseríos 2019*; Chilean National Statistics Institute (INE): Santiago, Chile, 2019; p. 171.
29. Chilean National Congress. *Crea el Servicio de Biodiversidad y Áreas Protegidas y el Sistema Nacional de Áreas Protegidas*; Biblioteca del Congreso Nacional de Chile: Valparaiso, Chile, 2023; p. 71.
30. United Nations Educational, Scientific and Cultural Organization. *UNESCO Headquarters, Paris, Room II (Fontenoy Building): Final Report*; UNESCO Man and the Biosphere Program: Paris, France, 2019; p. 104.
31. Pontificia Universidad Católica de Chile. *Pontificia Universidad Católica de Chile Lineamientos Del Plan de Gestión, Reserva de La Biosfera Laguna San Rafael, Región de Aysén, Chile*; UNESCO Man and the Biosphere Program: Paris, France, 2018; p. 18.
32. Harrison, H.; Birks, M.; Franklin, R.; Mills, J. Case Study Research: Foundations and Methodological Orientations. *Forum Qual. Sozialforschung* **2017**, *18*, 1. [CrossRef]
33. Crowe, S.; Cresswell, K.; Robertson, A.; Huby, G.; Avery, A.; Sheikh, A. The Case Study Approach. *BMC Med. Res. Methodol.* **2011**, *11*, 100. [CrossRef]
34. Yin, R.K. *Case Study Research: Design and Methods*, 5th ed.; SAGE: Los Angeles, CA, USA, 2014; ISBN 978-1-4522-4256-9.
35. Grant, M.J.; Booth, A. A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies. *Health Inf. Libr. J.* **2009**, *26*, 91–108. [CrossRef] [PubMed]
36. Huelin, R.; Iheanacho, I.; Payne, K.; Sandman, K. What's in a Name? Systematic and Non-Systematic Literature Reviews, and Why the Distinction Matters. *Evid. Forum* **2015**, 34–37. Available online: https://www.evidera.com/wp-content/uploads/2015/06/Whats-in-a-Name-Systematic-and-Non-Systematic-Literature-Reviews-and-Why-the-Distinction-Matters.pdf (accessed on 10 September 2024).
37. Bourlon, F.; Gale, T.; Adiego, A.; Álvarez-Barra, V.; Salazar, A. Grounding Sustainable Tourism in Science—A Geographic Approach. *Sustainability* **2021**, *13*, 7455. [CrossRef]
38. Gale, T.; Adiego, A.; Ednie, A.; Beeftink, K.; Báez, A. A Systematized Spatial Review of Global Protected Area Soundscape Research. *Biodivers. Conserv.* **2022**, *31*, 2945–2964. [CrossRef]
39. UNGEGN. *Toponymy Training Manual*; United Nations Group of Experts on Geographical Names (UNGEGN): New York, NY, USA, 2017; p. 218.
40. Gale, T.; Ednie, A.; Beeftink, K. Worldviews, Levels of Consciousness, and the Evolution of Planning Paradigms in Protected Areas. *J. Sustain. Tour.* **2019**, *27*, 1609–1633. [CrossRef]
41. Graneheim, U.H.; Lindgren, B.-M.; Lundman, B. Methodological Challenges in Qualitative Content Analysis: A Discussion Paper. *Nurse Educ. Today* **2017**, *56*, 29–34. [CrossRef] [PubMed]
42. Hsieh, H.F.; Shannon, S.E. Three Approaches to Qualitative Content Analysis. *Qual. Health Res.* **2005**, *15*, 1277–1288. [CrossRef]
43. Nowell, L.S.; Norris, J.M.; White, D.E.; Moules, N.J. Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *Int. J. Qual. Methods* **2017**, *16*, 160940691773384. [CrossRef]
44. Rucks-Ahidiana, Z.; Bierbaum, A.H. Qualitative Spaces: Integrating Spatial Analysis for a Mixed Methods Approach. *Int. J. Qual. Methods* **2015**, *14*, 92–103. [CrossRef]
45. Archibald, M.M. Investigator Triangulation: A Collaborative Strategy with Potential for Mixed Methods Research. *J. Mix. Methods Res.* **2016**, *10*, 228–250. [CrossRef]
46. Gale, T.; Ednie, A.; Beeftink, K. Acceptability and Appeal: How Visitors' Perceptions of Sounds Can Contribute to Shared Learning and Transdisciplinary Protected Area Governance. *J. Outdoor Recreat. Tour.* **2021**, *35*, 100414. [CrossRef]
47. Aylwin, J.; Arce, L.; Guerra, F.; Nuñez, D.; Álvarez, R.; Mansilla, P.; Alday, D.; Caro, L.; Chiguay, C.; Huencoy, C. Conservación y Pueblos Indígenas En La Patagonia Chilena. In *Conservación de la Patagonia Chilena: Evaluación del Conocimiento, Oportunidades y Desafíos*; Castilla, J.C., Armesto, J.J., Martínez-Harms, M.J., Eds.; Ediciones Universidad Católica: Santiago, Chile, 2021; pp. 495–531. ISBN 978-956-14-2821-8.
