

Review

The Role of Zoos and Aquariums in Contributing to the Kunming–Montreal Global Biodiversity Framework

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Abstract: It is now well established that human-induced species extinctions and habitat degradation are currently occurring at unprecedented rates. To halt and reverse this decline, the international community adopted the Kunming–Montreal Global Biodiversity Framework (GBF), as part of the Kunming–Montreal Biodiversity Package, in December 2022. We clarify what this new framework means for conservation zoos and aquariums in their mission to prevent species extinction by highlighting areas of focus. We explain why it is necessary that conservation zoos and aquariums establish the appropriate mechanisms for contributing towards such a framework to help validate their role in the 21st Century. Conservation zoos and aquariums should be reassured that much of their work already fits within the GBF. However, the current mechanisms for individual zoos and aquariums to directly contribute to the implementation of the GBF mostly rely on close collaboration with individual national governments and/or are only possible at a national level. It is therefore critical that national, regional, and global zoo membership organisations take a leading role in championing the work of their members. Equally, adequately linking the efforts of zoos and aquariums to the national implementation of international instruments, such as the GBF, is imperative to ensure that these organizations' contributions feed into the understanding we have of global progress towards the implementation of international instruments.

Keywords: zoo; aquarium; role; sustainable development goals; Aichi targets; policy; Kunming–Montreal Global Biodiversity Framework



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1. Introduction

In December 2022, after much delay due to the COVID pandemic, the Kunming–Montreal Global Biodiversity Framework (GBF) was adopted by the international community at the 15th Conference of the Parties (COP) in Montreal, Quebec [1] as part of a package of decisions, known as the Kunming–Montreal Biodiversity Package. In brief, this framework sets out the roadmap for how the nations of the world will attempt to halt and then reverse biodiversity loss through 2030. The 2030 deadline has been set as it coincides with the 2030 Agenda for Sustainable Development which includes the Sustainable Development Goals (SDG) [2]. The GBF builds on the 2011–2020 Strategic Plan for Biodiversity and its Aichi targets [3].

Perhaps unsurprisingly, a global framework such as this is comprehensive, complex, the result of compromise, and, unfortunately for many, indecipherable. This may well be the case for the world's conservation zoos and aquariums (from here on referred to as 'zoos'). For example, during the period covered by the 2011–2020 Strategic Plan for Biodiversity, we are aware of only one zoo-led project that was included in the official reporting of its implementation. This was a project that measured the biodiversity understanding (or literacy) in world zoos and was led by the World Association of Zoos and Aquariums (WAZA), Chester Zoo, Chester, UK, and the University of Warwick, Coventry, UK [4]. The project was conceived as way of measuring the educational impact of visiting zoos but was also directly relevant to the Aichi Target 1 which stated that "by 2020, at the latest, people

are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably” [5]. The project methods were included as an agreed indicator for Aichi Target 1, as part of the Biodiversity Indicators Partnership [6].

Another study in 2017, led by academic institutions, investigated the contribution of zoos to Aichi Target 12 [7], that “by 2020, the extinction of known threatened species has been prevented and their conservation status (. . .) improved or sustained” [5]. The study indicated that zoos effectively contributed to Target 12 through providing “space and expertise” for conservation actions such as captive breeding, reintroductions, and head-starting [7]. However, unlike Moss et al. (2015) [4], it did not consider the global contribution of zoos and only examined a case study of four, well established and accredited (CAZA and AZA) Canadian zoos. Several other zoo-led studies mention the Aichi Targets (for example, [8–10]), suggesting a general awareness of them. However, targets are not explicitly used to frame activities or research outputs, meaning that evidencing zoo contributions against these global goals is presently a challenge.

In a world where zoos have increasingly improved their standing as biodiversity conservation organisations [11], this fairly minor involvement by zoos to the 2011–2020 Strategic Plan seems amiss. At a very basic level, this suggests one of two things. Either world zoos are not as significant to global biodiversity conservation as they themselves portray (or lack the evidence to support their assertions), or they are not adequately linked to the national implementation of, and reporting on, global frameworks and/or strategies. We would strongly argue it is the latter, and we seek to address this in this paper. This will be done firstly by describing the new GBF in general, top-level terms, and secondly by outlining the specific targets within the GBF that world zoos are well-placed to contribute towards. Finally, we discuss the process in which world zoos might get their work recognised as part of the GBF. We note that this recognition is not simple and will require support from national and international zoo member bodies to collate evidence at a national level and ensure these are fed into measurements of global progress.

2. The Global Biodiversity Framework, 2020–2030

The final, adopted GBF [1] is structured into four main levels or tiers. These are, from broadest to most specific, the Vision, the Mission, the Goals, and finally, the specific Targets (Figure 1.)

The 2050 Vision and 2030 Mission of the GBF set out the broad objective of valuing and conserving biodiversity (Figure 1). Whilst the Vision and Mission are undoubtedly critical to the GBF, they are of limited use in terms of practical application as they are, by definition, aspirational. The four GBF Goals, however, provide a scaffold by which actions can be framed. These goals are paraphrased in Table 1 (for the exact wording refer to [1]). Of these four Goals, it is Goal A that is most relevant to zoos as it focuses on the prevention of extinction, which is the primary objective of conservation zoos.

