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Review

Human Communities in Protected Natural Areas and Biodiversity Conservation

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Abstract: Using socioecological concepts and within a historical biodiversity conservation context, this research study reviews the main interactions between human communities and protected natural areas (PNAs) to describe their different stages over time and assess the implications arising from climate change. The review suggests that both society and governments have raised awareness and interest regarding the importance of biodiversity conservation. The interactions of human communities in these areas have had different effects on biodiversity use, management, and conservation. Local communities have historically developed traditional uses of natural resources that allow them to remain over time and conserve them. Thus, the interest in PNAs as a conservation instrument has increased worldwide. Regarding climate change, this study found evidence indicating that PNAs may act as buffer barriers to prevent biodiversity loss and mitigate the impacts of extreme events; nevertheless, a great variation can be expected. The magnitude of the impacts on human communities, levels of vulnerability, and resilience capacity of PNAs facing climate change (CC) rely on many factors, such as location, extent, composition, management, and ecology of a given protected area. Therefore, the new scenarios that CC may bring are challenging current systematic conservation planning and traditional management methods of the natural resources that are vital for people. Finally, the authors suggest that society is increasingly aware of PNAs as one of the best tools humans have to prevent biodiversity loss, and potentially buffer the effects of CC. These increases in social awareness of biodiversity conservation importance and PNAs are gratifying and spread optimism about the future that next generations may face.

Keywords: biodiversity; conservation; protected natural areas; human communities; climate change

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1. Introduction

The mission of natural heritage conservation through different modalities has its main instrument in the creation and management of protected natural areas (PNAs) based on a conservation culture of natural ecosystems and sustainable development [1]. Protected areas are well received throughout the world as environmental policy tools characterized by the preservation and protection of diverse ecosystems, where the original environment has not been essentially altered, producing a series of increasingly valued environmental services [2].

Academic, social, and legislative systems are conscious of their obligation to protect natural spaces, as well as the systems and cycles that are completely dependent on natural resources and that have supported life throughout millions of years of evolution [3,4].

The potential for economic, social, and political wellbeing that a PNA offers depends on the strategies implemented for natural biodiversity management and conservation [5]. Therefore, this study analyzes the interactions between human communities and biodiversity with emphasis on climate change impact and resilience in protected natural areas.

2. Methods

This literature review article does not have the typical "background section" [6], because it is not an introductory substantiation for a primary research study. Instead, this article has a predominant objective: to synthesize the literature in Socioecology, without analyzing or even collecting primary data [7].

The article started by formulating the research question: What is the relationship between socioecology and biodiversity conservation in natural protected areas? The second step was to define the objective of this study, which is to create a solid starting point for all members of the community interested in socioecology and biodiversity conservation. Then, the authors proceeded to search extant literature, for suitability of the material to be considered in this review [8], which was based entirely on the research background of each co-author.

3. The History of Biodiversity Conservation

In the current context of climate change and the post-COVID-19 pandemic, people in the developed world are looking anew at rural environments and natural ecosystems where human societies have had an historically balanced long-term relationship with nature. Populations trapped in crowded cities are showing more interest in nature, not just looking for beautiful landscapes but also places where they can escape to on holidays. As a result of this worldwide crisis, the idea of having a better quality of life, even urban life, through the conservation of natural ecosystems and nature-based solutions has become common [4,9].

Media coverage now favors this viewpoint of better life quality. For example, people now value the need for healthy food, organic cosmetics, space for leisure, clothes, and furniture made from ethically produced materials. Nowadays, sustainable consumption practices are becoming trendy in everyday urban life, if not common. For instance, regional suppliers, local markets, organic farms, sustainable fisheries, urban gardens, and allotments are examples of new ways to fulfill desires and return to harmony with nature in a more rational way of living [10].

Additionally, a renewed interest in the natural world is growing. Apart from the obvious and now more frequent catastrophic climate events (fires, droughts, heavy rains, and floods), the perception is that society is equally interested in topics such as pollinator decline, ocean pollution, and air quality. Specialized conservationists have had a particular resonance with the public, such as Carl Safina, whose books are global best-sellers.

Where is all this public interest coming from? Ecological studies and conservation efforts are not new. As early as 1869, the British naturalist Alfred Russel Wallace wrote in his book *The Malay Archipelago* about the value of biodiversity itself. He noticed the perfect equilibrium of the species on the islands and reflected on how their beauty is wasted in the "dark and gloomy woods, with no intelligent eye to gaze upon their loveliness, but when "civilized man" reaches the islands, he will certainly upset the balance of nature and make the birds extinct" [11] (p. 486).

The tradition of setting aside wilderness –its beauty and equilibrium, away from human actions–was the ideal of American conservationist pioneers, Henry David Thoreau, John Muir, and Aldo Leopold. However, the idea of preserving landscapes, flora, and fauna alone developed into one of conservation in conjunction with human activities in the 20th century [12].

More than half a century ago, the science of conservation biology started in 1985 when a group of researchers met in La Jolla, San Diego, CA, USA, concerned about increased loss of species and the accelerated reduction in tropical forest [13]. The term biodiversity first appeared at the National Forum on Biodiversity held by the National Academy of Sciences (NAS) and Smithsonian Institute in September 1986. The focus of the forum was habitat destruction and species extinction, and the results were published with the title *Biodiversity* [14]. The concept of biodiversity, or biological diversity, relates to evolutionary biology and ecology. The key elements are individual species, but biodiversity also considers the role of the evolutionary process in species emergence and extinction, the causes of biodiversity loss, habitat destruction, invasive species, pollution, and overexploitation. In the Rio Convention, the definition of biological diversity covered three levels: species diversity, genetic diversity, and ecosystem diversity [15], but what ways have been found to preserve biodiversity whilst sharing the same space?

The Biological Dynamics of Forest Fragments Project demonstrated that to maintain species diversity, the variety of habitats was more important than the size of an area [16]. For that reason, the importance of the protected areas was clearly to be big enough and with sufficient habitat diversity suitable for keystone species. These type of species are those that maintain ecosystem cohesion over time and ensure population viability [17].

