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THE IMPORTANCE OF ZOOLOGICAL GARDENS IN THE CONSERVATION OF BIODIVERSITY

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ABSTRACT
The ecosystems of 50,000 years ago were populated with different species of animals that are now extinct species, these extinctions coinciding with the beginning of the migration of people from the African continent to the other continents. After the industrial revolution, these phenomena became even more pronounced and thus the need for various actions to preserve biodiversity. Even though various organizations are currently criticizing zoos and generally the practice of keeping wild animals in captivity, many zoos have played an important role both in the past and in the present in the conservation of biological diversity. In total, a number of seven in-situ and ex-situ strategies were identified and exemplified by which zoos contribute to biodiversity conservation.
KEY WORDS: *biodiversity, zoos, anthropogenic impact, in-situ, ex-situ.*

INTRODUCTION

Ecosystems 50.000 years ago were populated by a variety of large animals (animals weighing ≥ 44 kg) that have since disappeared, with an estimated 90 genera of mammals becoming extinct. This is thought to have happened around 10.000 years ago, with the most susceptible species being those with slow reproduction, specifically those with a reproduction rate of 1 offspring / female per year (Koch & Barnosky, 2006). These extinctions coincided with the beginning of the humans' migration from the African continent to the other continents starting about 80,000 years ago. Thus, practically very early in time, humans' impact on biodiversity began to be observed (Turvey & Fritz, 2011).

Many scientists believe that humanity is witnessing the next mass extinction, with various studies indicating that the human species may be the cause of this extinction. Thus, biodiversity loss is regarded as a problem that has had and will continue to have devastating effects on many ecosystems, as well as potentially catastrophic effects on the human species in the future. These views are supported by evidence showing the impact of humans on biodiversity immediately after their dispersal, a

dispersal that was unfortunately followed by a large number of anthropogenic extinctions of vertebrates. It is also worth noting that the extinction rate has risen alarmingly in recent years, particularly since the industrial revolution (Ceballos *et al.*, 2015).

Today, the primary factors affecting biodiversity are habitat loss and habitat fragmentation, which can lead to a reduction of genetic diversity in certain populations. The second important factor is the unintentional or intentional introduction of new plant or animal species that have a negative impact on area's native species. Last but not least, many species face the negative effects of excessive and unsustainable harvesting of various natural resources. This category includes the hunting and trapping of various species, mainly illegal actions (Van Kooten *et al.*, 2000). Finally, a threat as serious as the ones mentioned above, namely pollution and global warming, must be mentioned.

Considering all these aspects, there is a need to develop strategies to help endangered species survive. The purpose of the article is to identify and exemplify the main methods and strategies by which zoos have contributed and are contributing to the conservation of biodiversity.

MATERIAL AND METHODS

A search in the specialized literature was conducted in order to identify the zoos' strategies. Furthermore, Google Scholar was used to find clear and concise examples of past or ongoing projects in which zoos from around the world participated.

The zoos' official websites were also used as a direct source of information, which was processed and used to identify additional strategies not covered in the specialized literature.

Simultaneously, an effort was made to use the most plausible sources for retrieving images related to the species, particularly the official IUCN website where possible.

RESULTS AND DISCUSSION

Most biodiversity conservation activities must typically operate on multiple fronts due to the numerous factors, such as economic ones, that must be considered and influence the successful implementation of conservation strategies. Thus, the conservation strategies adopted can be classified into two important categories: in-situ and ex-situ.

Among the most important advantages of zoos is their possibility to participate simultaneously in several types of activities, a zoo can even implement all the strategies to be mentioned.

In total, seven ways were identified in which zoos contributed and contribute to biodiversity conservation, with each aspect explained and exemplified in the following:

- Zoos as genetic reserves for improving the genetic background in programs to save rare or endangered species;
- Zoos as biological tissue banks;
- Reproduction in zoos different species and reintroduction into the natural environment;
- Rehabilitation of injured specimens;
- Adult and child education and awareness;
- Research;
- Financial aspects as contribution to the conservation of in-situ projects.

