

## Review

# Why Partner with a Zoo or Garden? Selected Lessons from Seventy Years of Regional Conservation Partnerships at the Arizona-Sonora Desert Museum

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**Abstract:** Zoos and botanical gardens (ZBGs) play a variety of roles in regional conservation partnerships, including their most common role as the ex situ managers of rare plant and animal populations. Using case studies from a 70-year history of conservation work at the Arizona-Sonora Desert Museum in Tucson, Arizona, USA, this paper illustrates these roles and the characteristics of ZBGs that make them versatile and effective regional conservation partners. ZBGs commonly play the role of conservation advocates, as discussed in the context of the establishment of protected islands in the Gulf of California. ZBGs also conduct field research, including the collection of long-term datasets, as exemplified by the establishment of the Ironwood Forest National Monument and a 40-year Sonoran Desert phenology database. ZBGs can be effective conveners of communities and conservation partners in regional-scale efforts, such as the Sonoran Desert Conservation Plan and Cooperative Weed Management Areas. The paper also explores the challenges faced by ZBGs in sustaining their conservation work.



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## 1. Introduction

For many people on our urbanizing planet, zoos, aquariums and botanical gardens (ZBGs) help to bridge the gap between their human-dominated environments and the rest of nature. With over 700 million annual visitors to zoos and 300 million annual visitors of botanical gardens worldwide [1,2], ZBGs help people to feel more connected to plants and other animals and learn about threats to biodiversity [3,4]. In addition to their critical role in education, ZBGs play many additional roles in the conservation arena. According to the World Association of Zoos and Aquariums, its members spend more than USD 350 million annually on field conservation and research, making them the third-largest funder of conservation worldwide [5]. ZBGs manage living collections for the ex situ conservation of rare species, host seed banks and frozen cell lines to preserve genetic diversity, conduct field research, collaborate with governments and non-governmental organizations in coordinated species and habitat conservation efforts, and engage the public in conservation activities [3,6,7]. A number of plants and animals that are or were extinct in the wild exist today due to the efforts of ZBGs [7,8].

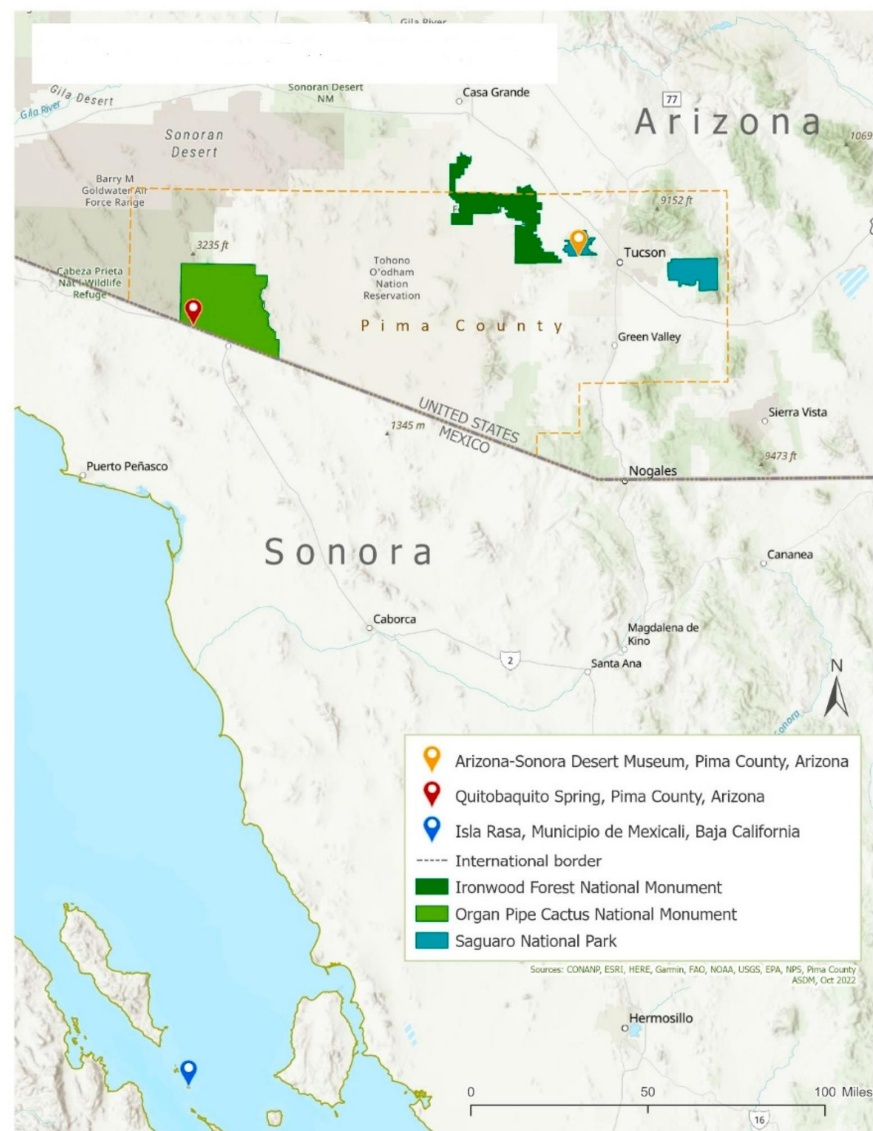
ZBGs have a variety of management and funding structures. They are funded and managed by both public and private entities, and many depend on admission and membership fees, as well as private donations, to pay for their operations. Some (especially botanical gardens) are managed by universities or other research institutions. Due to the extensive public interactions and dependencies of most ZBGs, they also tend to be responsive to societal needs. As Christine Flanagan, former Public Programs Manager at the US Botanical Garden, explained: “More nimble than governments, more flexible than university programs, and more altruistic than private enterprise, public gardens have found ways to forge important academic, conservation and therapeutic programs” [3].