Table 1. A summary of the four GBF 2050 Goals. Note that Goal A is the primary objective for zoos.

GBF Goal	Summarised Content
Goal A:	covers the fundamental essence of biodiversity conservation. Namely, the prevention of extinction, the reduction of threats to ecosystems and species, with the longer-term reversal of these negative trends. Specifically relevant to zoos is the reference to the maintenance of genetic diversity within populations of species.
Goal B:	covers the ongoing sustainable use of biodiversity. Here, we see specific reference to people and the benefits that biodiversity might confer onto them. (We note that zoos and aquariums “use” animals for a variety of purposes. It is important that this “use” of animals is sustainable, including where animals, plants, and biological materials are sourced.).
Goal C:	covers the benefits, both monetary and non-monetary, of the utilisation of genetic resources, and how this should be shared equitably among local communities and indigenous peoples.
Goal D:	covers the broad approach for enabling the overall implementation of the GBF, including the financial, technical, and scientific resources that might be required.

From the GBF Goals, we move to the GBF Targets (Figure 1). These Targets are action-orientated and have a definitive end date in terms of achievement (2030), as such, they specify the work needed to help achieve the GBF. In total, there are 23 targets, ranging across the four goals [11].

Notably, these global targets are set to be translated by CBD Parties to national circumstances as the implementation of the CBD occurs at the national level. Consequently, CBD Parties will be developing and updating their national targets that reflect their contribution towards GBF Targets, and it is these national targets that zoos and aquariums are able to contribute towards achieving.

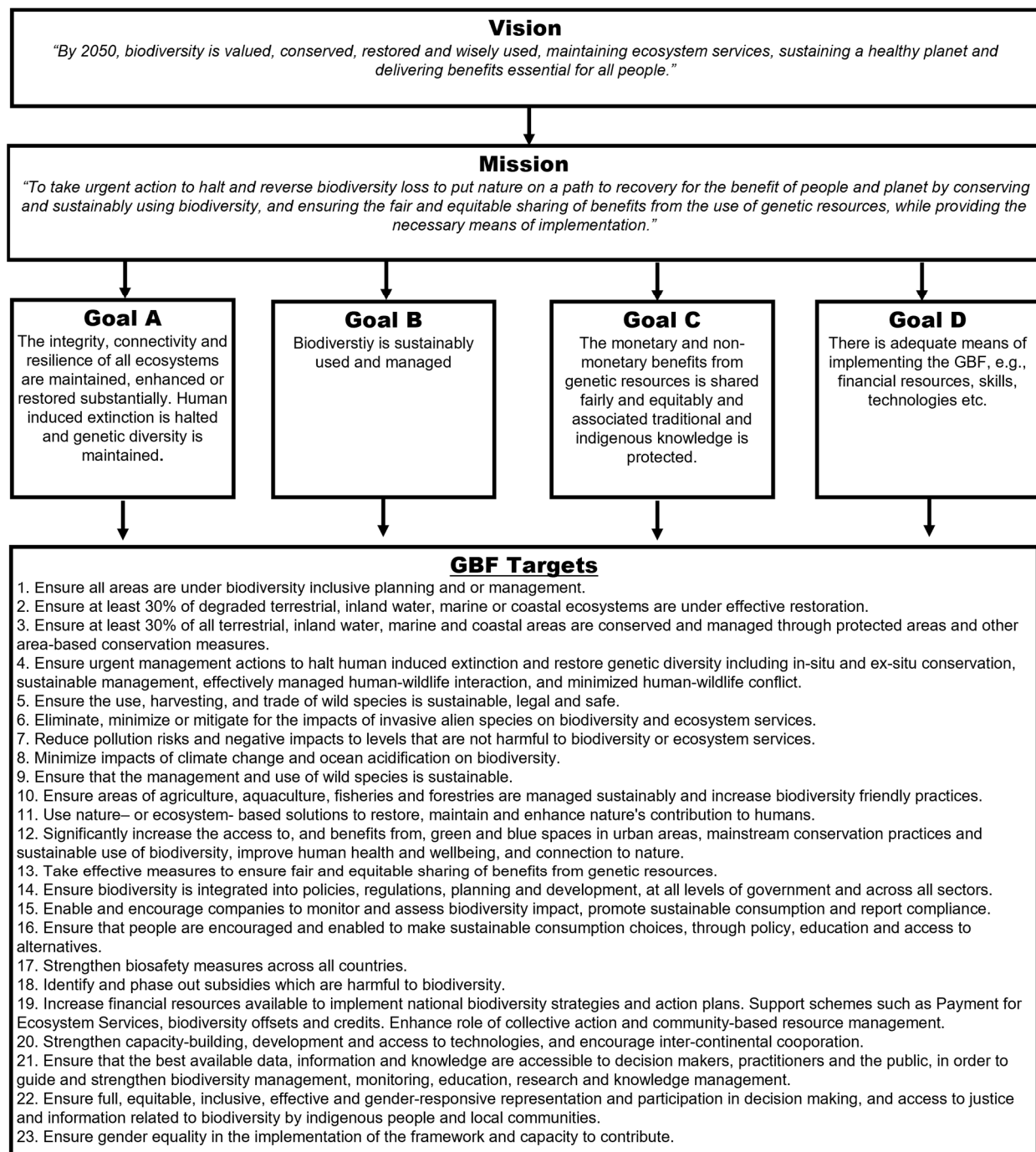


Figure 1. Summarised version of the Global Biodiversity Framework (figure created by authors based on content from the GBF), for the exact wording refer to [1].

