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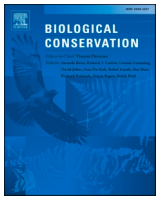

Perspective

The value of zoos for species and society: The need for a new model

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ABSTRACT

Zoos and aquaria were founded in a world fundamentally different from today, and yet, the need for such conservation organisations could not be stronger. We are currently in a climate and biodiversity crisis, with unprecedented species loss, exacerbated by human actions. The mission of many conservation zoos is to prevent such extinctions through integrated species conservation actions. The role of zoos has historically been categorised as fitting within the four pillars of conservation, education, research, and recreation. These 'pillars' no longer align with present day conservation zoos which provide a vast spectrum of services for species and society. However, in the absence of a new model, the value of zoos has been underestimated and under-supported. We propose a new model and assessment framework for viewing conservation zoos, with the zoo at the centre of a web of conservation and societal activities. We acknowledge zoos' potential as conservation hubs able to provide advice and skills to communities and policy makers. We also reflect on the criticisms and conservation challenges faced by zoos which may prevent them fulfilling their full potential and how these might impact their future role.

1. Introduction

In an environment of climate crisis and biodiversity loss (Bellard et al., 2012; McLaughlin et al., 2022), the need for zoological gardens and aquariums (herein termed zoos) to be effective conservation organisations has never been more critical. Zoos have been transformed since their roots as exotic menageries, designed to showcase wealth and status (Bostock, 1993), and many are now conservation centres with extensive expertise and skills which address many of the Sustainable Development Goals (SDG) and Global Biodiversity Framework (GBF) targets (CBD Convention on Biological Diversity, 2022; DEFRA, 2018; UNEP and CBD, 2011; United Nations, 2015). The World Association of Zoos and Aquariums advocates the One Plan Approach, whereby zoos are integrated with other organisations to collectively conserve biodiversity (Barongi et al., 2015; Gusset, 2019). We refer to zoos which adopt this attitude and embrace integrated species conservation as "conservation zoos" in acknowledgement of their focus on sustainability, and the protection of biodiversity and the environment.

We acknowledge that not all zoos can be considered conservation zoos as they fail to embrace global conservation objectives or fail to maintain acceptable animal welfare which in turn undermines the conservation message. Born-Free's EU Zoo Inquiry 2011 highlighted how, in their view, some zoos within the EU were not meeting the minimum standards set out in the EC directive (EU Zoo Directive 1999/22/EC, 1999), including raising issues with enclosure design, education provision, research objectives and contributions to conservation of biodiversity (Born Free Foundation, 2011). Additionally, there have been several instances where sub-standard zoos have lost their right to operate due to poor animal welfare. In 2010, seven zoo parks in China lost their licence after a government review of zoo conditions (BBC, 2010), in 2017, a UK zoo lost its zoo licence due to poor animal management (Barrow Borough Council, 2017), and in 2022 the US Senate passed the Big Cat Public Safety Act aiming to end the practice of unregulated private roadside zoos in the USA, which have notoriously poor welfare, especially for big cat species (*H.R.263 Big Cat Public Safety Act*, 2022). These examples create a negative reputation for zoos. However, there are many examples of organisations positively fulfilling an integrated species conservation role. To name just a few: Temaiken Biopark in Argentina has a conservation recovery plan across the Paraná river system, and has their own nature reserves and species recovery centre (Temaikèn Foundation, 2019); Chester Zoo, UK, implements a Conservation Master Plan across six global regions including having its own nature reserve and working with local communities (Chester Zoo, 2021); San Diego Conservation Alliance, USA, targets conservation at nine global habitats and has produced a conservation toolbox to empower and train conservationists (San Diego Zoo Wildlife Alliance, 2022);

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Auckland Zoos' Conservation Fund, NZ, has raised over $4 Million for conservation since 2001 (Auckland Zoo, 2023), and there are many more examples. There is currently no standardised measure for highlighting the areas where zoos are succeeding, or to differentiate between best and worst practices.