Many ZBGs whose collections and conservation efforts span the globe also participate in conservation in their own backyards, as observed from the many studies reported in this Special Issue. A smaller number of institutions focus solely on their own regions, such as the Arizona-Sonora Desert Museum (Tucson, AZ, USA), Monterey Bay Aquarium (Monterey, CA, USA), and many zoos around the world that feature local animals that cannot survive in the wild for a variety of reasons. This article uses case studies from the conservation work of the Arizona-Sonora Desert Museum to illustrate the nimbleness, flexibility, altruism, and impact of ZBGs on regional conservation efforts.

Over its 70-year history, the Arizona-Sonora Desert Museum in Tucson, AR, USA, has been a partner in numerous regional conservation efforts. The Desert Museum is a regional zoo, botanical garden, natural history museum, and art institute that immerses its visitors in the Sonoran Desert ecosystems. As a regional conservation organization, collaboration with the public agencies and communities in its region is at the core of its mission. From its earliest history, its staff have worked with regional governments to secure the protection of significant places and to hold and augment populations of rare species. The Desert Museum and its partners have learned from these experiences, sharing lessons through formal reports and publications (for example, [9–13]) and through informal professional networks.

The Desert Museum, similar to other ZBGs, has played a variety of roles in conservation partnerships. ZBGs are probably best known for their role in ex situ animal and plant care and propagation. However, education, advocacy, research, and project coordination conducted by ZBGs have made equally important contributions to regional conservation efforts (see the many projects described in this Special Issue). Government, university, and private partners turn to the Desert Museum and to other zoos and botanical gardens because of their specialized expertise, their connections with public audiences, and their versatility. ZBGs participate in both basic and applied research, engage in both in situ and ex situ conservation, work across jurisdictions, and are trusted ambassadors for conservation among many in their communities [14,15]. Although they often have more flexibility than their university or agency partners, many smaller ZBGs lack dedicated funding to support staff with a conservation focus. Nevertheless, at times, ZBGs are able to commit to long-term research, which can be difficult for university researchers tied to grants and agencies tied to annual budgets.