3. Targets of the Kunming–Montreal Global Biodiversity Framework

The GBF is intended to be viewed holistically and, as such, zoos should aim at addressing all areas. There are undoubtedly some targets that are more relevant for zoos to contribute towards compared to others.

The targets that we feel reflect the current roles of most conservation zoos are Target 3 (with potential for Target 2), Target 4, Target 12, and Target 16 (outlined below as ‘core achievable GBF targets for zoos’). We have selected these targets as there is already a body of evidence to demonstrate zoos’ roles in these areas. As such, collating and extending the evidence for these areas should be an achievable goal.

We acknowledge that many zoos have the capability to achieve, and are already addressing, GBF targets in other areas [11]. We demonstrate a selection of these other targets in the section ‘GBF Targets with potential contribution from zoos’. Here, we outline examples of how zoos can address these targets. We acknowledge that this is not a comprehensive list and individual zoos may already be meeting targets in other areas. Ultimately, zoos collectively should address or support targets from across the whole GBF.

3.1. Core Achievable GBF Targets for Zoos

The following targets are areas where zoos can easily demonstrate their achievements. Whilst some zoos are already able to evidence fulfilling parts of the GBF, we stress that there is always room for improvement.

Target 3

“Ensure and enable that by 2030 at least 30% of terrestrial, inland water, and of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures, recognizing indigenous and traditional territories, where applicable, and integrated into wider landscapes, seascapes and the ocean, while ensuring that any sustainable use, where appropriate in such areas, is fully consistent with conservation outcomes, recognizing and respecting the rights of indigenous peoples and local communities, including over their traditional territories” [1]

Target 3 has a very clear objective; namely, to protect 30% of all habitats, both terrestrial and aquatic, by 2030. It is worth noting that the effectiveness and quality of this protection is a key part of this target. Through their numerous field projects, zoos are well-placed to contribute to this target. The GBF suggests that successful fulfilment of Target 3 will be indicated by greater coverage of protected areas and areas managed sustainably to the benefit of biodiversity [1].

Many zoos already have their own protected areas for native species [12–14] and encourage native wildlife on their grounds [15,16]. For example, the Toledo Zoo and Aquarium, USA, assists in the management and creation of protected areas as part of their Plants and Prairies initiative [17]. This project has converted areas of low biodiversity into urban prairies. This is a crucial part of their conservation strategy and species bred or raised in the zoo such as the Karner blue (*Lycæides melissa samuelis*), Mitchell’s satyr (*Neonympha mitchellii*), and Monarch (*Danaus plexippus plexippus*) butterflies utilise these protected areas as reintroduction release sites [18]. Another example is the Swift Parrot Programme at Zoos Victoria, Australia, where the zoos, in partnership with other organisations, aid habitat management to reduce predation of invasive species and to encourage parrot nest sites [19].

Habitat management and engagement with local communities for the benefit of improving biodiversity is a core aspect of the integrated species conservation ‘One Plan’ approach, which was initiated and developed by the IUCN Conservation Planning Specialist Group (CPSG) [20] and adopted as a conservation strategy by WAZA and other zoo organisations [21,22]. Zoos play an important role working with local and state governments to initiate conservation policy, such as introducing no deforestation standards [23,24] and designating protected areas [25]. Zoos also contribute through financial and in-kind

resources. For example, Flamingo Land, Malton, UK, in partnership with other NGOs, provided legal resources to officially protect the Magombera forest in Tanzania [25]. Therefore, Target 3 is an area that zoos are already working towards.

Target 3 goes hand in hand with Target 2 of the GBF which stresses that “at least 30% of degraded terrestrial, inland water, and coastal, and marine ecosystems are under effective restoration” [1]. If zoos restore degraded habitats as part of their habitat management and protection of ecosystems, they are additionally addressing Target 2.

Target 4

“Ensure urgent management actions to halt human induced extinction of known threatened species and for the recovery and conservation of species, in particular threatened species, to significantly reduce extinction risk, as well as to maintain and restore the genetic diversity within and between populations of native, wild and domesticated species to maintain their adaptive potential, including through in situ and ex situ conservation and sustainable management practices, and effectively manage human-wildlife interactions to minimize human-wildlife conflict for coexistence” [1]

Target 4 is groundbreaking for zoos as the words ‘ex situ conservation’ appear in the headline targets of a major biodiversity strategy. We note that although Articles 8 and 9 of the Convention on Biological Diversity previously mentioned in situ (protecting species within their natural habitats) and ex situ (protecting species away from their natural habitat, e.g., through captive breeding programmes) conservation [26], it was not explicitly stated as a global target. Ex situ conservation is probably the most widely acknowledged contribution that zoos make in relation to biodiversity conservation. The management of zoo-kept populations of species has been the central theme for zoo-based conservation for decades.