1.1 Zoos as genetic reserves for improving the gene pool in programs to save rare or protected species

Various zoo federations, including Species360, have been established to account for genetic diversity and population sizes within zoos. This organization created a database called ZIMS (acronym for Zoological Information Management System) that included wild animals cared for by organizations such as zoos as well as those owned by individuals. The significance of this organization is demonstrated not only by the large number of zoos and associations served, but also by the vast geographical areas in which it operates, namely in over 99 countries in 2016. This database contains information on over 22.000 species, making it an important tool for biodiversity because it allows zoos to choose partners for reproduction based on their genetic background (Link 1). This is especially important because the species in question are considered more vulnerable, with a less diverse genetic pool. These breeding methods are used to try to avoid inbreeding depression, especially in populations that are already very small.

As a result, the role of genetic reserves played by many zoos can mean the difference between a species' survival and extinction. The existence of a database such as ZIMS connects all these institutions and makes interactions and information exchange as efficient as possible.

Oryx leucoryx breeding project

A first example of this was the *Oryx leucoryx* species reintroduction project, carried out in Oman, Arabian Peninsula. Around 1962-1963, the population of this species plummeted to the point where eight individuals were captured and sent to various zoos around the world to serve as a genetic reserve. Later, these eight individuals reproduced to the point where, in 1981, they had a population of approximately 130 captive individuals, forming the Herd of the World (Islam *et al*., 2011).

In terms of the wild population, the species was declared extinct in 1972 due to a variety of factors such as poaching and capture. Before this species was declared extinct in the wild, the last individuals were captured and used for reproduction. To ensure the success of this project, the genetic pool was expanded by bringing individuals from the World Herd to Oman to supplement the initially captured population.

Following breeding efforts, the population gradually increased so that the first ten individuals were released in 1982. The population size reached 280 individuals in 1995. Unfortunately, illegal hunting started to intensify again, negatively affecting the population of *Oryx leucoryx* (Spalton *et al*., 1999).

After numerous actions to educate the public and improve eco-tourism, it finally reached in 2008 a population of 1.000 individuals in the wild and between 7.000 and 8.000 individuals in captivity (Arabian Oryx Regional Conservation Strategy and Action Plan).

Captive breeding program of the species Acinonyx jubatus

If the population of cheetahs *Acinonyx jubatus* was approximately 25.000 individuals in 1980, habitat loss and illegal hunting have reduced the population to approximately 7.000 individuals today (Crosier *et al*., 2020).

Captive breeding of this species was nearly impossible, with only one success until 1956 (McDermott, 2019). Fortunately, between 1980 and 1990, several field studies were conducted that highlighted their reproductive behavior, specifically the need to separate females and males, which was later implemented in zoos (Manning & Dawkins, 2012). This, along with subsequent studies of their reproduction, such as ovulation cycles in females and poor sperm quality in males, resulted in higher breeding rates in captivity.

The objective of breeding this species in captivity is to eventually introduce the gene pool from zoos into the wild and thus improve their genetic pool. This is due to the extremely low population size, as well as the fact that the genetic variation of this species is extremely low in comparison to other mammals, as demonstrated by a 1983 study McDermott (1999). According to studies conducted by the Smithsonian Conservation

Biology Institute (SCBI) in Virginia (USA), the genetic variation of this species is also in continuous decline. It is important to note that genetic diversity has been preserved within zoos due to the cooperation of various institutions in the reproduction of the species,

Aside from the fact that zoos keep individuals of this species in captivity, numerous studies are conducted in collaboration with them in order to improve the reproductive rate and preserve the genetic background. One example is the use of ovules from females unable to reproduce with a valuable genetic pool through in vitro fertilization (IVF), which resulted in the birth of the first cheetah cubs in February 2020.

The approximately 350 individuals in zoos managed by the Species Survival Plan (SSP) currently represent the gene reservoir of individuals in the wild (Crosier *et al*., 2020).

1.2 Zoos as biological tissue banks

Biological tissue banks are collections of biological samples and their associated data, which are of fundamental importance for scientific research and more recently for the conservation of genetic biodiversity.

Motion "094" called "Connecting in-situ and ex-situ efforts to save threatened species" approved by the IUCN, aims to encourage the storage of genetic material in such banks. These efforts attempt to improve genetic diversity in wild or captive populations, with the potential to stop the extinction of species in certain situations (Link 2).