We consider why the historic model of depicting zoos' role as conservation, education, research, and recreation is no longer fit for purpose and explain how our new model is a practical alternative. We present a new holistic model of the role of conservation zoos for species and society including suggesting an assessment framework to evaluate individual zoo's impact. Finally, we reflect on the integrated conservation roles of zoos as depicted by our new "Sphere of Influence" model and consider the challenges, and criticisms zoos face.

2. The role of zoos for species and society

2.1. What is a zoo?

The term zoo encompasses a wide range of organisations that house wild or exotic animals. In many countries these organisations must hold a zoo-licence or similar permit. Although enforcing some standards of husbandry and welfare *e.g.*, (*Zoo Licencing Act 1981*, 2012), this does not ensure all expectations of a conservation zoo are met. Membership to international zoo bodies (Barongi et al., 2015; BIAZA British and Irish Association of Zoos and Aquariums, 2019; EAZA European Association of Zoos and Aquaria, 2022; Thomas, 2020) adds a layer of accountability especially through zoo association accreditation schemes (AZA, 2022; Wild Welfare, 2021; Zoo Aquarium Association Australia, 2022), however, organisations of different sizes and capabilities can all be members.

Organisational structure impacts conservation capability. Very small zoos may be unable to generate the large visitor numbers (and associated revenue) needed to run their own conservation projects or have dedicated staff for research and education (Miller et al., 2004), however, they may fulfil other important conservation roles. Charity-run zoos are mission driven, not-for-profit organisations, whose surplus revenue is directed at conservation activities. Many charities must evidence their spend and actions through a board of trustees, which can ensure greater accountability but can also slow decision-making. State or Local Authority run zoos may have additional objectives such as increasing local socio-economic engagement which may restrict funding to specific activities. In contrast, privately owned zoos have more freedom of spending but are often driven primarily by financial motives. Some private individuals may hold a zoo licence to enable them to house exotic animals for personal interest (Animal Welfare (Kept Animals) Bill, 2021) whilst other institutions are based around strong conservation objectives (Durrell, 2022). Despite variance in organisational structure and objectives, all can be viewed as zoos. As such, without an official accreditation or way to differentiate, the term 'zoo' can be applied to both the best and worst organisations with the latter giving the industry a poor reputation.

2.2. Zoo reputation and trust

Public support of zoos is critical for ensuring continued visitor numbers and associated conservation initiatives. However, maintaining this in a changing society is increasingly challenging. Additional pressures such as pandemics, increased cost of living, and inflation, inevitably affect family decisions on whether they pay zoo entry costs, donate to projects, or make environmentally friendly choices at home.

The Covid-19 pandemic put substantial pressure on zoos as they were closed to visitors, yet still faced daily operational costs. In the UK, discussions in parliament, although generally supportive, did not fully acknowledge the broad role conservation zoos play in society (Hansard, 2020, 2021). As such, zoos were one of the last venues in the UK to be allowed to re-open after nationwide lockdowns.

Public support during the pandemic through campaigns such as Chester Zoo's "Save our Zoo" (which generated over £3 million in public donations to help offset the £1.6 million per month zoo running costs) (Chester Zoo, 2022a) enabled many zoos to survive. This highlights how valued zoos are within society but also indicates their vulnerability without wider understanding of their role by influential decision makers.

Zoos remain hugely popular tourist and leisure attractions, with over 700 million visits globally (Gusset and Dick, 2011). In the UK, four out of the top ten most visited paid-for-attractions are zoos (Visit Britain, 2022) and there are 35 million visits to British and Irish Association of Zoos and Aquariums (BIAZA) zoos every year (BIAZA, 2022). The zoo experience encourages positive family memories and is an important educational experience (Fraser, 2009; Turley, 2001). However, where criticism exists it is primarily over the justification for keeping animals in captivity (Verband der Zoologischen Garten, 2020).