Ex situ conservation efforts have a key role in halting biodiversity loss and ending extinction. At least 17 species would have gone extinct without the captive breeding programmes of zoos [27]. Captive breeding efforts have ensured the survival of species such as the California condor (*Gymnogyps californianus*) [28], Przewalski’s horse (*Equus ferus przewalskii*) [29–33], and golden lion tamarin (*Leontopithecus rosalia*) [34]. More recent success includes species of Bermuda snails (*Poecilozonites* spp.), thought to be extinct except for a single isolated population, which were bred in vast numbers within the zoo community and re-released, ensuring a thriving wild population [35,36].

According to assessments in 2013, 15% of the world’s most threatened vertebrate species are housed in zoos [37], including around 7% of all extant amphibian species [38,39]. Association of Zoos and Aquariums (AZA) member zoos alone house around 900 species classified as IUCN Vulnerable to Extinct in the Wild [33], and amongst the four Canadian zoos examined by Olive et al. (2017) [7], each participated in between 8–50 breeding programmes. Additionally, there are currently more than 130 active international studbooks [40] and (as of 2018) nine working Global Species Management Plans [41].

To successfully monitor progress towards achieving Target 4, the Conference of Parties adopted the following indicators: Firstly, using the Red List Index to demonstrate whether a species’ conservation threat status has been reduced, and secondly, by the number (proportion) of populations which are considered sustainable (i.e., have an effective population > 500) [1]. We note the use of the term ‘effective population’, meaning that it is not simply a case of having 500 individuals, but they should be genetically distinct enough, and of appropriate age, and gender balance to ensure a sustainable future population. This is an area where zoos can excel as they likely house genetically valuable individuals. Through the One Plan approach of integrated species conservation [21], all populations of a species, both in situ and ex situ, are considered in the overall conservation plan. This ensures that zoo populations are included in global strategies for population management. The critically endangered mountain bongo (*Tragelaphus eurycerus isaaci*) is one such species which has benefited from this management strategy, as captive bred Bongo have been translocated from the USA to Mount Kenya Forest Reserve as part of coordinated efforts between multiple international organisations considering the species population as a whole [42].

There is now a strong emphasis on managing zoo populations sustainably. Zoos broadly aim for 90% genetic diversity amongst their populations for 100 years [43]. Population sustainability features in the WAZA strategy [21,22] and the AZA have made this a core objective of their population management planning [44]. The genetic composition of many of the zoo populations is still unknown. This is due to historic animal collection practices where animals were selected based on availability rather than for their genetic viability. Understanding genetic diversity amongst zoo populations is now a key priority and much work has already been done to rectify and understand existing populations [45,46]. The European studbook has even gone so far as to stop breeding recommendations for some species until genetic evaluations have been completed [47]. Despite this, there is still a way to go before all breeding programmes meet sustainability criteria.

A more recent development is the use of cryobanking and seedbanks, which enable the genetic material of species to be maintained in a living state even if the animals/ plants themselves are deceased [48,49]. There is still a need to embed biobanking practices into conservation planning, and to determine areas of priority as to which items and species are stored. While biobanking is still not the norm, it is an area of conservation which is gaining traction. Biobanking and cryopreservation advisory groups have now been created by both EAZA [50] and IUCN [51]. The black-footed ferret (*Mustela nigripes*) is one such species where preserved genetic material and cloning has been used to regenerate a species [52]. Another example is the Przewalski's horse (*Equus przewalskii*), where cryopreserved cells have been used to increase the genetic diversity of the species and address the genetic bottle neck caused by having a small founder population [31]. In addition, technologies used to preserve the now functionally extinct Northern white rhino (*Ceratotherium simum cottoni*), have furthered knowledge in the field, to the benefit of other species. Cryopreservation is an area that is very much developing and will be crucial for the future sustainability of at-risk species.

Evidencing Target 4 should be achievable for global zoos as there are extensive international records (Species 360), studbooks, regional and international studbooks, and Regional and Global Management Plans [41,46,53]. Additionally, as the One Plan approach considers all populations including wild individuals or private holdings [54], there should be an understanding of the status of each managed population. Whilst we acknowledge that there may be challenges such as cultural and language barriers, the foundations are there, and it is now a case of collating this data at scale.

Another aspect of zoo conservation and management is zoos involvement in the IUCN Species Survival Commission Specialist Groups (IUCN SSC). Zoo staff contribute as volunteer experts and coordinators to help develop policies, guidelines, and standards [55]. Knowledge and skills developed through ex situ animal management and zoo field programmes enable zoo experts to guide conservation strategies, such as supporting the reintroduction of species. One such example of zoo involvement with the IUCN SSC is the Reverse the Red initiative where zoos are working collectively with other organisations to target species survival [56,57].