Various biological banks store various types of cells, particularly germ cells and, more recently, non-germ cells. When technology allows it, the preservation of somatic cells aims to direct or indirect use for the production of offspring in the future. The genetic material of many species would have been lost forever if such genetic conservation actions had not been implemented (Comizzoli, 2017).

With the help of the ZIMS for Medical database created by Species360, it is possible to track the species whose genetic material is stored in the genetic banks as well as their location (Link 3).

An example of this is the Zoological Society of London (ZSL) which runs London Zoo and Whipsnade Zoo. ZSL has a partnership with The Frozen Ark in Nottingham, UK, whose core activities focus specifically on the conservation of genetic material (somatic cells) of endangered species. In addition to the partnership with ZSL, they also cooperate with specialists from IUCN but also with many other institutions distributed

in other European countries as well as countries in North America, Asia and Australia (Link 4).

Another example of this is the San Diego ZOO, also known as the Frozen Zoo. It has been collecting and preserving tissues from various animal species since 1975, including both species with stable populations and species that are on the verge of becoming extinct or are already considered extinct.

The San Diego ZOO's efforts also focus on research that takes into account aspects such as genome sequencing but also the reprogramming of somatic cells in order to obtain pluripotent stem cells.

The death of the last male northern white rhinoceros (*Ceratotherium simum cottoni*) in March 2018 is an example of this; the last two individuals of this species are two females. The San Diego Zoo has stored samples of its skin tissue in order to preserve its genetic material in the hope that technology will one day allow the transformation of skin tissue into sex cells (Link 5).

1.3 Reproduction in zoos of different species and reintroduction into the natural environment

Because some wild populations have insufficient populations, some zoos contribute to biodiversity conservation by reproducing them ex-situ so that later these individuals can be released and thus help to stabilize wild populations (Fa *et al*. 2011). Even though the capacity of many zoos is insufficient to maintain and breed large numbers of individuals, the collective actions of several zoos make this possible. The need for reproduction inside zoos is growing as the causes that affect biodiversity persist and the number of vulnerable animals is continuously increasing. According to the data presented in the work Zoos through the Lens of the IUCN Red List: A Global Metapopulation Approach to Support Conservation Breeding Programs, in 2013 zoos held a number of 3.955 species of terrestrial vertebrates of which 695 were endangered (Mammalia – 262; Aves – 195; Reptilia – 178; Amphibia – 56).

The breeding program of the species Leontopithecus rosalia

The Golden Lion Tamarin Conservation Program (GLTCP), which aimed to breed the species *Leontopithecus rosalia*, which is endemic to the forest near Rio de Janiro in Brazil, in captivity, is a great example of an ex-situ breeding program. Both the intensive exploitation of the forest for agricultural purposes and the expansion of the city led to an excessive destruction and fragmentation of the habitat. These actions resulted in a significant population reduction, thus creating the need for an ex-situ breeding program

(Kierulff *et al*., 2012). Thanks to this breeding program, which began in 1972, the population grew from 70 to 500 individuals in just 8 years. A large proportion of these 500 people were released to repopulate the area (Tribe & Booth, 2003). The participation of 30 zoos from North America and Europe, as well as very solid genetic and demographic management, contributed to the success of this breeding program.

Captive reproduction of Gymnogyps californianus

This captive breeding program was clear evidence of zoos' contribution to biodiversity conservation.

In 1982, there were only 22 individuals of *Gymnogyps californianus* worldwide due to a variety of factors such as a lack of food, conflicts with humans, and DDT poisoning (US Fish and Wildlife Service Pacific Southwest Region). This species was declared extinct in the wild in 1987, with the last individual captured.

Thanks to the involvement of several zoos such as the Los Angeles Zoo, San Diego Wild Animal Park, the Peregrine Fund in Boise (Idaho), the Oregon Zoo (Portland), and this species was saved. The breeding process was difficult, but the results were unexpected. *Gymnogyps californianus* was first reproduced in 1988, with a reproduction rate of 20 individuals per year for the next two years. The first individuals were released in 1992 but were later recaptured due to behavioral issues. Their reintroduction continued after 1995, and their population is now equal to that of 1950, with this species' reproduction considered a success that exceeded all expectations (Walters *et al*., 2008).