Criticism of keeping exotic animals is not new (Keulartz, 2015). Even before the Zoological Society of London was founded in 1826 there were campaigns against the treatment of captive wild animals (Bostock, 1993). Historic zoo practices such as chimpanzees' tea parties, and parrots riding bicycles (generally condemned amongst the conservation zoo community) have instilled a reputation for zoos "using" animals for human entertainment (Carr, 2018). The concept of what is acceptable is made more confusing by the wealth of animal encounter experiences, such as feeding and photo opportunities, offered by zoos (D'Cruze et al., 2019) and further through the diverse range of animal talks and shows which are popular amongst visitors (Moss et al., 2010; Spooner et al., 2021). These can sometimes appear as entertainment or commercial opportunities and detract from the conservation message.

Television series such as such as Chester Zoo's 'Secret Life of the Zoo' (Blast! Productions, 2016) and Longleat's 'Animal Park' (BBC & Endemol, 2000) brought zoos into people's homes. Such series potentially reach new audiences and raise awareness about conservation work that is not always visible to day-visitors. Conversely, documentary-dramas such as Tiger King (Imagine Entertainment, 2020) and Black Fish (Cowperth, 2013) may counter gains in positive reputation (Bennett and Johnson, 2021; Boissat et al., 2021; Parsons and Rose, 2018).

Furthermore, whilst social media can share zoo successes, it is quick to propagate negative content. When, in 2016, Harambe the gorilla was shot at Cincinnati Zoo in accordance with zoo safety protocols, anti-zoo debates quickly followed on social media (Mkono and Holder, 2019).

Zoos should be transparent about conservation realities and challenges. However, as family-friendly leisure venues, it is assumed that visitors expect a sanitised version of wild animals. As such zoos tend to prioritise decisions for perceived public benefit (Fa et al., 2014). Recent research suggests that zoo visitors may not focus as much on leisure as zoos imagine and are more interested in the learning opportunities that a visit provides (Lee, 2015; Roe et al., 2014).

The terminology used by zoos presents a further challenge. Many terms have historic origins and do not reflect current practice. These terms portray zoos as museums or farms (*e.g.*, collection, keeper, curator, exhibit, display, stock, holding) or reinforce concepts that animals are trapped (*e.g.*, captive, enclosure). Even when positive terms are used, such as calling zoos 'progressive' or 'modern', this automatically conjures the opposite word association and highlights that there are, by-default, 'bad' zoos. As a result of the integrated species conservation approach, the terms *in-situ* and *ex-situ* are also now outdated when describing conservation efforts generally; as conservation should not occur in one location, but instead be an integrated combination of sites, skills, and expertise (Gusset, 2019). Despite this, we use the terms *in-situ* and *ex-situ* to indicate location of specific aspects of zoos' work, such as field projects, which are a part of this broader, integrated conservation approach.

Additionally, whilst the anthropomorphising of animals (*e.g.*, giving names, describing personalities using human traits) may increase visitor-animal connection, it risks propagating the idea that wild animals are pets or "owned" by zoos. For animals that are naturally solitary,