GBF Target 4 also stresses the need to minimise human–wildlife conflict. This is an area that zoos extensively target through field programmes and global partnerships [58]. Examples where zoos have been involved in reducing such conflict include Sumatran tiger (*Panthera tigris sumatrae*) in Indonesia [59], and Asian elephant (*Elephas maximus*) in Assam, India [60]. For many species, human–wildlife conflict is the core threat to their survival. Wild animals may be viewed as a threat to livestock or to the community, and in some cases, superstitions mean species are deliberately targeted and killed. For conservation to be successful, the concerns of the local community, such as threats to livelihoods or personal safety, need to be addressed.

Zoos fund and administer a wide range of initiatives to address human–wildlife conflicts, these include stakeholder consultations, education campaigns, training initiatives, and livelihood-focused interventions. An example of this is in Brazil, where protected wildlife such as tapir and giant anteater are regularly killed in road collisions or are attacked

by domestic dogs. Charities such as Instituto de Conservacao de Animais Silvestres [61] are supported through zoo funding and expertise to develop stakeholder consultations, create new road signage and warning systems to reduce collisions, and educate communities about the threats domestic dogs pose to wildlife. Other zoo campaigns have addressed similar issues, such as campaigns to keep domestic cats indoors overnight to reduce the threats to nesting native bird species [62].

Target 12

“Significantly increase the area and quality and connectivity of, access to, and benefits from green and blue spaces in urban and densely populated areas sustainably, by mainstreaming the conservation and sustainable use of biodiversity, and ensure biodiversity-inclusive urban planning, enhancing native biodiversity, ecological connectivity and integrity, and improving human health and well-being and connection to nature and contributing to inclusive and sustainable urbanization and the provision of ecosystem functions and services” [1]

Target 12 might not seem, on the surface, to be highly related to zoos, but we would strongly argue the opposite. This target has two main areas which, while not well-evidenced currently, are synonymous to the *raison d’être* of world zoos. The first is regarding green and blue spaces in urban areas. Simply put, zoos are green and blue spaces that are found almost exclusively in more densely populated areas. This is also a global phenomenon, not restricted to one country or region, and so, as a broad approximation, it is fair to say that zoos can be easily accessed by urban dwellers the world over. In addition to themselves being blue–green spaces, zoos are also involved in community rewilding projects, such as Chester Zoos’ Nature Recovery Corridor [14], where the zoo works with other organisations to develop natural spaces in the wider community or through nature reserves or habitat restoration.

The second area relates to the benefits that people might gain from accessing urban green and blue spaces, such as improvements in human health and wellbeing, as well as connecting people to nature. There is a clear reason why Target 12 is included in the GBF. Namely, that there is a large body of evidence about the positive personal benefits of exposure to green and blue spaces. In a recent systematic review, Lackey et al. (2019) found that 90% (n = 46) of the studies reviewed demonstrated at least one positive association between nature-based recreation and components of mental health, such as improvements in cognition and wellbeing or decreases in symptoms of anxiety and depression [63]. Barton and Pretty (2010), in a large UK study, found significant improvements to self-reported mood and self-esteem linked to short exposures to nature-related exercise [64]. In a study that directly measured participant cortisol levels, Olafsdottir et al. (2018) found walking in nature reduced cortisol levels more than other experimental conditions, such as walking on a treadmill or watching nature documentaries on TV [65]. In a similar study, Hoffman et al. (2018) found that time spent in nature and physical activity were related to decreases in cortisol, whereas time spent being idle led to an increase in cortisol [66]. The recent COVID pandemic has further emphasized the importance of access to nature on mental health [67].

However, when it comes to studies that have looked specifically at the benefits of visiting zoos, the literature is sparser. For example, Cracknell et al. (2015) found that visitors to a UK aquarium displayed a lower heart rate and higher self-reported change in mood when exposed to fully stocked aquaria, compared to aquaria with lower or no stocking [68]. A study by Coolman et al. (2020) established a link between visiting an immersive zoo exhibit and reduced markers of stress (lowered blood pressure and salivary cortisol) [69]. Additionally, trial mental health programmes in zoos have shown early successes [70,71]. In summary, zoos can aid the fulfilment of Target 12 by creating more physical urban blue–green spaces (such as nature areas and corridors) and improving the connection to nature of the people that visit them. Crucially, more evidence is needed to demonstrate positive benefits of these spaces to people.

Target 16

“Ensure that people are encouraged and enabled to make sustainable consumption choices including by establishing supportive policy, legislative or regulatory frameworks, improving education and access to relevant and accurate information and alternatives, and by 2030, reduce the global footprint of consumption in an equitable manner, including through halving global food waste, significantly reducing overconsumption and substantially reducing waste generation, in order for all people to live well in harmony with Mother Earth” [1]

Target 16 covers the subject of human behaviour and behaviour change. This is an area that has become central to world zoos in the recent past. Indeed, in the most recent World Zoo and Aquarium Conservation Strategy [22], human behaviour change is seen as one of the key contributions zoos can make to conservation, boldly claiming that “Zoos and aquariums are trusted voices for conservation, and are able to engage and empower visitors, communities and staff measurably to save wildlife” (Page 44). In addition, their global spread and ability to attract around 700 million visits a year [72] make zoos ideal locations to deliver educational interventions specific to Target 16.