48. Barcaza, G.; Aniya, M.; Matsumoto, T.; Aoki, T. Satellite-Derived Equilibrium Lines in Northern Patagonia Icefield, Chile, and Their Implications to Glacier Variations. *Arct. Antarct. Alp. Res.* **2009**, *41*, 174–182. [CrossRef]
49. Bórquez-Reyes, R.; Bourlon, F.; Moreno-Escobedo, M. El Turismo Científico y Su Influencia En La Comunidad Local: El Estudio de Caso de La Red de Turismo Científico En Aysén, Chile. *Tur. Desarro.* **2019**, *12*, 1–14.

50. Bourlon, F. La Géographie Esthétique de Douglas Tompkins, Une Utopie Éco-Philanthropique En Patagonie. *Études Caribéennes* **2017**, *37*, 1–21. [CrossRef]
51. Bourlon, F. Destinos Turísticos de Naturaleza en un Contexto de Crisis Sanitaria Global. Perspectivas de Actores, Oportunidades y Desafíos, el Caso de la Región de Aysén, Chile. *Gestión Turística* **2020**, *33*, 63–93. [CrossRef]
52. Bourlon, F. La Ciencia Como Recurso Para El Desarrollo Turístico Sostenible de Los Archipiélagos Patagónicos. *PASOS. Rev. Tur. Patrim. Cult.* **2020**, *18*, 795–810. [CrossRef]
53. Bourlon, F. Quel Tourisme Pour Les Confins de Nature Dans Un Monde En Crise? Perspectives Depuis La Patagonie Chilienne. *Téoros: Rev. Rech. Tour.* **2021**, *39*. [CrossRef]
54. Braun, M.H.; Malz, P.; Sommer, C.; Farías-Barahona, D.; Sauter, T.; Casassa, G.; Soruco, A.; Skvarca, P.; Seehaus, T.C. Constraining Glacier Elevation and Mass Changes in South America. *Nat. Clim Change* **2019**, *9*, 130–136. [CrossRef]
55. Collao-Barrios, G.; Gillet-Chaulet, F.; Favier, V.; Casassa, G.; Berthier, E.; Dussaillant, I.; Mouginot, J.; Rignot, E. Ice Flow Modelling to Constrain the Surface Mass Balance and Ice Discharge of San Rafael Glacier, Northern Patagonia Icefield. *J. Glaciol.* **2018**, *64*, 568–582. [CrossRef]
56. Dussaillant, A.; Benito, G.; Buytaert, W.; Carling, P.; Meier, C.; Espinoza, F. Repeated Glacial-Lake Outburst Floods in Patagonia: An Increasing Hazard? *Nat. Hazards* **2010**, *54*, 469–481. [CrossRef]
57. Dussaillant, A.; Buytaert, W.; Meier, C.; Espinoza, F. Hydrological Regime of Remote Catchments With Extreme Gradients Under Accelerated Change: The Baker Basin in Patagonia. *Hydrol. Sci. J.* **2012**, *57*, 1530–1542. [CrossRef]
58. Fernández, R.A. *Variaciones Recientes de Glaciares Ubicados Entre 41° y 49° de Latitud Sur y Su Relación Con Cambios Climáticos*; Título de Geógrafo; Universidad de Chile: Santiago, Chile, 2003.