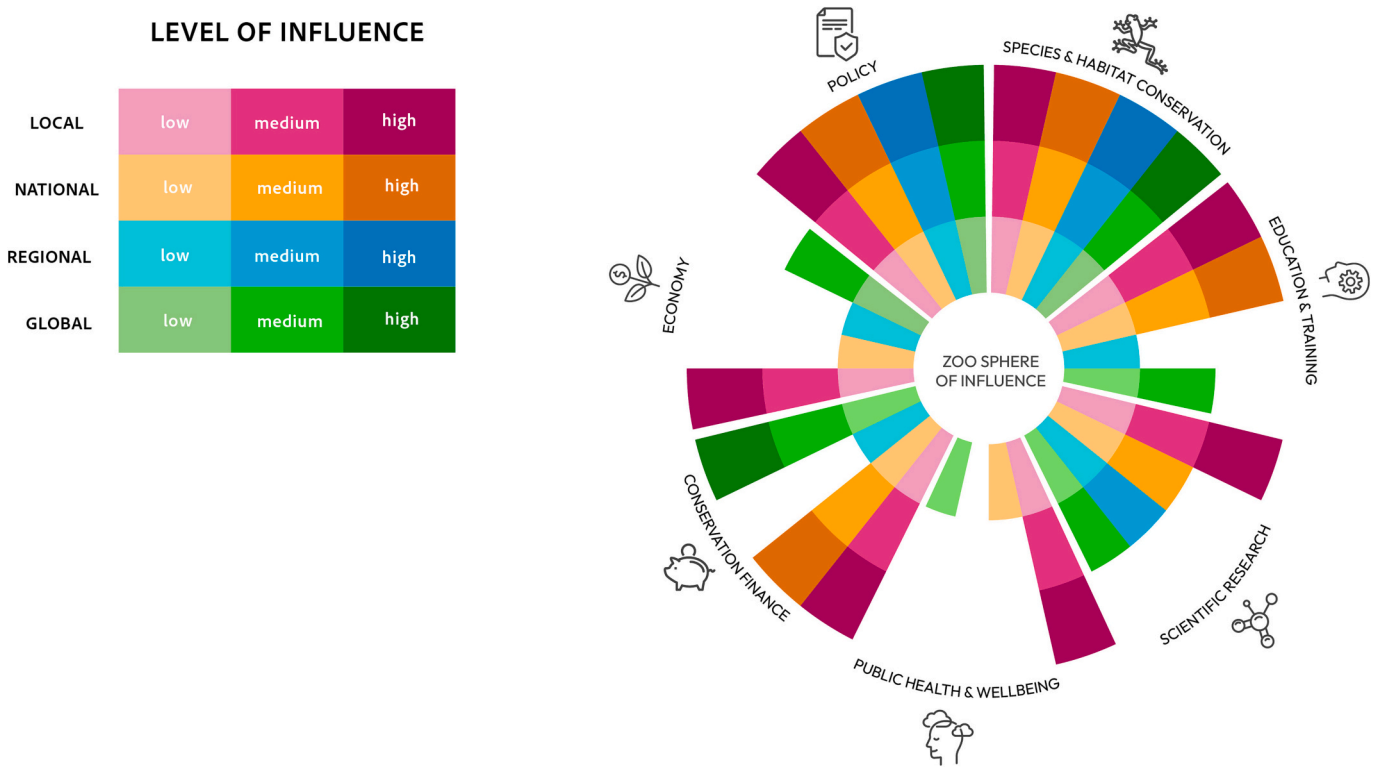

Fig. 1. New holistic model: zoo sphere of influence. A model of the potential reach of conservation zoos across a range of conservation areas and at different influence levels (from local to global, low to high). The current diagram is based on zoos' current collective ability to achieve in each conservation area which is why there are some gaps in the model. It is possible that with future zoo developments and iterations of the model all segments could be represented.

anthropomorphic comparisons can create perceptions that the animal is lonely or unhappy.

Institutionally, there is a need to overhaul zoo terminology to reflect conservation practices and disassociate with historic legacy. Reframing zoo language may result in better public perception and greater understanding.

Without a clear framework within which the role of zoos can be viewed, it is likely their achievements will remain undervalued. Further, without knowing the strengths and weaknesses of individual zoos it is difficult to assess how they can work as a complete network and support one another. A comprehensive evaluation system is required.

2.3. The existing 'pillars' model

For over half a century, zoos have been defined by the 'pillars' of conservation, education, research (Conway, 1969), and recreation. These objectives feature throughout zoo mission statements (Patrick et al., 2007) and have been echoed in requirements for licensing and international zoo guidelines (Barongi et al., 2015). Whilst these pillars acknowledge the basic roles of zoos, they fail to reflect the multi-faceted range of activities that conservation zoos engage with. Furthermore, this historic model fails to provide any indicator or measurement of success. This means that organisations can claim they fulfil the basic objectives of zoos even if their contribution is minimal.

There are areas of zoos' work (such as Public Health, community engagement, and economy) which do not fit into the existing pillar model. Whilst there have been suggestions that additional pillars such as "Wellbeing" could be added (Rose and Riley, 2022), the 'pillar' model fails to acknowledge the interconnected system in which zoos function, leading to them being viewed in isolation from the rest of society. Zoos provide a wealth of skills, services and expertise that reach across society, through community engagement, policy influence and informing global conservation, in addition to their traditional roles. As such, zoos form a central pin holding conservation actions together.