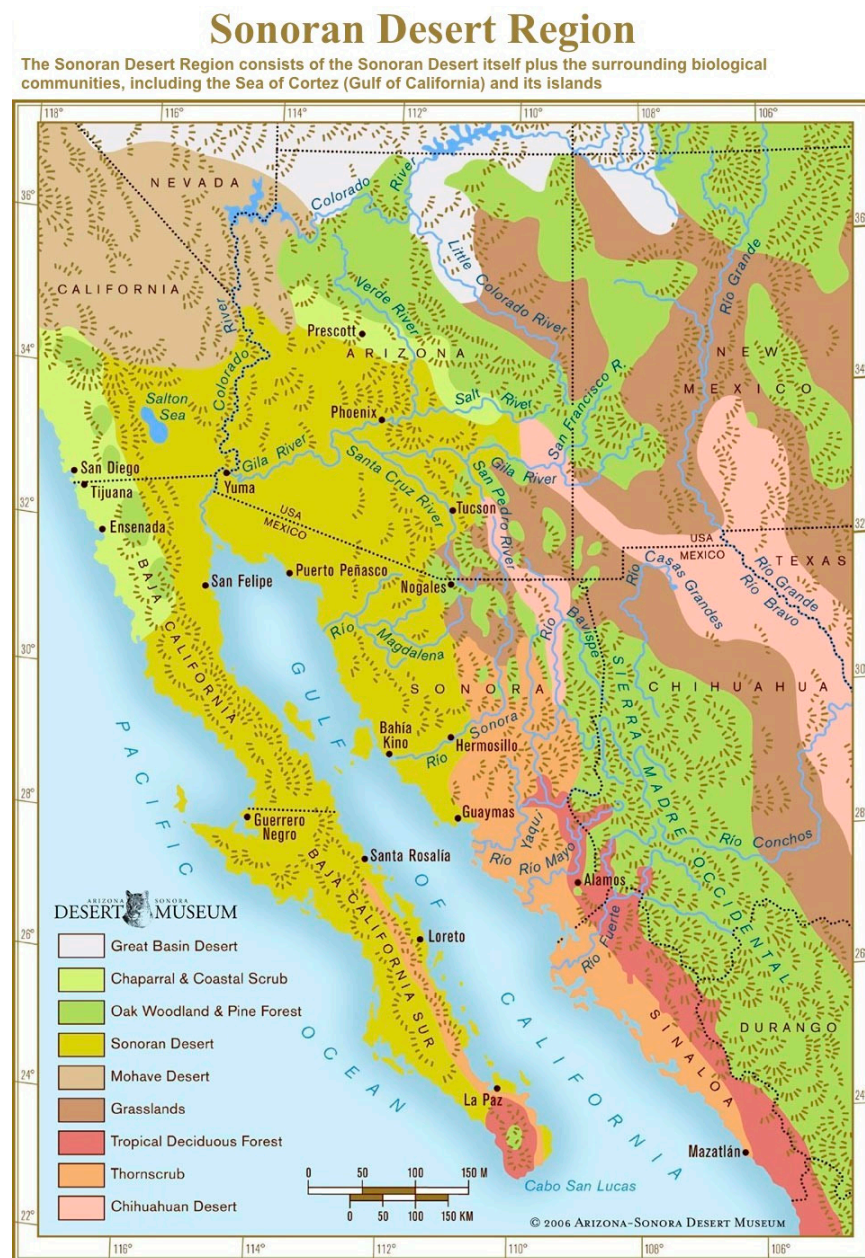
Here, we present several short case studies of Sonoran Desert conservation initiatives in a roughly chronological order in which the Museum played various roles, including that of conservation advocate, field researcher, public educator, project coordinator, and ex situ care and propagation manager. In each case, we focus on some of the advantages of partnering with zoos and gardens, as well as the potential challenges. The sites of these projects are shown on the map in Figure 1.



**Figure 1.** Regional map showing locations referenced in the text.

The Desert Museum's mission is to inspire people to live in harmony with the natural world by fostering love, appreciation, and understanding of the Sonoran Desert. The Sonoran Desert is one of the most diverse deserts in the world due to its varied geography, topography, and bimodal rainfall pattern, with summer and winter rainy seasons [16]. A variety of cultures have lived in and shaped the landscape and biodiversity for at least 13,000 years [17]. As seen in Figure 2, the Sonoran Desert region covers approximately 260,000 km<sup>2</sup> and includes several biotic communities, which are sometimes interlaced and alternated along the undulating basins and mountain ranges [16]. It also surrounds the extremely diverse and productive Gulf of California, with over 900 islands and islets [18]. The Sonoran Desert encompasses most of southern Arizona in the U.S., the northwestern part of Sonora, Mexico, and most of the Baja California Peninsula. It also extends slightly into southeastern California, U.S. It is home to a relatively high number of vulnerable species due to its relatively high biodiversity, habitat degradation, introduced species and pathogens, and the impacts of climate change [19,20]. Over its history, the Museum has partnered with university researchers, non-governmental organizations, indigenous communities and nations, and local, state, and federal agencies in the U.S. and Mexico to conserve the region's rich biological heritage.