According to information published by the United States Department of the Interior, the total population in 2019 reached 518 individuals (337 - wild population; 181 - captive population).

1.4 Rehabilitation of injured / found specimens in zoos

As human-populated areas expand, there are an increasing number of cases of unintended interactions between humans and various wildlife species. Such interactions occur because the habitats of human and wildlife populations overlap, resulting in competition for food and space. Traps or toxic substances used by farmers to protect livestock or crops are an example of this; these methods do not have the ability to filter out which species is gone be affected. As a result, many species of protected animals require medical attention.

There are also instances where various species may require medical attention due to natural causes such as exhaustion, juveniles left without parents, animals that have fallen into rivers, and so forth.

As a result, many zoos are involved in such rehabilitation efforts, so that the animals can be released back into their natural habitat if the situation allows. In addition to rehabilitating injured people, the public can be educated on the devastation that human actions can cause to wildlife.

Hortobágy Bird Park

The Hortobágy Bird Park in Hortobágy, Hungary is the only hospital in the country that takes in animals with different ailments, with a particular focus on bird species. Each year, on average, 1,000 individuals enter this facility, and depending on their state of recovery, 35–40% of them are released into the wild (Link 6).

The one-way windows allow for public access to the hospital while simultaneously protecting the animals from the stress that visitors may inflict and preventing them from becoming used to people, which would jeopardize their eventual release. The majority of the bird species rescued by this park are protected species, including: *Haliaeetus albicilla*, *Aquila heliaca*, *Aquila chrysaetos*, *Gypaetus barbatus*, *Falco peregrinus*, *Pandion haliaetus*, *Falco biarmicus*, *Buteo buteo*, *Falco subbuteus*, *Sagittarius serpentarius*, *Bubo nipalens*, *Bubo lacteus*, *Bubo scandiacus*, *Grus grus*, *Ciconia ciconia*, *Aegolius funereus*, *Cygnus olor*, *Tachybaptus ruficollis*, *Corvus corax*, *Platalea leucorodia* and *Ixobrychus sturmii*. The following species, among others, were also rescued in addition to the ones already mentioned: *Corvus frugilegus*, *Phasianus colchicus*, *Anas platyrhynchos*, etc (Link 7).

Australia Zoo Queensland Hospital

The Australia Zoo in Queensland is also involved in such reconditioning and rehabilitation of sick or injured animals, thanks to the Australia Zoo Wildlife Hospital on the zoo's grounds.

Since the hospital's inception in 2004, between 6.000 and 8.000 individuals have been admitted each year, making it one of the busiest in the world. Since its inception, 98.732 individuals have been admitted. Traffic accidents involving animals and domestic animal attacks have been two of the most common reasons for admission.

Among the activities in which this zoo is involved are interventions on the ground, their transport to the hospital but also the recovery of individuals from situations with a high level of risk (Link 8).

Also, this hospital permanently has over 1.000 individuals of the species *Phascolarctos cinereus* (Link 9), which is currently considered vulnerable. Urbanization, the constant decrease of resources due to deforestation, the invasion of

non-native species, traffic accidents, and changes to the habitat as a result of extreme climatic conditions are among the causes that determine this species' constant need for medical care (Link 10). Furthermore, this species faces the devastating effects of infection with the bacterium *Chlamydia pecorum* which increases the mortality rate of the species and affects female fertility (Fabijan *et al.*, 2019).

1.5 Information and awareness of adults and children

Since the progress in biodiversity conservation is dependent on educating the public, any support in this regard is welcome.

Education of communities and people is essential to the effectiveness of conservation efforts and to their long-term success, as was demonstrated in the captive breeding of *Oryx leucoryx*. Because they may carry out the activity of educating the public in a variety of ways both within them and at the level of local communities, zoos thus represent institutions with enormous potential in this respect.

Immersive exhibitions

The so-called "immersion exhibitions" are a recent trend that several zoos have embraced. This kind of exhibition uses special effects like various sounds, such as those generated by insects, amphibians, birds, as well as the sounds produced by trees, wind, etc., to recreate the natural habitats of the species in question as accurately as possible.

An attempt is made to replicate as closely as possible the habitats of the exposed animals, while also concealing the animal-human barriers to give the public the impression that they are present in the species' natural habitat (Fa *et al*., 2011).