MacArthur and Wilson [18] developed the theory of island biogeography and Simberloff and Abele [19] used it to propose that creating several small but connected NPAs could eventually contain and preserve more species than a bigger but more isolated reserve. Shaffer [20] developed the concept of minimum viable population; meanwhile, Newmar [21] demonstrated that in fragmented isolated habitats, small populations became extinct more quickly. All these elements together were used as key tools in designing wildlife reserves capable of maintaining and preserving biodiversity.

Nevertheless, and despite the creation of natural protected areas, numerous conferences, meetings, and thousands of published articles on the importance of biodiversity conservation remained confined to the academic world. Even broad political efforts, such as the United Nations Earth Summit in Rio de Janeiro [15] or the Paris Agreement [22], seemed to hold little interest for the public.

Because lifestyle is now in danger, as early as 2007, George Beals Schaller pointed out that conservation problems are also social and economic as well as scientific, since humans benefit from wildlife [23]. In order to assign an intrinsic value to biodiversity, one looks at services that can be obtained from it. Ecosystem services have been defined as the conditions and processes through which natural ecosystems sustain and fulfill human life [24]. The services that species of microorganisms, animals, and plants provide and that are required to sustain human life are uncountable. The systems and natural cycles are product of billions of years of evolution. Whether humans appreciate it or not, all living beings depend entirely on ecosystems because both knowledge and ability are required to substitute them. For millennia, ecosystem services have been almost unnoticed, because they were not disrupted, although nowadays few places on Earth remain untouched (chemically, physically, or biologically). However, society likely values ecosystem services more as human impacts on the environment intensify, and the cost and limits of technological substitution (when possible) become more difficult or expensive [24].

Because humans have evolved and lived embedded in nature until recent times, the relationship between biophysical and sociocultural components of the ecosystems are historically interdependent, and a biocultural approach is now recognized as critical in conservation and restoration projects [25]. In fact, 11 of the 17 Sustainable Development Goals of the United Nations are directly related to biodiversity conservation [26,27].

Since the mid-20th century, society has found that an effective method to improve biodiversity conservation is to involve local communities in the government of protected natural areas [12], which could either be by collaborative management (helping authorities) or co-management (jointly with authorities) [28]. Both methods incorporate traditional knowledge and current necessities of the inhabitants and can lead to more long-term, sustainable results. Collaborative governance is a way to eliminate imbalance between strong governmental politics and weak communities who live closely with wildlife. At the end, life quality improves both local communities and society [29–31].

Unfortunately, the richest countries in biodiversity are not always the most developed; for that reason, in 2014, the Nagoya Protocol, signed by many countries, established a global policy to improve biodiversity conservation, including sharing the benefits arising from using genetic resources fairly and equitably. Despite being signatories, many governments, companies, and institutions still do not adhere to the treaty. They still retain numerous patents, plant breeder rights, genetic resources, and plant varieties. However, the international community is trying to correct that and working to ensure that the profits of any natural exploitation or genetic resources stay in each nation. On top of that, in the current post-2020 Global Biodiversity Framework (GBF), the Aichi Targets about biodiversity loss have not been met, so society and researchers must work together to achieve them [31–34].

In the last two decades, involving people in biodiversity conservation through a process called citizen science has become a powerful tool. In this process, the public is involved in scientific projects in different ways. The easiest and most common one is to ask lay people for their help in gathering data for scientific projects following a specific protocol. In other cases, nonscientists can be engaged in the process of decision-making about policy issues that have technical or scientific components; alternatively, the scientific community becomes part of the policy decision-making process [35]. These projects are sometimes global, involving people from every continent, such as the example below about pollination [36]: (https://www.beeproject.science/croppollination.html, accessed on 10 April 2022).

This project was created to compile crop pollination data from published studies across the world and help predict pollination services. It also permits sharing data since the database has open access online, so scientists and institutions that want to contribute to new pollination datasets can add them easily.

In conclusion, a renewed desire (or necessity) is perceived to reinforce the reciprocal relationship with nature, and return to traditional crop methods instead of industrialized agriculture, small farms instead of macro livestock production, fields free of chemicals instead of insecticides, rational logging instead of deforestation, and a biocultural approach to restoration [37]. All these practices are perfect on a small scale, but none of them are possible on a major scale if consumption habits do not change. The amount of energy and resources and ecological cost of crowded urban societies have become unsustainable and new models, energies, productive forms, and imaginative solutions for waste and recycling are imperative.

4. Protected Natural Areas

In the evolution of humanity, the passage from nomadic hunter-gatherers to sedentary farmers has had significant effects on ecosystems and the environment. These changes were caused by tree felling and forest clearing, using wood for construction and as fuel, competing for land and water, and evicting and consuming wild animals in the same area [38]. At the same time, some plants and animals were intensively exploited, which led to the appearance of the first domesticated species [39,40].

However, ancient cultures, such as Egyptians, Vikings, Persians, Romans, and Indians, have protected natural spaces for several centuries.

In pre-Columbian Mesoamerica and in almost every ancient culture, people worshiped the sun, stars, moon, Earth, water, many animals, and almost all vegetation. All these elements of nature were conceived as divine, and cultures expressed their own realities linked to a cosmogony of which they were part and had to respect to maintain harmony with nature [41].

Incas used agricultural techniques, such as the construction of platforms or terraces to avoid soil erosion and take advantage of the slopes and hills [42]. Mayans linked their development with the tropical forest, basing their agricultural, horticultural, and forestry practices on protected pluriculturalism, called Pet-koot (round fence) [43].

In Mexico in the 15th century, the Mexica King Nezahualcóyotl established the first botanical garden in Texcotzingo, prohibiting hunting and imposing limits on obtaining firewood to protect the forests of his dominions in Texcoco. In 1428, he fenced the Chapultepec forest, enriched flora, planted the famous ahuehuete trees, and implanted a rich fauna, thus initiating its protection [44].