59. Fretwell, P.T.; Jackson, J.A.; Ulloa Encina, M.J.; Häussermann, V.; Perez Alvarez, M.J.; Olavarría, C.; Gutstein, C.S. Using Remote Sensing to Detect Whale Strandings in Remote Areas: The Case of Sei Whales Mass Mortality in Chilean Patagonia. *PLoS ONE* **2019**, *14*, e0222498. [CrossRef]
60. Hennicke Laporte, K.M.; Davinson Pacheco, L.G. Conflictividad Ambiental En Botaderos Mineros de Comunidades Del Lago General Carrera. *Rev. Geogr. Norte Gd.* **2021**, *80*, 209–225. [CrossRef]
61. Iribarren Anacona, P.; Mackintosh, A.; Norton, K. Reconstruction of a Glacial Lake Outburst Flood (GLOF) in the Engaño Valley, Chilean Patagonia: Lessons for GLOF Risk Management. *Sci. Total Environ.* **2015**, *527*, 1–11. [CrossRef] [PubMed]
62. Jacquet, J.; McCoy, S.W.; McGrath, D.; Nimick, D.A.; Fahey, M.; O'kuinghttons, J.; Friesen, B.A.; Leidich, J. Hydrologic and Geomorphic Changes Resulting from Episodic Glacial Lake Outburst Floods: Rio Colonia, Patagonia, Chile. *Geophys. Res. Lett.* **2017**, *44*, 854–864. [CrossRef]
63. Koppes, M.; Conway, H.; Rasmussen, L.A.; Chernos, M. Deriving Mass Balance and Calving Variations from Reanalysis Data and Sparse Observations, Glaciar San Rafael, Northern Patagonia, 1950–2005. *Cryosphere* **2011**, *5*, 791–808. [CrossRef]
64. Lafon, A.; Sánchez-Jardón, L. *Laboratorio Abierto de Ciencias Subantárticas: Macroalgas Del Litoral de Aysén*; Ediciones Universidad de Magallanes: Coyhaique, Chile, 2021; ISBN 978-956-7189-98-4.
65. Maas, H.G.; Mulsow, C.; Wendt, A.; Casassa, G. Pilot Studies with a Photogrammetric Glacier Lake Outburst Flood Early Warning System. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2012**, *39*, 523–527. [CrossRef]
66. Madriz, R.I.; Sepúlveda, J.; Cole, M.; Sánchez-Jardón, L. *La Perla de los Andes, Andiperla: El Dragón de la Patagonia: Laboratorio Abierto de Ciencias Subantárticas*, 1st ed.; Ediciones Universidad de Magallanes: Coyhaique, Chile, 2021; ISBN 978-956-7189-99-1.
67. Mansilla, C.A.; Domínguez, E.; Mackenzie, R.; Hoyos-Santillan, J.; Henríquez, J.M.; Aravena, J.C.; Villa-Martínez, R. Peatlands in Chilean Patagonia: Distribution, Biodiversity, Ecosystem Services, and Conservation. In *Conservation in Chilean Patagonia*; Castilla, J.C., Armesto Zamudio, J.J., Martínez-Harms, M.J., Tecklin, D., Eds.; Integrated Science; Springer International Publishing: Cham, Switzerland, 2021; Volume 19, pp. 153–174. ISBN 978-3-031-39407-2.