Such exhibits provide information to the public through a multitude of sensory pathways, turning the visit to the zoo into an experience that can be imprinted on visitors' minds for long periods of time.

Asian elephant exhibit at Zurich Zoo

The Zurich Zoo in Switzerland, for example, has created an immersive exhibit for the endangered species *Elephas maximus*. The goal of this exhibition was to provide the necessary conditions for the species' well-being as well as to educate the public (Link 11).

This species is housed in the Kaeng Krachan Elephant Park, which consists of an external area and an enclosure measuring 5.400 m^2, with the entire complex measuring 11.000 m^2. The enclosed space has a wooden roof made to look like a network of tree

branches, with 271 panes made of UV-permeable ethylene tetrafluoroethylene material (ETFE).

An attempt was made to imitate as detailed as possible both the external enclosure and the closed space with the natural habitat of the species, using numerous biotic and abiotic components. Among the abiotic components are rocks, sand, water course but also aspects that denote the presence of humans in their habitat such as ivory boxes, thus emphasizing the anthropogenic impact on the species.

The biotic components are represented by vegetation and animal species whose habitat overlaps with that of the Asian elephant such as*: Leucopsar rothschildi* (Critically Endangered - CR), *Antilope cervicapra* (Least Concern - LC), *Geoemyda spengleri* (Endangered - EN), *Heterometrus swammerdami, Rollulus rouloul* (Near Threatened - NT), *Tragulus javanicus* (Data Deficient - DD).

It is worth noting that this zoo breeds *Elephas maximus* in captivity not only to preserve genetic diversity but also as a reserve for the wild population.

Through all these mentioned aspects, visitors receive a multitude of information about the exhibited species, information related to its habitat, the species with which it coexists, but also aspects related to the impact of humans on the species (Link 11).

1.6 Classes and activities inside the zoos

ZSL London Zoo

Dedicated to people suffering from arachnophobia, the London Zoo (ZSL) in London, Great Britain offers a course called the "Friendly Spider Program". The purpose of the course is to educate the participants about the harmlessness of these invertebrates and obviously, to cure the arachnophobia.

This program includes an introductory course that explains how such phobias develop, followed by activities that provide detailed information about the fact that this type of phobia is an acquired phobia rather than an instinctual one, as well as general information about arachnids. This course also contains a hypnosis session, which aims to remove negative emotions associated with arachnids from the subconscious. The latter part of this course is voluntary only and includes direct contact by participants with various species of spiders' native to Great Britain and the handling of the species native to Mexico - *Brachypelma smithi* (Link 12).

The possibility of accommodation inside the zoological gardens

Some zoos provide public lodging within their grounds. The goal is to break down barriers between the public and the animals, with this type of activity serving an extremely personal and real educational role in addition to entertainment.

Nature Night Camping

ZSL Whipsnade Zoo in Bedfordshire, UK, is one of these zoos. Visitors are encouraged to camp overnight on the zoo's main lawn, allowing them to observe nocturnal species, particularly through the zoo's guided tours (Link 13).

La Flèche Zoo

Another example is La Flèche Zoo, which goes a step further by providing visitors with the option of staying in rooms separated from the animal shelter by a window. The rooms are specially designed to reflect the region where the species in question populates. Furthermore, the species involved in this type of activity include endangered species such as the African lion (*Panthera leo*), Sumatran tiger (*Panthera tigris sumatrae*), white tiger (*Panthera tigris tigris*), cheetah (*Acinonyx jubatus*), arctic wolf (*Canis lupus arctos*), polar bear (*Ursus maritimus*), grizzly bear (*Ursus arctos horribilis*) and the lemur (*Lemur catta*) (Link 14).

Information and awareness of local communities through activities carried out under the coordination of zoos

Conservation Credit Program

The Conservation Credit Program was launched in 2012 by Omaha's Henry Doorly Zoo and the Aquarium's Madagascar Biodiversity Partnership. This program used a variety of objects to encourage the local community to plant trees that are critical to the lemur's habitat. This program attempted to reduce the pressure placed on the forests by locals.