In 1450, Moctezuma Ilhuicamina established the Oaxtepec Garden, and in 1465, he took over Bosque de Chapultepec, a tradition that was followed by his successors. Moctezuma

Xocoyotzin established gardens at the hillsides of Popocatépetl volcano and Atlixco in Puebla and maintained the one in Oaxtepec, Morelos, which had been operating as a protected area for more than 75 years when the Spaniards arrived [45].

During the Middle Ages, royalty promoted laws for forests and wildlife protection. Nevertheless, after the emergence of industrial cities in the mid-1700s, the exploitation of mineral coal polluted waters, soil, and atmosphere, which had an impact on policies and actions for the conservation of natural areas [41].

When Europeans discovered North America in the 15th and 16th centuries, they found it populated by diverse groups of indigenous people who showed a deep respect for the land and animals. This continent had abundant and seemingly inexhaustible stocks of wood, fertile soil, wildlife, fresh water, minerals, and other resources, so the colonizers felt that it should be conquered, opened, disassembled, and used as quickly as possible [46,47].

During the conquest and colonization by the Spaniards, the demand for construction materials and fuels increased, paying for forest clearance and making alterations to ecosystems. To stop such deforestation, King Carlos V of Spain decreed in 1530 that Bosque de Chapultepec and the hill surrounding it be owned by the City of Mexico, making this area the first protected forest of the colonial era.

Throughout the expansion of Europeans in North America from 1607 to 1832, forests and wildlife were degraded and depleted at an alarming rate, so the task of protecting was passed down to subsequent generations. However, in the United States, federal action on the conservation of forest resources and wildlife did not properly begin until 1872 with the creation of Yellowstone National Park [47,48]. In the same decade, "Desierto de los Leones" was the first Mexican protected area, created in 1876 with the purpose of protecting the springs that supplied water to Mexico City, and decreed in 1917 as a national park [49]. These parks were the first of their kind in North America and set a precedent for preservation of biodiversity and cultural history (Figure 1).

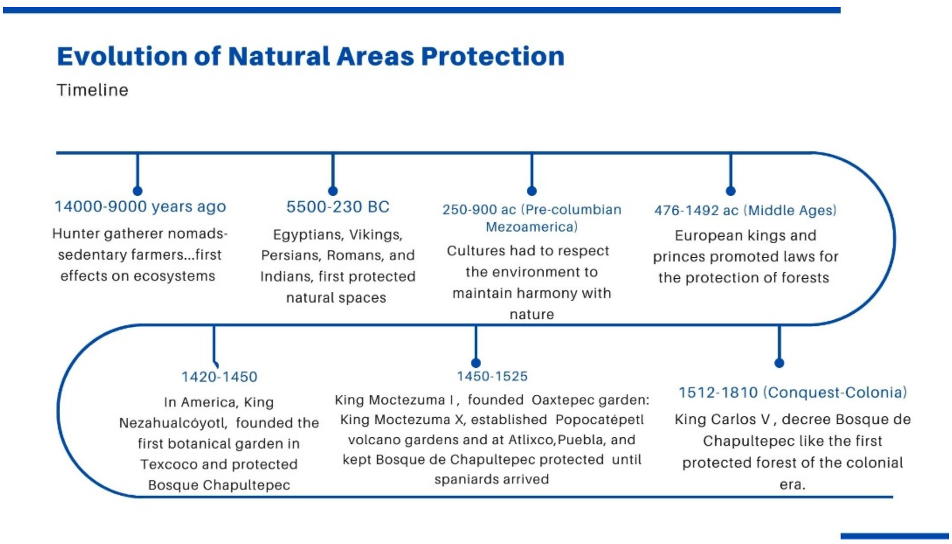

Figure 1. Timeline of the evolution of Natural Protected Areas until the 20th Century.

The definition of a protected area for the International Union for Conservation of Nature (IUCN) is "a clearly defined geographical space, recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" [50]. Although Yellowstone has been recognized as the first national park in the world, it was not the first protected natural area by a government. The oldest national parks on each continent have their own stories of origin and are home to evidence the world's complex and changing relationship to public conservation [51]. Some examples of protected areas worldwide are described below, with a timeline of the first PNAs summarized in Figure 2.

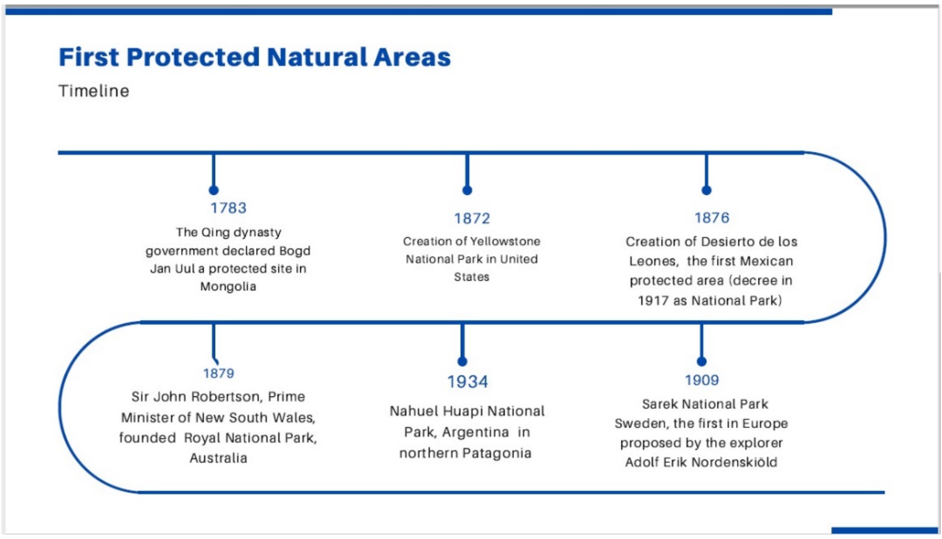

Figure 2. Timeline of some of the first Protected Natural Areas.