Because human behaviour is central to biodiversity loss, the environmental and conservation movements have placed great emphasis on interventions that seek to influence individual behaviour change [73]. Typical behaviours of focus are a reduction in domestic energy and water use, an increase in more ethical and sustainable purchasing patterns, increases in reusing and recycling of all types of materials and products, the adoption of more sustainable forms of travel, as well as more direct calls for donations.

For zoos, education programmes form the basis of many behaviour change interventions, including those that seek to promote pro-conservation behaviours [74]. At first glance, this may seem problematic; namely, that knowledge alone is a poor predictor of behaviour [75,76]. However, more progressive conservation education interventions seek to influence a much wider suite of outcomes than just knowledge, such as conservation-related attitudes [77,78], increased time spent in nature [79], an improved sense of connection to nature/wildlife [80–83], increases in participant health and wellbeing [84], as well as, of course, pro-conservation behaviour change [84–87]. Indeed, for zoos, the World Zoo and Aquarium Conservation Education Strategy [88] already recommends this diversity of outcomes, suggesting a transformational learning approach that “can support new ways for audiences to consciously make meaning of their lives in relation to sustainable futures for species, ecosystems, and humanity” [88] (p. 47). Consequently, conservation education interventions have moved away from solely ‘chalk and talk’ pedagogies to embrace more diverse methods of delivery, such as using digital technology [89], the performing arts [10], longer-term engagement with participants [90], post-intervention tools and resources [91], as well as combining interventions with direct nature and wildlife experiences [87,92–96].

Target 16 is, therefore, a target that many zoos already direct their efforts towards, and while the published evidence for zoos contributing positively to pro-conservation human behaviour change is growing, it is not comprehensive. A focus on producing more supporting evidence will still be needed for zoos to demonstrate their contribution to this target. Once headline indicators are adopted for Target 16, we strongly recommend that zoos direct their resources towards evidencing them.

3.2. GBF Targets with Potential Contribution from Zoos

As previously mentioned, the GBF is designed to be approached holistically with all targets addressed. In addition to the above ‘core’ targets for zoos, there are many other areas which zoos can potentially address. We outline some of these below:

Sustainability Targets 5, 7, 9, 10, and 19

Sustainability is now a key issue for most medium–large-scale businesses. Whilst zoos are themselves businesses with a responsibility for sustainability, as conservation organisations, they are at the forefront of modelling sustainable practices.

Target 5 ensures *'the use, harvesting and trade of wild species is sustainable, safe and legal'* [1]. Zoos play a key role in supporting the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) [97]. Zoos represent 0.06% of CITES live animal transactions globally [97], for the purposes of breeding, species rescue, translocation, and reintroduction. In addition, zoos are involved in educating the public about illegal trafficking and trade of species, for example, through EAZAs 'Silent Forest' campaign [98]. In addition, the veterinary and husbandry expertise of zoos means they often act as temporary housing for confiscated trafficked animals.

Target 7 is an objective to *'reduce pollution risks and the negative impact of pollution from all sources'* [1]. This can be addressed through consideration of zoo waste, including how rubbish is disposed of or recycled, but also how zoo sites use and produce energy, and the carbon impacts of staff travel, resource use, and building materials. Woodland Park Zoo, Seattle, has demonstrated how sustainability can be embedded throughout zoo practices through their Green Team and a wide range of initiatives including geothermal heating, stormwater filtering, sustainable finance, and social responsibility programmes [99].

Targets 9 and 10 focus on the sustainability of wild species in *'providing social, economic and environmental benefits to people'* and *'that areas under agriculture, aquaculture, fisheries and forestry are managed sustainably'* [1]. Zoos consume a wide range of goods, from the products sold to visitors, to animal bedding and fodder. Considering the sustainability and environmental impact of these supply chains is important for transparency and as inspiration for others. This is particularly important for aquariums and butterfly houses in consideration of where their animals are sourced and what happens when a species outgrows the space available.

Additionally, Target 19 suggests *'encouraging the private sector to invest in biodiversity, including through impact funds and other instruments'* and *'stimulating innovative schemes such as payment for ecosystem services, green bonds, biodiversity offsets and credits'* [1]. The IUCN Conservation Planning Specialist Group is working with global zoos to promote the Zoos and Aquariums for 350 Movement (Z & A for 350); this aims to ensure zoos are diversifying from fossil fuels, are offsetting or neutralising their carbon footprint, and are communicating about climate change [100,101]. For example, Wellington Zoo, NZ, buys carbon credits to offset the carbon emissions that it is unable to reduce completely, these carbon credits then fund the protection of Hawaiian forests [102].

Other zoos have created their own Payment for Ecosystem Services and Carbon Credit schemes where businesses can offset their carbon emissions. One such scheme is the Re-Wild Carbon Scheme from Durrell Wildlife Conservation Trust, which in its first year planted 144,000 trees in the Atlantic Forest, Brazil, to offset 28,500 tonnes of CO₂ [103,104]. Whilst carbon credit or similar offsetting schemes have great potential, there is a need to manage them carefully. It needs to be clear who owns the land where offsetting occurs, ensure there is net overall benefit, and guarantee that funds are directed to the right places [105].