68. Mardones, M.; Aguayo, M.; Smith, E.; Ruiz, P. Retroceso Glacial Reciente En El Campo de Hielo Norte, Región de Aysén, Chile: Relación Con Variaciones Climáticas. *Rev. Geogr. Norte Gd.* **2018**, *69*, 121–147. [CrossRef]
69. Medel Santibáñez, P.A. Proyecto de Plaza-Embarcadero En Caleta Tortel, Región de Aysén, Patagonia de Chile. *Rev. Urban.* **2007**, *9*, 84–101. [CrossRef]
70. Mulsow, C.; Koschitzki, R.; Maas, H.-G. Photogrammetric Monitoring of Glacier Margin Lakes. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2014**, *6*, 1–6. [CrossRef]
71. Quiroga, E.; Ortiz, P.; Gerdes, D.; Reid, B.; Villagran, S.; Quiñones, R. Organic Enrichment and Structure of Macrobenthic Communities in the Glacial Baker Fjord, Northern Patagonia, Chile. *J. Mar. Biol. Ass.* **2012**, *92*, 73–83. [CrossRef]
72. Quiroga, E.; Ortiz, P.; Reid, B.; Gerdes, D. Classification of the Ecological Quality of the Aysen and Baker Fjords (Patagonia, Chile) Using Biotic Indices. *Mar. Pollut. Bull.* **2013**, *68*, 117–126. [CrossRef] [PubMed]
73. Rozzi, R.; Rosenfeld, S.; Armesto, J.J.; Mansilla, A.; Nuñez-Ávila, M.; Massardo, F. Conexiones Ecológicas a Través de La Interfaz Marino-Terrestre En La Patagonia Chilena. In *Conservación de la Patagonia Chilena: Evaluación del Conocimiento, Oportunidades y Desafíos*; Castilla, J.C., Armesto, J.J., Martínez-Harms, M.J., Eds.; Ediciones Universidad Católica: Santiago, Chile, 2021; pp. 391–425. ISBN 978-956-14-2821-8.
74. Semmens, K.; Ramage, J. Melt Patterns and Dynamics in Alaska and Patagonia Derived from Passive Microwave Brightness Temperatures. *Remote Sens.* **2014**, *6*, 603–620. [CrossRef]
75. Teillier, S.; Marticorena, C. Riqueza Florística Del Parque Nacional Laguna San Rafael, XI Región, Chile. *Boletín Mus. Nac. Hist. Nat.* **2002**, *51*, 43–73. [CrossRef]

76. Ulloa, H.; Mazzorana, B.; Batalla, R.J.; Jullian, C.; Iribarren-Anacona, P.; Barrientos, G.; Reid, B.; Oyarzun, C.; Schaefer, M.; Iroumé, A. Morphological Characterization of a Highly-Dynamic Fluvial Landscape: The River Baker (Chilean Patagonia). *J. South Am. Earth Sci.* **2018**, *86*, 1–14. [CrossRef]
77. Vandekerkhove, E. *Impact of Climate Change on the Occurrence of Late Holocene Glacial Lake Outburst Floods in Patagonia: A Sediment Perspective*; Ghent University: Ghent, Belgium, 2021.
78. Vandekerkhove, E.; Bertrand, S.; Mauquoy, D.; McWethy, D.; Reid, B.; Stammen, S.; Saunders, K.; Torrejón, F. Neoglacial Increase in High-Magnitude Glacial Lake Outburst Flood Frequency, Upper Baker River, Chilean Patagonia (47 °S). *Quat. Sci. Rev.* **2020**, *248*, 1–14. [CrossRef]
79. Wilson, R.; Harrison, S.; Reynolds, J.; Hubbard, A.; Glasser, N.F.; Wündrich, O.; Iribarren Anacona, P.; Mao, L.; Shannon, S. The 2015 Chileno Valley Glacial Lake Outburst Flood, Patagonia. *Geomorphology* **2019**, *332*, 51–65. [CrossRef]
80. Valdovinos, C.; Kiessling, A.; Mardones, M.; Moya, C.; Oyanedel, A.; Salvo, J.; Olmos, V.; Parra, Ó. Distribución de macroinvertebrados (Plecoptera y Aeglidae) en ecosistemas fluviales de la Patagonia chilena: ¿Muestran señales biológicas de la evolución geomorfológica postglacial? *Rev. Chil. Hist. Nat.* **2010**, *83*, 267–287. [CrossRef]
81. Vargas, C.A.; Martinez, R.A.; San Martin, V.; Aguayo, M.; Silva, N.; Torres, R. Allochthonous Subsidies of Organic Matter across a Lake–River–Fjord Landscape in the Chilean Patagonia: Implications for Marine Zooplankton in Inner Fjord Areas. *Cont. Shelf Res.* **2011**, *31*, 187–201. [CrossRef]
82. Leon, C.; Campos, V.; Urrutia, R.; Mondaca, M.-A. Metabolic and Molecular Characterization of Bacterial Community Associated to Patagonian Chilean Oligotrophic-Lakes of Quaternary Glacial Origin. *World J. Microbiol. Biotechnol.* **2012**, *28*, 1511–1521. [CrossRef]
83. Araneda, S.; Sierra, M. Las Dinámicas Territoriales Naturales como Articuladores del Espacio e Imagen Urbana: Coyhaique y Cochrane XI Región de Aysén. *AUS* **2013**, *13*, 11–14. [CrossRef]
84. Romero Toledo, H. Agua, Poder y Discursos: Conflictos Socio-territoriales por la Construcción de Centrales Hidroeléctricas en la Patagonia Chilena. *Anu. Estud. Am.* **2009**, *66*, 81–103. [CrossRef]
85. Segura, P.; Bourlon, F. Represas En Aysén: ¿Traba o Trampolín Para El Desarrollo Turístico Regional? *Soc. Hoy* **2011**, *20*, 145–157.