4.1. Bogd Jan Uul Protected Area, Mongolia

Since the 14th century, Bogd Jan has been considered one of the holiest mountains in Mongolia. The Qing dynasty government declared it a protected site in 1783. Since then, the coniferous forests, endangered musk deer, and other wildlife of Bogd Jan have survived political upheaval that lasted until the 1990s. Finally, in 1996 the United Nations Educational, Scientific, and Cultural Organization (UNESCO) declared it a biosphere reserve [52].

4.2. Yellowstone National Park, United States of America

The creation of the protected area by President Ulysses S. Grant in 1872 was a great success for early conservation initiatives and influenced global growth of national parks. As was the case in many national parks, poaching and illegal logging plagued Yellowstone from the 1880s to 1890s, until Congress passed tougher protective measures [48,49].

4.3. Royal National Park, Australia

This environment of more than 15,000 ha is home to rare birds, clifftops, and lagoons. Centuries earlier, it was home to the Gweagal Aboriginal community. In 1879, Sir John Robertson, Prime Minister of New South Wales, founded the park through a series of land reforms [52].

4.4. Nahuel Huapi National Park, Argentina

More than 800,000 ha of vast slopes and glaciers are found in the depths of northern Patagonia. In the 1880s, the explorer Francisco Pascasio Moreno surveyed the terrain for the Argentine government that contributed to the inclusion of the area under federal jurisdiction. In 1903, he donated part of the land to the government with the intention of making it a national park, which was achieved in 1934 [51].

4.5. Sarek National Park, Sweden

With more than 100 glaciers and thousands of elks, Sarek National Park is the jewel of Sweden's diverse flora and fauna. The explorer Adolf Erik Nordenskiöld proposed the foundation of national parks, which influenced the decision of the Swedish parliament to create the first one in Europe in 1909. The indigenous Lapp or Saami people lived in the area before Sarek obtained park status [53].

The greatest conservation success story in the 21st century is the exponential growth of protected areas, a primary defense mechanism against Earth's biodiversity loss [54]. Protected areas play a key role in preserving the benefits or "ecosystem services" that nature brings to people and includes the provision of food and fresh water, regulation of floods and droughts, nutrient cycling, and recreational opportunities [55].

The initial goal was to keep nature safe from people. While it remains true today, new targets were added over time as protected wildlife areas often have often become tourist attractions and important economic mainstays since the beginning of the 1970s. Since the Convention on Biological Diversity was opened for signing in 1992, its 168 member states have nearly doubled the size of their protected areas in an effort to meet the goal of that treaty: each nation committed to have at least 17% of its land area and 10% of its oceans protected by 2020. As of 2019 the nations of the world have legally designated more than 202,000 protected lands covering 19.8 million square kilometers, or 15% of the Earth's surface [54,56,57].

Globally, a third of all protected areas are under intense human pressure. They face pressure from agriculture, encroachment on human settlements, roads, light pollution, railways, and infrastructure development on waterways. Only 10% of the lands are completely free from human activity, but they are in remote areas of high-latitude nations, such as Russia and Canada [58]. Protected areas are globally underfunded, and their mismanagement opens the door to many human impacts, including poaching, illegal logging and fishing, and habitat destruction [59].

Although a rapid progress in developing protected areas and a great increase in protected land and ocean percentages have been reported [56,60,61], such efforts are not ecologically representative nor do they optimally protect biodiversity [62–65]. Quantitative targets tend to overshadow qualitative ones. For example, within the Aichi Target 11 established by the United Nations Convention on Biological Diversity, 17% terrestrial/10% marine protected areas have tended to be the primary goal, rather than the qualitative elements of ecological representation, equity and effectiveness management, and integration into wider landscapes [15,61,66].

Similarly to terrestrial PNAs, Marine Protected Areas (MPAs) can be directed at conserving overall biodiversity or some portions of it (e.g., key species, top predators, commercial fish species, endangered species, communities, or ecosystems). If the main goal is biodiversity conservation, today's approach is generally the development of "ecologically representative" protected areas [67–69].

A well-conserved protected area is the result of collaboration between law enforcement departments, policy makers, local communities, and other stakeholders. Management objectives of the protected areas, in addition to the main one of biodiversity conservation, now also include social and economic ones. Reconciling goals with the needs of local livelihoods requires building partnerships and alliances with local businesses and communities [54].

5. Human Communities in Protected Natural Areas

Traditionally, the communities that have lived within protected natural areas or in their area of influence depend on the use of available natural resources and this condition defines the characteristics of the population [70]. The study of human communities in PNAs has expanded into more than just the interaction of nature and society. From a sociological perspective, all these interactions become models that integrate social and natural systems for better human development through sustainable and environmental management, conservation, and governance, among other disciplines [71,72].

Thus, Salas-Zapata et al. [73] assume that social (culture, society, economy, and politics) and ecological systems converge in such a way that they interact, couple, dominate, and cause impacts and disturbances among them. This section shows some examples of the interactions between both kinds of systems grouped in different interacting categories: coupled, one dominating the other, or mutual disturbance.

Parathian [74] studied the impact-based conservation of two communities of Tikuna in the Colombian Amazon. Those communities have adopted some transcultural beliefs and shown innovation and resilience, which allowed them to cope with climate and environmental change and generate conservation processes and initiatives that influence local livelihoods; the study concluded that indigenous populations are malleable groups with a practical understanding and vital dynamics for identifying solutions to socio-ecological problems.

In other cases, community perception is an important way of evaluating conservation performance. In this case, the community members work on projects for effective biodiversity protection and the wellbeing of the people who live within or near protected areas. For instance, in Tarangire National Park in Tanzania and in Mole National Park in Ghana, watching wildlife and enjoying nature tourism not only have a positive impact on livelihoods and community development, and especially in governance matters, but also on national and international tourism [75].

Natural and human systems sometimes do not seem to influence each other. Harris et al. [76] studied interactions and links among users and mammals that inhabit a protected area, for example, direct (poaching) and indirect (domestic animals) human activities to the fauna of the largest complex of protected areas in West Africa (W-Arly-Pendjari). They found that although human pressure is dominant, it did not influence species richness or composition, which led them to label it a coupled human-dynamic system.