Following the zoo's collaboration with the University of Nebraska, identification cards were created, and locals were rewarded with credits based on the number of trees planted. In exchange for the credits accumulated on the cards, the locals received various items such as high-efficiency stoves, solar panels, Hippo water rollers, commercially valuable trees, etc. The cards have made it easier and more efficient to track the number, location, and species of trees planted.

This project represents an exceptional example through which biodiversity conservation takes place, specifically the lemur species that were in focus, but also the education and support of the local community (Link 15).

1.7 Research

Because observing many aspects of animal biology in the wild is difficult, many zoos have entered into partnerships with various universities so that the data accumulated here complements that taken in-situ. Employees, students, volunteers, and specialists can collect observations on topics such as animal behavior, diet, animal care, contraception, disease, management, reproduction, aging, and animal welfare.

Research conducted at Burgers Zoo

Burgers Zoo together with Utrecht University have carried out numerous research, the best known being those in the Arnhem Zoo department, which involved the chimpanzee colony (*Pan troglodytes*).

These studies began in 1989 and lasted until 2007. A variety of behavioral aspects were studied, including aggression, reciprocity, and social relationships, social behavior in groups of *Pan troglodytes*, related individuals versus unrelated individuals, and the methods by which individuals resolve conflicts within the group (Link 16).

ZooMonitor created by the Lincoln Park Zoo in Chicago

Free software named ZooMonitor was developed to keep track on the activities of the animals at the Lincoln Park Zoo in Chicago, Illinois, USA. The purpose of this software is to collect a large quantity of information that can later be used both to improve the welfare and health of animals as well as to improve conservation efforts by retrieving data on the reproductive behavior of species (Link 17).

An example of this is the use of the ZooMonitor software to collect information on environmental factors that can particularly influence the reproductive behavior of the shark species *Carcharias taurus* (Vulnerable - VU).

This species is currently listed as vulnerable on the IUCN Red List due to factors such as overfishing (in countries where fishing for this species is permitted), illegal fishing (in countries where fishing for this species is prohibited), and bycatch.

This species' current population on the Australian coast is estimated to be less than 500 individuals, and it is also declining in the United States (Link 18). In addition to anthropogenic factors, there are specifics about the species' slow reproduction, such as late sexual maturity (approximately 6-8 years), reproduction every two years, but also

specific aspects about the habitat, such as the existence of a numerically reduced population (Otwaya *et al*., 2004).

For these reasons, the software is currently used in zoos in the United States such as the Georgia Aquarium, National Aquarium, North Carolina Aquariums, and Ripley's Aquariums to better understand the behavior of this species in order to implement as appropriate ex-situ protection measures as possible, as well as to better manage current populations within zoos (Link 17).

1.8 Financial aspects as contribution to the conservation of in-situ projects

The conservation actions and strategies mentioned in the previous chapters require significant financial support. As mentioned at the beginning of this paper, zoos are required by law to participate in various conservation programs. Despite the broad interpretation of the European Commission Directive 1999/22/EC of 29 March 1999, many zoos choose to use financial contributions.

Parc Animalier des Pyrénées

The Zoo Animalier des Pyrénées provides visitors with the option to donate to either the zoo's animals or those of another zoo, making the act a unique experience in which the donor selects the recipient of the money (Link 19).

This zoo contributes financially to many other projects, such as those carried out by:

- University of La Rochelle, Marine Mammal Monitoring Center;
- Arche de la Nature - Le Mans Métropole: raising awareness about the conservation of reptiles and monitoring their populations;
- Red Panda Network - Know and Protect the Red Panda (Nepal): ranger training program on research and protection of the *Ailurus fulgens* species;
- Huro (Indonesia) which aims to protect *Hoolock hooloc* primate species;
- Anoulak involved in the protection of endangered species in the Lao People's Democratic Republic;
- Pour que vive Maroala: responsible for supporting the animal population of Madagascar;
- Lola Ya Bonobo (Democratic Republic of Congo), organization responsible for taking in orphaned bonobo individuals (*Pan paniscus*) and reintroducing them into the natural habitat (Link 20).

Another zoo involved in a multitude of projects is the Naples Zoo, Florida (USA), which is among the top zoos in terms of financial support for conservation programs.

They have provided $2.1 million in financial support to various conservation programs from 2014 to date in projects in various regions of Uganda, Tanzania, Madagascar and Brazil (Link 21).