**Figure 2.** Sonoran Desert Region Biotic Communities.

## 2. Roles and Assets of Zoos and Botanical Gardens (ZBGs) in Regional Conservation Partnerships

### 2.1. ZBGs as Advocates: Establishment of Protection for Islands in the Gulf of California

Lewis Wayne Walker served as the associate director of the Arizona-Sonora Desert Museum from 1954 to 1970. Walker had been exploring the Baja California Peninsula and the Gulf of California since the late 1930s and first visited Isla Rasa in 1946. Located approximately 640 km south of the head of the Gulf, Isla Rasa is less than 2.6 km<sup>2</sup> in total and, at its highest point, not quite 30 m above sea level. The island is the primary nesting and breeding area of both Elegant Terns (*Sterna elegans*) and Heermann's Gulls (*Larus heermanni*). It is estimated that the Gulf of California islands, primarily Isla Rasa, provide a nesting habitat for 90 percent of the North American populations of these species [21]. Over subsequent visits, Walker and his colleagues noticed an astounding decline in the bird populations, mostly due to excessive egg harvesting by the residents of the Baja Peninsula. Early in the breeding season, people would destroy all the eggs they could find

so that the birds would lay new eggs (without developed embryos). A few days later, they would collect the fresh eggs and sell them at local markets [22]. By the early 1960s, the bird populations had declined from more than one million nesting birds in the 1940s to approximately 25,000.

Walker published a richly illustrated article on the island in *National Geographic* in 1951 [23], which attracted additional attention in the U.S. and Mexico. He brought together influential leaders, including Dr. Joseph Wood Krutch (author, English professor, environmentalist, and pantheist), Kenneth Bechtel (founding member of the Bechtel Corporation), and William Woodin (Desert Museum Director) to revisit the islands in order to document their need for protection. He also collaborated with Dr. Bernardo Villa Ramírez from the National University of México (UNAM) and community leaders of Bahía de los Angeles on the Baja Peninsula (notably Antero Díaz). Walker enlisted the help of renowned ornithologist, Roger Tory Peterson, and the presidents of the California Academy of Sciences and National Audubon Society to publicize the importance of these habitats and the plight of its seabird populations. They worked together to produce a film, which they distributed widely to raise public awareness of the birds' plight. They also advocated in the halls of government in Mexico City and won legal protection for the island in 1964 [22]. Once established as a protected area, the island became the subject of long-term research by Mexican biologists continuing to this day.

One of the scientists visiting Isla Rasa in the 1960s was a PhD student at the Universidad Nacional Autónoma de México, Enriqueta Velarde, now posted at the Universidad Veracruzana. Dr. Velarde continued to study these seabirds, inspiring generations of Mexican scientists to further research and document the spectacular biodiversity of the Gulf of California. Their science and advocacy led to broader protections. In 1978, Isla Rasa became part of the much larger protected area under the official designation of the Área de Protección de Flora y Fauna Islas del Golfo de California, which was followed by a series of expanding protections as a Parque Nacional, a Wetland of International Importance recognized by the Ramsar Convention, and, finally, its designation as a World Biosphere Reserve in 2007 [22]. Recent surveys have documented a remarkable recovery of these birds (as well as others), with as many as 260,000 Heermann's Gulls and 200,000 Elegant Terns [22].

In the case of Isla Rasa, the public awareness and international attention made possible by the networks through which U.S. zoos operate supported the work of Mexican conservation scientists aiming to study and protect the amazing biodiversity of their country.

## 2.2. ZBGs in Field Research: The Ironwood Forest National Monument

Federal agencies will sometimes turn to zoos, botanical gardens, and other private conservation organizations to complete surveys on public lands that are necessary to establish or monitor management plans. In the case of the creation of the Ironwood Forest National Monument, the Desert Museum was a natural partner for the completion of the plant and animal inventories necessary to demonstrate the need for the protection of this area. Previous decades of study of the region, motivated by scientific questions arising from multiple disciplines, set the stage for the protection of this land and the Desert Museum's involvement.

Before 1970, only a few plant collections existed in this relatively undeveloped area, located just northwest of Tucson, AZ. In the 1970s and 1980s, Museum scientists began to document the flora of the area, motivated first by studies of packrat middens as records of vegetation change and later by the unusual plant communities, rare plants, and their relationships with the area's diverse geology [24]. Throughout the 1990s, the museum's botanists extended and deepened the biological surveys, discovering plants found nowhere else in the United States and mapping several rare and endangered plants for the Bureau of Land Management and U.S. Fish and Wildlife Service.