86. Inostroza Villanueva, G.; Bourlon, F.; Gale-Detrich, T.; Blair, H. Exploring Social Representations of Nature-Based Tourism, Development Conflict, and Sustainable Development Futures in Chilean Patagonia. In *Tourism and Conservation-based Development in the Periphery*; Gale-Detrich, T., Ednie, A., Bosak, K., Eds.; Natural and Social Sciences of Patagonia; Springer International Publishing: Cham, Switzerland, 2023; pp. 229–261. ISBN 978-3-031-38047-1.
87. Sandoval, V.; Ramírez, C.; San Martín, C.; Vidal, O.; Álvarez, M.; Marticorena, A.; Pérez, Y. Diversidad Vegetal en las Cuencas de los Ríos Baker y Pascua (Aisén, Patagonia Chilena). *Bosque Valdivia* **2016**, *37*, 243–253. [CrossRef]
88. Montes, R.M.; Quiñones, R.A. Long-Range Dependence in the Runoff Time Series of the Most Important Patagonian River Draining to the Pacific Ocean. *N. Z. J. Mar. Freshw. Res.* **2018**, *52*, 264–283. [CrossRef]
89. Bañales-Seguel, C.; Salazar, A.; Mao, L. Hydro-Morphological Characteristics and Recent Changes of a Nearly Pristine River System in Chilean Patagonia: The Exploradores River Network. *J. South Am. Earth Sci.* **2020**, *98*, 102444. [CrossRef]
90. Piper, F.I. Decoupling between Growth Rate and Storage Remobilization in Broadleaf Temperate Tree Species. *Funct. Ecol.* **2020**, *34*, 1180–1192. [CrossRef]
91. Cornejo, P.; Guerrero, N.M.; Montes, R.M.; Quiñones, R.A.; Sepúlveda, H.H. Hydrodynamic Effect of Biofouling in Fish Cage Aquaculture Netting. *Aquaculture* **2020**, *526*, 735367. [CrossRef]
92. Meerhoff, E.; Castro, L.R.; Tapia, F.J.; Pérez-Santos, I. Hydrographic and Biological Impacts of a Glacial Lake Outburst Flood (GLOF) in a Patagonian Fjord. *Estuaries Coasts* **2019**, *42*, 132–143. [CrossRef]
93. Gale-Detrich, T.; Sánchez Jardón, L.; Adiego, A.; Rozzi, R.; Maldonado, P.; Navarrete Almonacid, M.; Coloma Zapata, J.; Hernández Soto, D.; Mora Chepo, M.; Cancino Salas, R.; et al. Catalyzing Holistic Conservation-Based Development Through Ethical Travel Experiences Rooted in the Bioculture of Patagonia's Subantarctic Natural Laboratories. In *Tourism and Conservation-based Development in the Periphery*; Gale-Detrich, T., Ednie, A., Bosak, K., Eds.; Natural and Social Sciences of Patagonia; Springer International Publishing: Cham, Switzerland, 2023; pp. 427–461. ISBN 978-3-031-38047-1.
94. Andrés Adiego, A.; Gale, T. Mobilizing Global Change Science for Effective Governance Action in the Laguna San Rafael y el Guayaneco Biosphere Reserve. *Mendeley Data* **2024**, V1. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.