Another aspect of Target 19 is the enhancement of local collective actions and empowerment of local communities. As mentioned in relation to Target 4, zoos are involved in several livelihood-focused interventions which aim to support local communities in engaging in more sustainable practices. Examples include providing more fuel-efficient stoves to villages in Uganda in order to reduce unsustainable forest use [106,107], enabling alternative income sources such as ecotourism and selling produce such as jewelry to raise money for the Sera Wildlife Conservancy, Kenya, and cheetah conservation in Namibia [108], or training individuals to be wildlife wardens to protect Elephants in India rather than poaching wildlife [109]. These integrated conservation approaches have the capacity to target threats to wildlife whilst ensuring sustainable livelihoods for local communities. However, understanding the customs and values of local and indigenous people is vital for these initiatives to be successful [110]. A positive example where indigenous skills and knowledge are being utilised is the Tree Kangaroo Conservation Programme which

works with the indigenous people of Yopno–Uruwa–Som and Lumni Nation in Papua New Guinea to produce sustainable coffee at the same time as protecting the tree kangaroo [111].

Invasive species—Target 6

Target 6 aims to ‘*Eliminate, minimize, reduce and or mitigate the impacts of invasive alien species on biodiversity and ecosystem services*’ [1]. Invasive species removal is a fundamental part of habitat restoration necessary for reintroducing species. The EAZA Position Statement acknowledges that invasive alien species pose a major threat to biodiversity and have the potential to damage the economy [112]. They advocate efforts to protect native biodiversity against invasive alien species, using practices which are not to the detriment of the roles of zoos [112]. There are numerous examples of zoos partnering with other organisations involved in invasive species removal to create predator-free or invasive-species-free spaces necessary for native species reintroductions. For example, the white clawed crayfish *Austropotamobius pallipes* [113], red squirrel *Sciurus vulgaris* [114], and kiwi *Apteryx* spp. [115,116] reintroductions have all depended, at least in part, on eradicating invasive alien species from the release sites.

Data , Skills, and Resource Sharing—Targets 13, 20, and 21

A key aspect of Target 13 is ‘*the fair and equitable sharing of benefits that arise from the utilisation of genetic resources*’. Zoos are becoming increasingly involved in biobanking, storing genetic material, and genome sequencing as part of long-term species conservation. Consequently, the sharing of genomic information should be something which is freely available in open access sources, and not owned by an individual.

Target 21 covers scientific research more broadly and aims to “*Ensure that the best available data, information and knowledge, are accessible to decision makers, practitioners and the public to guide effective and equitable governance, integrated and participatory management of biodiversity, and to strengthen communication, awareness-raising, education, monitoring, research and knowledge management and, also in this context, traditional knowledge, innovations, practices and technologies of indigenous peoples and local communities should only be accessed with their free, prior and informed consent, in accordance with national legislation.*” [1].

Conservation zoos employ experts in a wide range of fields including ecologists, nutritionists, veterinary scientists, endocrine and disease specialists, social and behavioural researchers, and many more. As such, zoos are in an ideal position to provide interdisciplinary expertise on conservation issues [11,117]. Furthermore, as the research conducted within zoos is needs-driven and has direct practical applications, zoo scientific research has the capability of providing the most up to date and best-practice knowledge in their associated fields [118].

Target 20 aims for “*access to innovation and technical and scientific cooperation*” [1]. Zoos are experts in capacity building and connecting stakeholders to address conservation issues. This is demonstrated through their involvement with the IUCN SSC [55] and Conservation Planning Specialist Group (CPSG) [119].

Whilst zoos provide a wealth of training and expertise, there are still some issues with dissemination. Much of zoo research is shared internally within the zoo community at conferences and meetings but may not be publicly available. This is often due to zoos conducting smaller-scale studies to meet their own needs. As such, there is a shortage of large-scale international zoo studies which collate findings. Despite this, EAZA member zoos contributed 3345 peer-reviewed papers between 1998 and 2018 [120] and AZA members contributed 5175 peer-reviewed publications between 1993 and 2013 [121]. In addition, zoo research is already influencing conservation policy; for example, successfully campaigning for a no deforestation standard by the Round Table on Sustainable Palm Oil (RSPO) [23].

Social justice—Targets 22 and 23

The final two targets relate to social justice and equal opportunities. Whilst not specific to zoos, they are possible to achieve through equity of opportunities and ensuring that all

stakeholders are consulted, regardless of their background or protected characteristics. The One Plan Approach and WAZA strategies are in support of social justice, and the value of local and indigenous knowledge is now explicitly stated in strategy documents [88].

Other targets

We acknowledge that zoos have the potential to address many other aspects of the GBF and many zoos are already doing so. It is important that these actions are evidenced and collated so that they can be officially acknowledged as contributing to the GBF.

4. Processes for Zoos to Contribute to the Kunming–Montreal Global Biodiversity Framework

Demonstrating that zoos fulfil key GBF targets provides vital evidence of their international conservation role. Whilst much of the work zoos do already fits within key target areas, it is, as of yet, largely unrecognised by the wider conservation community. For zoos to be acknowledged as contributing to the GBF, they must first visibly evidence their achievements and highlight how these fit the GBF targets. As well as addressing targets directly, zoos have additional objectives providing resources and expertise, capacity building, establishing and leading partnerships, and communicating conservation activities (Table 2).