In 1998, Dr. Gary Nabhan, the museum's director of conservation and science, brought his interests and background in ethnobotany to the research of these interesting mountain ranges. He studied the ethnobotanical uses, animal interactions, and plant associations with the desert ironwood tree (*Olneya tesota*), eventually publishing a book on the topic [25],

which caught the attention of local conservationists, including the county administrator. The county was engaged in a multi-decade effort to gain federal approval for a multispecies habitat conservation plan (see the Sonoran Desert Conservation Plan, below), which required the conservation of this area for rare species and for habitat connectivity. The area also contained many fragile archeological sites in need of protection. At the same time, U.S. President Clinton was eager to bolster his legacy in conservation by protecting more land as his second term was coming to an end. This parcel containing rare and unique plants and plant communities, archeological treasures, and the ecologically and culturally significant desert ironwood tree was proposed by the county for federal protection.

Given the breadth and depth of the existing museum data for this tract of land, the agencies were able to fast-track its consideration for protection, and the area was designated as the Ironwood Forest National Monument in 2000. The designation was the beginning of yet another round of study, as the Bureau of Land Management required more quantitative and comprehensive surveys of the flora and fauna of their new monument. This round of surveys also led to the discovery of a new invasive grass, buffelgrass, and motivated further study, mapping, and recommendations for its control [13].

The Monument contains 520 km<sup>2</sup> of varied Sonoran Desert habitat encompassing seven desert mountain ranges and protects over 600 taxa of plants and a great variety of invertebrate and vertebrate life [13]. The support of basic natural history research over the long term by the Desert Museum and the close collaboration between scientists from different disciplines (paleobiology, botany, ethnobotany, geology, and zoology) in its small science department made it a unique partner for the establishment of this protected area.

### 2.3. ZBGs in Long-Term Research: Phenology

Phenology, or the study of the timing of the life cycles of plants and animals, is critical to understanding basic ecological relationships, as well as the impacts of climate change on these relationships. Climate-change-induced phenological mismatches have been documented around the world in cases where pollinating insects emerge before the plants flower, birds hatch after their favorite caterpillars have peaked, or plants mature before the young animals dependent on their shoots are ready to forage [26–28]. Studying climate impacts on phenology requires extensive and long-term datasets, many of which are held by botanical gardens. Botanical gardens are also uniquely positioned to engage the public in phenological observations, as in the case of the Chicago Botanic Garden's Budburst Project [29].

The Desert Museum's horticulturalists have been collecting phenology data on dozens of native plants for nearly 40 years. Highly variable precipitation is a defining characteristic of desert regions and a confounder in phenological studies. Only now are ecologists developing sophisticated statistical techniques for studying the impact of climate change on phenology in arid regions. A recent collaboration between Conservation Science Partners, the US Geological Survey, and the Desert Museum analyzed 36 years of data on six abundant woody species and expanded on the traditional models of phenology by incorporating different metrics of moisture availability, in addition to the temperature, weather, and climate [30]. They also studied the impact of climate events on several time scales, from the daily through to the seasonal. Five of the six species studied showed advancing flowering dates in response to rising temperatures, ranging from 1 to 4 days earlier per decade, and the results for one species were uncertain. More specifically, the models suggested that flowering dates are responding to the more rapid accumulation of growing degree days occurring earlier in the year. The species' responses to moisture-related variables were less consistent and may be explained by variations in functional traits or ecological interactions, such as the mode of pollination. The study indicates the potential for phenological mismatches between pollinators and plants in this rapidly warming region of the world.

In this case, a strong connection with and desire to serve public audiences motivated the initial research. The study did not begin with climate change in mind but rather the desire to be able to answer frequently asked questions about when the peak wild flower



season can be expected to occur in a given year. The scientific curiosity of the museum botanists sustained the data collection both on the museum grounds and in the adjacent Saguaro National Park. Because the data collection protocols were not exceedingly costly or time consuming, the staff and volunteers were able to sustain the data collection for 40 years. The foresight of successive museum curators and staff maintained the project despite competing priorities and a lack of funding. The value of this legacy dataset was obvious to the partners involved in the U.S. Geological Survey and the non-profit organization known as Conservation Science Partners, both of whom helped the museum with the data analysis.