In other cases, forcing regulations in protected natural areas are necessary as a strategy for biodiversity protection. A study from Adamik and Berros [77] analyzed one of such situations on the Argentine coast (Santa Fe, Entre Ríos, Corrientes, and Misiones). In the case of Santa Fe and Misiones, the authors indicate that there is a sustainable exploitation of natural resources based on existing regulations. Although the legislation allows for the creation of PNAs in the four territories, their classification and specific treatment result on different management categories. However, these authors warn that in territories where few protected areas exist, natural environments are underrepresented. On the contrary, where many protected areas are established, precarious control by the authorities is observed, which causes impacts and disturbances.

In another example Olmos-Martínez et al. [70] studied the effect of implementing a protected natural area on the wellbeing of rural communities in Baja California Sur, México. In this case, although the creation of the protected area has hampered access to natural resources, it has also increased the sense of wellbeing of the population based on social and economic indicators in the Sierra La Laguna Biosphere Reserve.

Karanth et al. [78] carried out a study on voluntary community resettlements of the protected areas of India. The authors studied the strategy of people exclusion to minimize the anthropogenic threats of wildlife. The project is challenging for the government since an estimated 4.3 million people share spaces with megafauna within protected areas, indicating that resettlement policies focus on paying in cash or a compensation package for land for families relocating voluntarily. These authors also found that 89% wanted to move to get better education, health care, roads, less human conflict, and better wildlife; thus, households that depend on wage labor decided to move and smallholders looked for better opportunities in agriculture.

In addition, research on the analysis of conservation policies in urban contexts leads to challenges faced by decision makers and society in general. In that sense De la Mora [79] shows two convergent conservation policies in Mexico, which are about Environmental Services and PNAs as instruments of public policy and the interactions from their implementation for the conservation of urban socio-ecosystems. The author alluded that urban and peri-urban PNAs should enjoy greater political visibility in urban and environmental decision-making territorial processes for their permanence. Thus, the conservation policy of environmental services can lead to the social and political reassessment of their strategic importance, which would contribute to urban planning (housing, hydraulic sector, forest areas, among others).

On the other hand, Mutanga et al. [80] conducted a study on community perception of wildlife conservation and tourism in adjacent communities within four protected areas in Zimbabwe. These authors found that one community had neutral perceptions on wildlife conservation, but the other three had positive perceptions on the same issue. However, all four communities had negative tourism perceptions because they have not been involved, and natural resource benefits are not shared fairly among stakeholders.

Related to the above, Olmos-Martínez et al. [81] alluded to this situation in their study on anthropogenic pressure in the PNA Archipelago Espíritu Santo, in Baja California Sur, Mexico. The authors concluded that tourism exerts greater pressure than other activities, such as fishing, because of its high demand and growing activity. Although the type of tourism practiced is eco- and adventure tourism, their activities produce pollution, flora and fauna alteration, exotic species introduction, and fishing sector problems.

However, Olmos-Martínez et al. [82] found a successful case related to the use of natural resources and ecotourism in the PNA "Tortuguero El Verde Camacho" sanctuary, in Mazatlán, Sinaloa, Mexico. Based on the collaboration between the society, the government, and the organization within an ecotourism cooperative society, the community has generated socioeconomic development that bolsters ecotourism services with an emphasis on the conservation, preservation, and management of the coastal wetland and endangered species, such as the olive ridley turtle. In addition, tourism in Mexico is established as a permitted activity in the PNA management program since it allows raising awareness of biodiversity protection, which also represents an economic alternative that benefits local communities and users [3].

Some studies of PNAs are related to evaluating vulnerability as a management element; this is the case in the analysis by Verdugo et al. [83], which calculated the environmental vulnerability of the marine part of Bahía de Loreto National Park in Baja California Sur, Mexico, based on environmental indicators using the exposure-sensitivity-capacity method. Their results show that the greatest vulnerability is found in the coastal zone in front of the Peninsula and in Isla del Carmen where ecotourism is practiced, as well as in Isla Catarina due to the pressure from fisheries and, therefore, interactions in social and ecological systems.

Andrade and Rhodes [84] mention that PNA management, in some cases, fully integrates important factors, such as social, cultural, and political factors. However, they have caused adverse social impacts in some cases on local communities that altered their traditional ways of life, limited their control and access to natural resources, and generated conflicts between administrators and local communities. The authors analyzed the key factors that lead to better compliance with conservation strategies and observed that local community participation is the only variable that reacted significantly with the level of compliance with the PNA policies—the greater the participation is, the greater the compliance is.

In addition to the above and because tourism has a social representation approach, this activity allows for the inclusion of interactions, history, and culture. Sarr et al. [85] reviewed these interactions in La Langue de Barbarie National Park in Northern Senegal. Members of the community found evidence of the failure of tourism programs and projects with community participation given the perception of the same communities, which implies division in groups with different interests, to such a degree that inhabitants consider emigration from the site.

Likewise, Olaniyi, et al. [86] state that biological diversity in Nigeria is highly degraded and far from the Sustainable Development Goals. This situation leads to a major problem since PNAs constitute the food base for survival of the host communities in that area. Thus, the authors propose community participation policies to improve rural livelihoods.

In addition, Fay [87] studied the process of merging Dwesa-Cwebe Nature Reserves with Pafuri Triangle reserves in South Africa. This author addresses that since PNA joint management has emerged, the communities have been involved in formal negotiations with government officials and groups of non-governmental organizations in search of mutual benefit. However, they have found that mutual gains and distributive approach have reduced the power of communities in decision-making.

Finally, Olmos-Martínez et al. [2] studied the perception of the population living in the PNAs of Baja California Sur, Mexico on climate change (CC) and environmental changes in the area where they live. The study was carried out from different topics (environment, coastal areas, soil, water, society, fishing, agriculture, livestock, and tourism). The results indicated that the local population has empirical knowledge about the effects of climate change, both economically and socially. This knowledge is a tool for decision makers that allows recognizing human behavior in social, economic, and environmental changes that may contribute to mitigation and adaptation strategies in facing the phenomenon.