Zoos whose existence negatively affects the conservation of biodiversity

While there are many positive examples of zoos contributing to biodiversity conservation, there are also many examples of the opposite.

The main reasons for this include poor living conditions, misleading the public about various aspects of animal biology, and influencing the public to associate zoos with institutions that abuse wildlife.

Unsuitable conditions for keeping wild animals in captivity

A simple Google search can reveal many images that succinctly exemplify this aspect characterized by extremely small spaces in which wild animals are housed, but generally characterized by conditions of captivity incompatible with the welfare of the species concerned.

Unfortunately, such images are difficult to identify from direct sources such as official zoo websites, as these aspects are not good marketing for the zoos in question. Despite this, examples of how these institutions undermine zoos' role in biodiversity conservation will be presented.

An example of this is the Safari Park Zoo in Fier, Albania, where the animals are kept in extremely confined spaces with extremely poor hygiene, a lack of access to water, and signs of disease (Link 22).

Misinforming the public about aspects of the biology of the species in question

Since the beginning of their existence, the main roles played by zoos has been to educate visitors about many aspects of the captive species. Currently, educating and informing the public is done through information boards, the exhibition itself that provides information about the general needs of the species, habitat, cohabiting species, etc. Unfortunately, this is not true in many zoos, the very limited space, metal barriers and concrete floors giving visitors wrong information about the natural habitat of the species.

The Himeji City Zoo in Japan falls as well into this category. As seen in figure 1, the species is housed in a room with a concrete floor and metal bars, with no information about the species' natural habitat. In contrast, the zoo in Aalborg, Denmark (figure 1) provides visitors with a wealth of information about the species' habitat and cohabiting

species. These exhibits not only provide a wealth of information, but they also have a greater positive impact on visitors aside from the obvious aspect of conditions consistent with the welfare of the species.

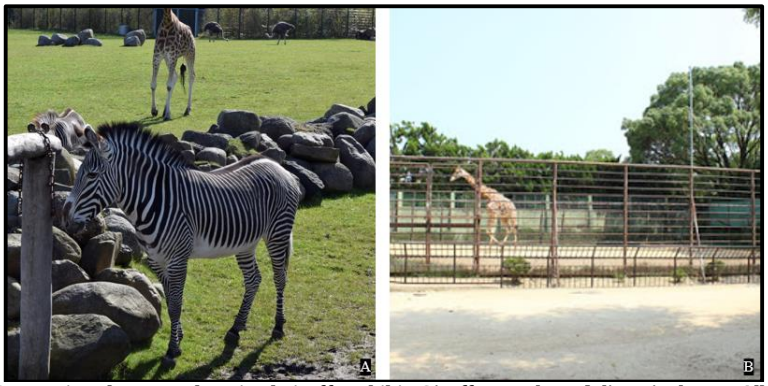

FIG. 1. Comparison between the mixed giraffe exhibit *Giraffa camelopardalis reticulata* at Alborg Zoo in Alborg, Denmark (photo: Mănduță, 2017) and the giraffe exhibit at Himeji City Zoo in Himeji, Japan (after Link 23).

In this category is also the fact that many zoos continue to use the standard and generalized method of keeping animals in captivity regardless of species or level of aggression, transmitting incorrect information about the species' aggressiveness and danger to humans. The Himeji City Zoo has adopted this standardized method, in which species that are harmless to humans, such as the domestic duck *Anas platyrhynchos domesticus* and the sheep *Ovis aries* (figure 2), are confined in spaces with metal barriers so that the public cannot distinguish between wild and domestic species (Link 23).

Also in the same zoo, species such as the lemur *Lemur catta* (EN) are also captive in cages with metal bars, even though in many other zoos this species is free (figure 3), and visitors have the opportunity to offer food to them (food provided by the zoo in question). This type of education and information is all the more welcome considering the fact that the lemur is a species on the IUCN Red List with the status of a species in danger of extinction.