#### 2.4. ZBGs in Local Community Conservation: The Sonoran Desert Conservation Plan

Much of the desert surrounding Tucson, Pima County, AZ, is a suitable habitat for the cactus ferruginous pygmy owl (*Glaucidium brasilianum cactorum*) [31]. When the U.S. Fish and Wildlife Service (USFWS) listed it as an endangered species in 1997, local developers and environmentalists braced for years of contentious and costly court battles over new development projects. Recognizing that the owl was just one of many threatened and endangered species in this biodiversity hotspot, Pima County planners sought an alternative approach to development.

A habitat conservation plan is such an approach. When approved by the USFWS, it allows for the limited incidental loss of endangered species for development purposes when adequate mitigation plans are in place. Pima County officials began the process of developing their plan in 1998, commissioning over 200 studies and holding over 600 public meetings. They invited anyone interested to apply to serve on a project steering committee and received almost 90 applications, all of which they accepted. The Steering Committee members represented ranching, conservation, housing development, realtors, neighborhood association, transportation, mining, and other business interests. The committee members had to agree to attend nearly one year's worth of educational presentations so that they would all start from a similar place when the deliberations began [32].

In the end, this Steering Committee released a report recognizing the importance of conservation lands not only for protecting biodiversity but also for protecting the quality of life of the region's residents and its long-term economic vitality. It also recognized the need for economic growth to support the region's burgeoning population. This community-based group, representing diverse and sometimes oppositional sectors, made recommendations on the principles, funding, approaches, partnerships, duration, and many other matters regarding the Multispecies Habitat Conservation Plan for Pima County [32].

The Desert Museum served as the site for some of the Steering Committee meetings, and the museum scientists participated in the Scientific and Technical Advisory Group for the process, which created a map of the priority conservation lands, the linkages between them, and the recommendations for their management. As in the case of the Ironwood Forest National Monument, the extensive natural history and ecological information supplied by the museum was an important part of the conservation planning.

The Steering Committee report, released in 2001 [33], was an important milestone in the process of winning federal approval, which came after further studies and more detailed planning. In the years since, the museum has continued to inform the public about this community success story through exhibits, programs, and publications. The Sonoran Desert Conservation Plan, of which the Multispecies Habitat Conservation Plan is one part, covers over six million acres and helps to protect 44 vulnerable plant and animal species, as well as the ecosystem services on which the regional human population depends.

#### 2.5. ZBGs as Ex Situ Conservation Partners

Perhaps the most common way in which ZBGs participate in local conservation partnerships is as a place for the protection and/or breeding of rare species. For example, the Association of Zoos and Aquariums reported that its member institutions spent USD 217 million on field conservation in 2021, benefitting 954 species with more than

960 partner organizations [34]. ZBGs may serve as temporary refuges during short-term habitat disruptions, work to augment populations for release or re-introduction, or they may hold long-term assurance populations of rare species. Although zookeepers and horticulturalists have expertise in managing a great variety of species, they are constantly reminded that every species is unique and that techniques which may have worked for some species may not work for others, even in the same taxon. Where ex situ conservation is being contemplated, it is important to develop partnerships with zoos and gardens early enough to develop the expertise needed to sustain the species.

Over its history, the museum has assisted in the ex situ conservation of a wide variety of plants and animals from a wide variety of taxa. As the needs for their care and breeding evolved over time, the museum found that it could be most impactful when working with species with smaller space needs, as it had a limited capacity to expand its staffing or facilities. The majority of the species of concern which it now cares for are aquatic reptiles, amphibians, and fish. Aquatic and riparian habitats have always been rare in the region and have been declining at a steady rate due to ground water pumping, surface water diversions, and a twenty-year drought [35,36]. The remaining streams and wetlands are also impacted by fires, flooding, and invasive and introduced species [35].

The Desert Museum has served as the ex situ conservation site for three species from the Quitobaquito Springs and Pond in the Organ Pipe Cactus National Monument and houses two of them currently. The Sonoyta pupfish (*Cyprinodon macularis eremus*), Sonoyta mud turtle (*Kinosternon sonoriense longifemorale*), and Quitobaquito spring snail (*Tryonia quitobaquitae*) are typical of many of the threatened and endangered aquatic species in the region [37–41]. They are endemic to a small portion of the watershed of the Rio Sonoyta and entirely dependent on heavily managed and/or impacted surface waters for their survival. The only populations of these animals in the United States live in the Quitobaquito Springs and Pond and, in the case of the snail, in two nearby springs.