In summary, human communities have a dynamic and adaptive relationship with nature within PNAs. Beyond being an instrument of environmental policy, PNA management, in some cases, fully integrates important social, cultural, and political factors.

6. Impacts and Resilience to Climate Change in Protected Natural Areas

Protected natural areas are widely recognized as one of the most effective ways to preserve biodiversity in both marine and terrestrial habitats [55,88], protect water supplies, and many other environmental and ecosystem services [89,90]. For example, there is evidence that supports conservation actions have been successful at buffering species from historical drivers of population declines, such as land-use change, pollution, hunting, deforestation, fragmentation, and habitat degradation [88,89,91–93]. However, locals and authorities in PNAs cannot similarly buffer species and natural ecosystems from the effects of anthropogenic CC, so their role in mitigating impacts has been questioned [60,94].

Some of the major limitations for ensuring biodiversity conservation under CC are the static nature of PNAs, their spatial and ecological bias, and low coverage [95–100]. Increases in greenhouse gas (GHG) emissions, linked to fossil fuel combustion and land-use changes, have distorted the chemical composition of the Eart's atmosphere, oceans, and freshwaters, and in turn, the global climate system, influencing global temperatures, precipitation patterns, and intensity and frequency of extreme weather events [101,102]. The observed impacts of CC across terrestrial and aquatic biomes are now affecting every ecosystem around the world [101,103–105] and most biological and ecological processes on Earth [106].

The perception of the PNA role of in relation to CC began in the late 1980s. Studies have pointed out paleoecological evidence of increasingly strong and widespread geographical species range shifts as a response to global climate changes [107–109]. A variety of aquatic and terrestrial species are already responding with elevation, depth (in the ocean), and latitudinal shifts in their distribution ranges, tracking shifting isotherms [16–18]. Therefore, changes in the relationships between species range limits (dynamic), protected area boundaries (fixed) [110–113], and land-use change [60,94,96,97] should be expected. These statements have been integrated into much of the literature on CC potential impacts on biodiversity management and nature reserve systems [60,94,113–116].

Peters and Darling [111] defined two important hypotheses concerning the expected process of CC impacts on nature reserves and natural habitats. The first one is that under changing land-use and climate conditions, the static nature of PNA boundaries may fail to encompass the species climate ranges they were intended to protect. The second one of species responses to CC concerns the potential species range movements along altitudinal gradients [111]. Under this hypothesis, increases in local temperature would move the species climate habitats upslope, and each successive altitudinal range would be replaced by the species habitat occupying the zone directly below. The expected CC impacts in mountainous PNAs would include the loss of the coldest climate habitats at the mountain peaks and linear migration of all remaining habitats upslope. The management deduction deriving from this altitudinal-response theory is that PNAs showing large altitudinal ranges and topographic relief offer the largest range of climate habitats. Therefore, they allow the greatest amount of internal species movement under changing climates. In contrast, climate shifts in PNAs having a limited altitudinal range would be expected to force species to migrate outside the reserve area boundaries—a conceptual model that has been used to analyze altitudinal ranges of global NPA networks in initial assessments [96,97,114].

Multispecies approaches examining potential CC impacts on species representation levels in PNA networks have been developed in several parts of the world [95,97,113]. The results suggest that range shifts cause declines in species representation in some reserves, but considering the assumptions about species dispersal abilities, they might result in increases in representation in other reserves [60,96,97]. The net effect of movements on individual reserve representation and across whole networks depends greatly on dispersal abilities and intervening land uses that may facilitate, complicate, or impede dispersal, affecting the PNA individual reserve and/or network ecological representation [60,113,117]. In terms of ecological representation, the issues or species of concern depend on the objectives of the PNA network and the particular characteristics of the geographic location [97,118–120].

System planning based entirely or partially on biotic elements may be the most vulnerable to CC impacts because species distribution, abundance, and habitat are largely determined by climate [121]. Theoretically, CC causes species range redistribution [105,106,122], so new communities and ecosystems emerge with novel species complements and assemblages that may not meet existing ecological representation targets [113,123]. The impact magnitude on ecological representation within PNAs depends on the location, composition, and ecology of a given one (or networks of NPAs). Therefore, the new scenarios that CC may bring are challenging current systematic conservation planning and management methods, such as the use of 'ecological representation' as a tool to identify the effectiveness of individual or networks of PNAs [91,97,102,124,125].

An alternative approach suggests that a classification framework of "enduring features", such as topographic relief and the origin and texture of parent materials and soil, should be the basis for representation of natural regions in a PNA network [118,124,126]. The assumption of this alternative is that these natural features are more stable in their distribution than biotic elements and yet reflect biological features. For example, a hierarchical classification approach for marine conservation that uses long-term and recurrent geophysical and oceanographic features has been advocated [127,128]. Other approaches have used a combination of biological and physical attributes to create classification hierarchies to be used in designing representative MPAs [118,128]. In this sense, the key to resilience in a complex adaptive system lies within heterogeneity maintenance—the essential variation that enables adaptation [129]. An ecologically resilient ecosystem can better absorb (climate-induced) disturbance, reorganize while undergoing change, and retain the same or similar function in a rapidly changing climate than a system that is not as resilient. Consequently, a PNA may encompass a greater range of physical characteristics and altitude, as well as a variety of habitat types, climates, and soils, and likely be more resilient to CC impacts [130–133].

The great diversity of PNAs in the world suggests that CC impacts are not uniform. Considering the relative climate sensitivity on different regions of the planet [101,134,135], differentiated impacts on individual areas or networks would be expected. Within the most natural and human systems, the current climate and its variability is a frequently limiting factor, but not the only one that determines the overall condition of these systems [134,135]. For example, projected population changes in different countries of the world, as well as the subsequent change in land-use and air and water quality, continue to put pressure on biodiversity, natural resources, and PNA effectiveness. Therefore, CC is seen as an additional factor that can affect the protected areas in different ways.