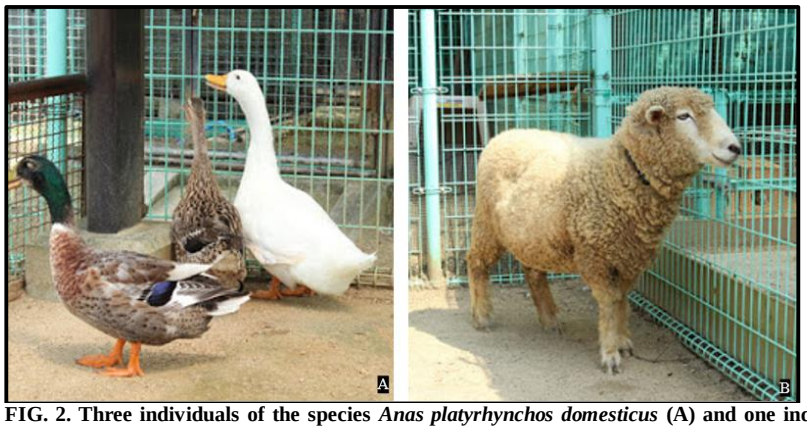

FIG. 2. Three individuals of the species *Anas platyrhynchos domesticus* (A) and one individual of the species *Ovis aries* (B) from the Himeji City Zoo in Japan (after Link 23).

FIG. 3. Comparison between the lemur exhibit at the La Vallee des Singes zoo, France (photo: Petrovici, 2022) and the exhibit at the Himeji City Zoo in Japan (after Link 23).

Another negative example is the zoo in Craiova, Romania, which has an electric fence surrounding individuals of the species *Ciconia ciconia*. In addition to misrepresenting the species' aggressiveness, this can result in unfounded public fear of the species in question. All of this can have a negative impact on future conservation efforts for the respective species.

Negative effects on public perception of zoos

Because of the aforementioned factors, many people associate zoos with something negative, leading to widespread criticism of all zoos, regardless of the conservation efforts in which they are involved, and a reluctance to participate in any type of activity carried out by them. Furthermore, most organizations that oppose these institutions only bring up negative examples, completely ignoring the role that zoos have played and continue to play in biodiversity conservation.

These negative associations of zoos with metal fences, concrete cages, and prisons can lead to the ineffectiveness of awareness and education actions. Furthermore, these factors can lead to a reduction in income, making actions focusing on the rehabilitation and reproduction of individuals both ex-situ and in-situ more difficult, with the financial contribution of zoos being critical for many projects.

CONCLUSIONS

According to various studies, the expansion of human populations from the African continent was followed by the extinction of many species, with species with a low reproductive rate predominating. The greatest impact was seen following the industrial revolution, which resulted in a massive increase in the rate of extinction.

For these and other reasons, there is a need for actions aimed at protecting and conserving biodiversity; any type of assistance can make a significant difference in the survival of the species in question, including zoos, which have played and continue to play an important role through the activities in which they participate, both in-situ and ex-situ.

The role of genetic reserves that zoos play is paramount, particularly for species that are already extinct in the wild, but also for vulnerable species whose populations are no longer considered viable.

Animals in zoos, in addition to being protected from external factors causing extinction, also play a major role in educating the population, a very important aspect in biodiversity conservation without which many projects would not be successful in the long term such as: Conservation Credit Program, Education and Technology Transfer, Education Promoting Reforestation Program (EPRP), Zoo's BUGS!, and the *Oryx leucoryx* breeding project.

Moreover, all projects need funding, especially those in developing countries. For this reason, the role of zoos is major because many choose to finance in-situ and ex-situ activities with the accumulated profit.

It is also important to remember an activity in which some zoos are involved, and which saves thousands of individuals annually, namely hospitals inside zoos. This enables zoos to provide medical care to injured specimens from outside the zoo for renaturalization and subsequent release of individuals.

Last but not least, they contribute significantly to research. Information gathered within zoos can be used to improve breeding programs within zoos or to develop in-situ conservation actions.

Despite the fact that there are still negative examples of zoo activities, they have an extraordinary potential in the fight for biodiversity conservation loss due to the wide range of methods that can be used both in-situ and ex-situ.

In light of the current extinction rate, as well as the future challenges posed by the effects of global warming, habitat degradation, and habitat segmentation, any kind of assistance is welcome in order to preserve biological diversity, and zoos should be viewed as a solution rather than a problem. We might not require them in the future, but for the time being they are vital.

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