Quitobaquito is a remarkable place that has been protected and managed by the generations of the Hia-Ced O’odham and Tohono O’odham, two indigenous nations of the region, as one of very few year-round sources of water. Ethnobotanist and former Desert Museum Director of Conservation and Science, Gary Nabhan, called Quitobaquito “a place in the Sonoran Desert borderlands which, more than any other I know, capsulizes what the term diversity has come to mean to both natural and social scientists alike” [19]. Additional populations of turtles and pupfish are found in small perennial stretches of the Rio Sonoyta and small ponds across the border in Sonora, Mexico. These are threatened by the continued depletion of groundwater, drought, variable seepage from sewage and dams, and the conversion of wetlands for farming and mining [41].

These aquatic species are extraordinary due to their persistence in one of the hottest, driest places in North America. The Rio Sonoyta pupfish and Quitobaquito pupfish are two subpopulations of the endangered species *Cyprinodon macularius eremus*, listed as endangered in 1986 [38]. The Sonoyta mud turtle was listed in 2017 [40]. The spring snail is a candidate for listing due to its extreme endemism [42]. The Desert Museum first became engaged in the ex situ conservation of the pupfish in the mid-1980s and of the mud turtles in 2008, aiming to provide temporary refuge to the species and establish assurance populations while hydrological studies and repairs were carried out in the area of the Quitobaquito Pond. In recent decades, the water levels of the pond have risen and fallen due to changes in precipitation and spring flow, leaks in the pond lining, and, most recently, the possible effects of groundwater pumping due to wall construction along the U.S.–Mexico border. The U.S. Fish and Wildlife Service, National Park Service, and Arizona Game and Fish Department established long-term assurance populations at the Desert Museum and Phoenix Zoo while consistently working to improve the habitat of these species.

The museum’s population of pupfish survived for over three decades, although its senescence outpaced its reproduction and supplementation, and the population eventually dwindled to zero. There are currently plans to re-establish these fish at the museum. Working with the Arizona Game and Fish Department (AZGFD), the museum began turtle



breeding trials in 2014. While most of the captive turtles live in separate indoor quarters, a multi-turtle outdoor habitat was designed to replicate wild conditions. After much experimentation with the habitat conditions, the first successful breeding and hatching of three turtles was accomplished in 2017, with several more baby turtles joining them over the following years.

At the request of the AZGFD and the National Park Service, the museum acquired a population of spring snails in 2022. Approximately the size of a grain of black pepper, they are extremely difficult to see, let alone count and assess. However, always ready for a new challenge, the museum keepers are learning how to keep them alive *ex situ* and developing care and monitoring protocols for this species.

At this time, the major conservation focus is on habitat restoration rather than captive breeding. Thus, there is no effort to breed large numbers of fish, turtles, or snails. Despite the continuing drought and fluctuations in pond water levels, the field surveys suggest that the populations *in situ* are currently stable. The *ex situ* populations are being maintained as an assurance and to continue to develop husbandry expertise as a hedge against more extreme challenges in the future. In this case, the museum's main contribution to the partnership is its expertise in, and facilities for, husbandry. The cost of this work is high (in terms of both labor and other expenses), and it is almost never fully compensated by the partnering agencies. Funding policies that prohibit labor costs are a major impediment to the support of this work. Additionally, many small institutions (including the Desert Museum) do not have federally established indirect cost rates, which limits the recovery of these costs. Although *ex situ* conservation work is clearly part of the mission of ZBGs, the lack of adequate funding can constrain these partnerships for smaller regional institutions.

#### 2.6. ZBGs as Conservation Coordinators: The Regional Management of Invasive Grasses

One of the greatest threats to Sonoran Desert biodiversity is an invasive grass. Brought to the area for the purposes of soil conservation and cattle forage in the 1930s, buffelgrass (*Cenchrus ciliaris*) creates thick carpets of continuous fuel for fires in a landscape that is not adapted to fires [43]. It also outcompetes the native shrubs and cacti for water and nutrients [44]. It has the potential, especially as it is aided by climate change, to reshape one of the most diverse deserts in the world into a grassland monoculture [45]. Buffelgrass fires also threaten well-being and property in urban and rural landscapes and at the wildland–urban interface [46,47].

Invasive species, similar to many other conservation issues, are difficult to manage because they cross jurisdictions and sectors. Various land management agencies have different priorities and may have different techniques of monitoring, treatment, mapping, and documentation. There may be varying technical or policy restrictions on data sharing and treatment methods. Yet, evidently, coordinated efforts are required to make progress.