Zoos can evidence how they address Goal A: Biodiversity Conservation through publishing records on the number of species saved, evidence of reduced threatened status, and amount of habitat protected, through conservation breeding, funding, field projects, and reintroductions. Zoos' roles in capacity building and communication, for example, through delivering conservation training and sustainable solutions, should be promoted in the context of the GBF. There are countless examples where zoos partner with or provide resources for other conservation organisations globally. However, if these partnerships are only published internally, or zoos are not explicitly mentioned when these organisations report success, then the zoos' contribution remains hidden. In the interests of transparency, zoos should publicise and quantify their contributions, including quantifying non-monetary resources, such as training and capacity building.

However, there are only a small number of mechanisms by which zoos can 'officially' contribute to the implementation and reporting of the GBF. The first, and most critical, is via national mechanisms. Being that the CBD is an international treaty, it is individual member states that hold the responsibility for reporting their individual contributions to the GBF. Therefore, the work of zoos, however useful to the success of the GBF, will only be included in implementation and reporting if those zoos establish suitable links to relevant national government departments that will be collecting the information. This may prove difficult for many individual zoos, so the support of national membership organisations could be key to this. Membership organisations, such as AZA and EAZA, already collate much of the data from their members, for example, through the Annual Report on Conservation and Science (ARCS) [122] and the EAZA Conservation Database [123], which could be used as evidence towards the GBF. Additionally, as these membership organisations work closely with the IUCN SSC, this may be an avenue for collating evidence globally. Ideally, reporting on international conservation should be a collective effort between national organisations and centralized bodies such as the IUCN SCC and WAZA, who could then report directly to the CBD secretariat. Whilst there is not currently a mechanism for these non-government organisations to report, WAZA and other zoo organisations are investigating ways to develop a consistent reporting model [57].

Outside of direct national/government collaboration, zoos could also look to report their contributions via the CBD Action Agenda Portal (<https://www.cbd.int/portals/action-agenda/>, accessed on 1 April 2023), although it must be noted that, at present, there is no mechanism to include those contributions systematically in any part of the global analysis that will be used to understand global progress. However, individual nations may use information gathered via the portal in their own national reporting. Another option could be to seek membership of the Consortium of Scientific Partners

(<https://www.cbd.int/cooperation/csp/>, accessed on 1 April 2023), although this again might be best approached by national, regional, and global zoo membership organisations.

Table 2. Examples of how zoos can contribute to GBF targets, and the types of outputs zoos could produce to evidence their role.

Main Objective:	Details	Example Outputs
Addressing the GBF goals and targets	Zoos focus on a specific GBF target and publish evidence to demonstrate how zoos are contributing towards achieving this target	Demonstrating that species loss has been reduced through zoo conservation actions, e.g., a species threat status has been downgraded. Quantifying the numbers of people that have been encouraged and enabled to make sustainable consumption choices. Increase the number/size of blue–green spaces through the creation of nature reserves/ protected areas. Evidence sustainable management of zoo populations. Demonstrable reduction in zoos’ own carbon footprint. Evidencing the human health and wellbeing benefits of visiting zoos.
Additional Objectives:		
Capacity building	Zoos work with national governments and help other organisations to understand, use, and report on the GBF as well as provide information to the wider public on this.	Providing technical advice, data collection and analysis. Providing training in conservation techniques and skills development.
Resource mobilisation	Zoos provide financial and non-financial support to other organisations to enable them to achieve conservation outcomes.	Calculate, quantify, and publish the exact financial and non-financial contribution of zoos given in support of conservation projects worldwide, e.g., number of communities supported, amount of funding given and how spent, quantity of tools, amount of training, and physical resources delivered.
Collaboration and Partnership	Zoos form partnerships with other conservation organisations and a wide range of stakeholders to enhance conservation impacts.	Evidence that communities directly impacted by human–wildlife conflicts are consulted, their needs addressed, and that effective solutions are found and implemented. Evidence that the One Plan approach of integrated species conservation has been applied and all stakeholders and populations have been considered. Demonstrate fair and equitable representation of stakeholders in conservation strategies.
Communication	Zoos should communicate and educate on the principles covered in the GBF: e.g., biodiversity, sustainability, access to nature, social justice, scientific knowledge	Evidence that there is an increased awareness and appreciation of biodiversity and nature directly through the work of the zoo, e.g., evidence of learning/behaviour changes after engagement in zoo programmes.

5. Conclusions

The adoption of the Global Biodiversity Framework presents an ideal opportunity for the world’s zoos to showcase their conservation capabilities. However, experience with the Aichi targets has shown limited engagement amongst zoos. We hope that by raising awareness of the GBF, and specifically the zoo-relevant targets, more zoos will seek to contribute to these international conservation objectives. Zoo membership bodies will likely play a crucial role in ensuring the efforts of zoos are recognised and represented as part of national biodiversity reporting.

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