Warren et al. [135] examined the potential regional CC impacts at different degrees of temperature rise, identifying vulnerable sectors in different regions of the world. The authors assessed climate impacts projected to the end of the 21st century on water stress, agriculture, coastal flooding, human health, energy demand, and ecosystems (including biodiversity and global vegetation). A valuable review of the field on protected areas and CC [96] underscored five broad categories of management recommendation for protected areas facing CC: redundant reserves; larger reserves; buffer zones around protected areas; landscape connectivity; and management of existing threats and disturbance regimes.

Another relevant publication by Hanna [97] summarizes progress related to the design of protected area networks, connectivity and corridors, individual protected areas, mobile reserves, and alternative management measures when protection alone is not enough.

The expected variety of impacts on PNAs arising from CC suggests that managers need to adopt response options to alleviate the negative ones or take advantage of opportunities arising from CC effects, tailored to the specific needs and characteristics of individual reserves [97,136–140]. Although all PNAs of the world are vulnerable to CC impacts to some degree, those located in different regions of the planet may exhibit differential sensitivity [134–136]. Organisms, populations, species, and ecological communities do not respond to approximated global averages; instead, regional changes are more relevant in the context of ecological response to CC [103,134,141]. The geographic asymmetry in warming trends of global temperatures and changes in precipitation patterns contribute to heterogeneity in ecological dynamics across systems and in the range of impacts that PNAs face in different regions of the world [101,134,135,142].

In that scenario, managers need to adopt response options to alleviate the negative impacts or take advantage of opportunities that address them, tailoring to the PNA needs and characteristics [97,118,126,143]. At this point, information availability is critical on the potential CC impacts on these areas and their interaction with other factors in each region that influence the integrity and effectiveness of conservation strategies [102,134].

Future CC impacts outside and within PNAs are projected to become more pronounced in the next decades with variable relative effects depending on the climate scenario and geographic region [101,134,135]. Changes in species ranges can negatively influence the capacity to safeguard species, increase local species turnover, and substantially increase the risk of extinction [112,113,115,144,145]. For example, some communities, such as coral reefs, are particularly vulnerable to CC, especially to the effects of sea warming and ocean acidification [146,147]. Increasing temperatures lead to increased levels of coral bleaching and mortality, and biodiversity depletion, even in the Great Barrier Reef World Heritage Area [148], which could have serious consequences for the Reef's biodiversity, ecology, and dependent recreational use and economic activities [146,147]. Overall, coral reefs are projected to decline from 10% to 30% of former cover at 1.5 °C warming and to less than 1% of former cover at 2 °C warming. Therefore, scenarios show that limiting global warming to well below 2 °C plays a critical role in reducing adverse impacts on coral reefs, ecosystem services, PNAs, natural resources, and their contributions to people [66,149].

A consistent conceptual vulnerability model that can be applied to any system has emerged in CC literature. This model is understood as function of nature, magnitude, and speed of the climate variation to which the system is exposed, its sensitivity to climate and weather conditions induced by anthropogenic CC, and the adaptive capacity of that system to cope, adapt, or recover from the effects of those conditions [150–153]. Exposure is the extent of CC likely to be experienced by a species or system, in this case PNAs, which is an external feature that depends on the rate and magnitude of physical changes. Some examples are temperature, precipitation, sea level rise, flood frequency, CO_2 concentrations, pH in the region where the system of assessment (PNAs) is located, climate variability, and extreme events. Sensitivity is the degree to which the system persistence, performance, or regeneration is dependent on prevalent climate, particularly climate variables that are likely to suffer a change soon. In the case of species, sensitivity depends on factors such as ecophysiology, life history, and microhabitat preferences. For instance, more sensitive PNAs are likely to show a greater degree of change with even small changes in climate variables. Highly sensitive protected areas could therefore be those located in the highest mountains, Artic, Tundra, or protecting coral reefs, where small changes in climate variables and patterns causes great impacts [135,143].

Finally, adaptive capacity refers to the ability of a species to cope with CC, depending on intrinsic factors, such as phenotypic plasticity, genetic diversity, evolutionary rates, dispersal, and colonization ability. In the case of PNAs, adaptive capacity can be seen as resilience of the reserve to recover to a starting condition after being impacted by a disturbance caused by CC [132,154]. The capacity of a system to adapt to CC is also highly variable among regions, countries, and socioeconomic groups. For example, countries with limited economic resources, poor infrastructure and skills, unstable and weak institutions, and unequal distributions of power and access to resources have limited adaptive capacity and thus highly vulnerable to CC [151,155–157].

México is considered one of the most vulnerable countries to CC impacts [158]. The country joined the United Nations Framework Convention on Climate Change (UNFCCC), committing to work together with other countries to stabilize GHG. The Climate Change Intersectoral Commission (CCIC) was created in 2005 to improve collaboration between federal and regional agencies, minimize conflicts between sectors and regions, and maximize benefits of the political integration. Its mission is to accomplish the commitments acquired and be in charge of the coordination, tracing, and evaluation of the National Strategy for Climate Change (NSCC) approved in 2007. Since that time, CC was incorporated as a priority in the National Development Plan (NDP) 2007–2012, establishing objectives, strategies, and priorities that different sectors (transport, health, energy, and environment, etc.) are intended to follow. This decision resulted in the creation of the Special Program of Climate Change (SPCC) 2009–2012, whose main goal was to guide mitigation and adaptation strategies at sectorial and regional levels [158]. Mitigation strategies from the SPCC are focused on encouraging the use of renewable technologies, promoting energetic efficiency, reducing greenhouse gas emissions in productive processes, and preserving carbon sinks, such as forests and soils. On the other hand, adaptation strategies are oriented to assess vulnerability from different sectors to strengthen their adaptation capacities. For example, with the purpose of forest preservation and their related ecosystem services (carbon storage, biodiversity conservation, water balance, etc.), the SPCC incorporates the strategies from the Natural Protected Areas Program (NPAP) created in 1996, Forest Development Program (PRODEFOR) in 1997, Forest Ecosystem Conservation and Restoration Program (PROCOREF), and others currently approved [158].