Recognizing the need for concerted action, regional conservation leaders established the Southern Arizona Buffelgrass Coordination Center in 2008. It successfully brought together dozens of landowners and managers so as to coordinate their efforts, enabling them to learn from each other and advocate together at the state and federal levels for funding. After several years of proving the concept, building a community of practitioners, developing an energetic volunteer effort, and attracting initial funding, the center's staff and advisory board realized that fluctuating funding cycles would not be able to sustain this independent non-profit endeavor in the long term. In 2016, the center approached the Desert Museum to absorb some of its functions. The Desert Museum science staff had been serving on the center's advisory board and recognized the threat posed to the Sonoran Desert. Conversation efforts with the museum's leadership, the Board of Trustees, and the Conservation and Science Team led to the decision to recognize that the threat was great enough, the museum's function in the project was clear enough, and the likelihood of external funding was good enough that this was a role which the museum could take on.

In the following years, the museum has brought together agencies, businesses, and utilities at the local, state, regional, and national levels to form the Sonoran Desert Coopera-

tive Weed Management Area (Table 1). Through quarterly meetings, the group has shared best practices, carried out and facilitated research, pursued funding opportunities, and advocated for more coordination at the state and federal levels. The museum continues to help the group to choose and maintain a common mapping platform and address other major shared challenges, such as the inadequate workforce. The museum plays a role in research and collating and analyzing data on treatment effectiveness and alternative treatment methods. Its research has also expanded to include social scientists studying the key routes to effective partnerships in complex multi-jurisdictional conservation programs [48]. Some of their initial findings have shown the success of the first two decades of public engagement, with a strong local awareness of the status of buffelgrass as an important issue in Tucson and the surrounding Pima County.

**Table 1.** Partners in the Sonoran Desert Cooperative Weed Management Area.

Arizona-Sonora Desert Museum (Coordinator)
Tucson Audubon Society
Arizona Department of Transportation
Arizona Game and Fish Department
Arizona Department of Forestry and Fire Management
The Arizona Native Plant Society
Bureau of Land Management
City of Tucson
Department of Defense
Freeport McMoran
Saguaro National Park, National Park Service
Pima County
Sky Island Alliance
Southwest Vegetation Management Association
Tohono O’odham Nation
Tucson Clean and Beautiful
University of Arizona, Arizona Cooperative Extension
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey
Strategic Habitat Enhancements

The museum also plays an important role in public education and outreach, coordinating ongoing volunteer groups and an annual “Save our Saguaros” event. Moreover, the remarkable volunteer effort that has been effective in controlling the buffelgrass in certain areas of the Tucson Basin is a testament to the strong sense of place and shared appreciation of the Sonoran Desert ecosystem that can be at least partially attributed to the work of the museum.

Another finding derived from this work with social scientists is that a key challenge for the management of invasive species is the identification and overcoming of the barriers to collaboration and coordination between actors representing diverse institutions. These barriers include cultural traditions, mandates, and insufficient staff and funding, all of which limit the ability of institutions to look beyond their own efforts and consider the problem from a broader, more regional perspective. Identifying the barriers to and incentives for collective action will be critical for the success of efforts to address many of the ecological challenges that we will face in coming decades [48].

Over the years, partners have sometimes turned to the museum not only for its expertise but also because of a perception regarding the lower barriers to the administration of complex projects. Not only can the museum work across jurisdictional boundaries, but it also has a more flexible mandate and can help to bridge cultures. On a very practical note, small ZBGs, such as the Desert Museum, also commonly have lower overhead rates due to the lack of federally recognized rates mentioned above. This can be an advantage for project work but a disincentive for small ZBGs to take on this work.

### 3. Conclusions

As a regional institution, the Arizona-Sonora Desert Museum offers many informative case studies of collaboration with local and regional conservation agencies that highlight the niches that ZBGs commonly fill in these collaborations. Depending on each project's needs, ZBGs might serve as advocates for the protection of land and/or species; provide natural history data, field research, and legacy data; participate in and serve as a resource for community-based conservation efforts; provide ex situ care; and serve as coordinators or conveners of multiple partners. The nature of ZBGs as trusted translators of scientific knowledge, their ability to work across disciplines and jurisdictions, their specialized expertise in husbandry and horticulture, and their administrative nimbleness make them a valuable partner in a variety of initiatives.

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