In 2010, the National Commission of Natural Protected Areas (CONANP) published the first version of the Climate Change Strategy from Natural Protected Areas (ECCAP), positioning the PNAs as natural solutions to face CC. The first version of the ECCAP was built upon two main substantive axes: mitigation and adaptation, with three support components (knowledge, communication, and capacity development), and a transversality component (public policy and bonding). Recently, the second version of the ECCAP (Climate Change Strategy from Natural Protected Areas: A Call to Resilience of México 2015–2020), sees mitigation and adaptation actions as two faces of the same coin, and underscore the role of PNAs to achieve the Sustainable Development Goals (SDG) and targets established in the United Nations Framework Convention on Climate Change [159].

The ECCAP 2015–2020 is structured by four components: institutional arrangements, land gestion in a climate change context, knowledge for decision-making, and communication and social participation. Those components are intended to increase resilience of socio-ecosystems based on the following seven principles: (1) maintaining and increasing diversity and redundancy; (2) managing connectivity; (3) managing slow change variable; (4) promoting the notion of complex adaptive systems; (5) encouraging knowledge and learning; (6) increasing participation; and (7) promoting a polycentric governance. Therefore, the ECCAP 2015–2020 is intended to be a dynamic instrument that guides the actions and decision-making of the CONANP at local, regional, and national levels to reduce the vulnerability of the socio-ecosystem to CC, contribute to ecosystem service conservation, and to provide and promote carbon capture and storage in PNAs [159].

Studies have demonstrated that PNAs have been managed for a much wider range of values than just biodiversity conservation. Society expects now that these areas also provide sustainable resource use, carbon sequestration, mitigation, and adaptation to CC, as well as vital ecosystem services, spiritual values, and support for local communities [55,89,160]. Indeed, PNAs are now widely recognized as natural solutions to face CC impacts and are considered within the ecosystem-based adaptation strategies to cope with future changes [161]. However, CC impacts on these areas may have strong unexpected effects on communities and people´s wellbeing by altering the natural resources and ecosystem services they rely on [160,161].

Nowadays, the potential CC impacts on PNAs come from the convergence of a better understanding of the physical science behind climate change [101] and a recognition of the multiple uncertainties that CC brings to conservation planning [119,162–165]. Additionally, the accumulative evidence from paleoecological observations, phenological and microevolutionary responses, field experiments, global circulation models, improved modeling tools, reserve selection algorithms, and fine-scale climate projections [141,166–168] allows for improvements in the way that PNAs are established and managed in order to reach global conservation targets in a changing world.

7. Concluding Remarks

This research study reviews the main interactions between human communities in protected natural areas and natural biodiversity conservation. To place these interactions in context, the diversity conservation evolution concept was analyzed, as well as the stages of the public interests alongside this evolution.

Protection of natural diversity has evolved over many years from old civilizations to modern day. In the 20th century, human activities began to be related to the importance of conservation in the search for a balance, giving rise to the science of conservation biology, which brought about the appearance of the term biodiversity in 1986, encompassing three levels: species, genetics, and ecosystems. This step was the gateway to the first United Nations Earth Summit with the Rio Convention on biological diversity in 1992 and the signing of international treaties with a biocultural approach, recognizing them as fundamental axes in conservation and restoration projects. These axes were recognized in different conventions and treaties, such as the Biological Diversity Convention where the Aichi goals were signed in 2010, the Nagoya Protocol in 2014, and the Sustainable Development Goals approved by the United Nations Assembly in 2015.

Currently, there has been a renewed interest in reinforcing the reciprocal relationship between nature and human activities from the international community [9,56,61]. To this end, at international level, one of the environmental policy tools most committed to biodiversity conservation is the creation of PNAs throughout the world. Since the Convention on Biological Diversity in 1992, 168 member states have nearly doubled their protected areas to meet the goal of at least 17% of land area and 10% of oceans. It should be noted that the objectives related to PNA management, in addition to biodiversity conservation, also have social and economic objectives because of the intense interaction of human communities with nature.

Moreover, the evolution of PNAs worldwide was reviewed with emphasis on Mexico, indicating that public attention regarding the PNA benefits has also increased. However, the relationship between protected areas and human settlements is complex, so they are either coupled, one dominates, and/or they cause themselves mutual impacts and disturbances. Thus, in cases starting from responsible PNA management, multiple innovative solutions were generated for their coupling and or decreasing impacts, which evidences the need to continue reviewing management policies for biodiversity conservation in the PNAs.

Concerning benefit awareness evolution of the interactions among local people inhabiting PNAs and biodiversity conservation, the social perception is that ancient local communities have had a positive effect on biodiversity conservation [75,80,169]. In this review, the evidence suggests that ancient local communities have developed sustainable traditional usages of Natural Resources that benefit not only human population, but also biodiversity conservation.

To conclude, the great PNA diversity worldwide suggests that CC impacts are not uniform. Considering the relative climate sensitivity on different regions of the planet, the impacts should be differentiated in the PNAs. System planning based on biotic elements may be the most vulnerable to CC impacts because species distribution, abundance, and habitat are largely determined by climate. The impact magnitude on the ecological representation within PNAs depends on the location, composition, and ecology of a given protected area. Therefore, the new scenarios that CC may bring are challenging current systematic conservation planning and management methods of the natural resources.

Finally, the authors suggest that society is increasingly aware of PNAs as one of the best tools humans have to prevent biodiversity loss, and potentially buffer the effects of CC. These increases in social awareness of biodiversity conservation importance and PNAs are gratifying and spread optimism about the future that next generations may face. Research limitations have been identified related to future research on biodiversity conservation. Some of them are: detailed analyses of the different international efforts, monitoring, and follow-up; analyses at continent level or by level of development of the countries; and literature reviews on social involvement in biodiversity conservation projects with a gender perspective.

The state of knowledge, limitations, and uncertainties on the potential CC impacts on PNAs and their resilience capacity come from the convergence of better understanding the physical science behind CC, different levels of vulnerability, and the acceptance of multiple challenges and uncertainties that future scenarios bring to conservation planning and to the wellbeing of human communities.

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