If the wide-ranging, conservation-led, roles of conservation zoos are not acknowledged and valued, there is a risk that zoos will not receive the support and funding necessary to continue their work. Furthermore, the true potential of their contribution to tackling the global challenges of biodiversity loss and climate change will not be realised. Consequently, a more representative and contemporary model is needed.

2.4. The new model: zoos' sphere of influence on species and society

We propose a new model (Fig. 1) to reflect the conservation zoos' role for species and society, viewing the zoo as the centre of a conservation and social network. This mirrors the integrated species conservation approach advocated by the World Association of Zoos and Aquariums (Barongi et al., 2015; Gusset, 2019).

The individual zoo (or zoos collectively) can be placed at the centre of the model with their sphere of influence radiating out, echoing the continuum of conservation management intensity set out by the One Plan approach to conservation (Gusset, 2019). The first "ray" of each section is zoos' influence onsite and within the local community, for example as an employer, educator, tourist attraction, and nature-based recreational wellbeing venue with their own internal governance and policy. The next rays reflect zoos work at national and international (within their global region) levels to coordinate breeding programmes, and share animals, genetics, skills, and knowledge. At their broadest level (represented by the final ray), zoos influence global issues. Zoos work internationally to protect flora and fauna, provide education and training, and support public health and local economies. Further, zoos work with international policy makers such as the UN to influence international conservation treaties and supporting the One Plan and One Planet approaches (Byers et al., 2013; UNEP United Nations

Environment Programme, 2018) and the SDGs and GBF (CBD Convention on Biological Diversity, 2022). Each ray can be viewed as having a low, medium, or high level of influence.

In addition to reflecting the level of influence (moving from local to global scales), the new model reflects the core areas that conservation zoos work on species and habitat conservation, education and training, scientific research, public health and wellbeing, conservation finance, economy, and policy. Although other NGOs can fill some of these roles individually, zoos are unique in their ability to do all these roles holistically and connect society with species.

The new model of zoos' role for species and society is more than just a visualization, it is also an evaluation tool. The associated table (Fig. 2) provides a suggested valuation matrix with different targets for each level of influence. The model (Fig. 1) is drawn based on the current potential of zoos collectively. For example, as public health and wellbeing are a relatively new focus for zoos, the potential influence is at the local level, with some global influence *e.g.*, where zoos engage with international health campaigns. Consequently, there are gaps which, at present, zoos are unable to fill (represented by the blank spaces in the model/matrix). It is, theoretically, possible for every section of the matrix and model to be completed if zoos can demonstrate working in these areas. Individual zoos can draw their own model based on their achievements, and this can be compared against the collective potential. Our matrix table (Fig. 2) presents suggested criteria for fulfilling each section, our next step is to consult with focus groups to confirm these criteria. It is likely that future iterations will include additional wedges or bands as zoos adapt to new challenges, the model is designed to incorporate these extensions.

2.4.1. *Using the new model to demonstrate zoos' value*

We propose that the new model could be used by zoos to self-assess achievement and acknowledge gaps. Some zoos may only achieve parts of the model or have strengths in a particular wedge (such as local influence) and thus will require support from others to fulfil a broader role. This fits with the latest zoo standards in the UK and Europe which encourage mentoring and shared resources (DEFRA, 2021; EAZA European Association of Zoos and Aquaria, 2022; UNCBD, n.d.). Ultimately, where zoos are unable or unwilling to fulfil key areas, even with support, it may be necessary to reclassify these organisations as having a different purpose to conservation zoos.

The model has the potential to be further tailored to aid in zoo population planning and help evidence each species' role. This is particularly relevant for species which are controversial or face increasing regulations and associated high costs of keeping them. In the UK such restrictions exist for Cetaceans, Elephants and Great Apes (DEFRA, 2017, 2021). Being able to evaluate the benefit and purpose of keeping such species aids zoo decision making. In such cases, instead of the zoo at the centre of the model, it could be streamlined to focus at a species level within a zoo. This species could then be evaluated against each of the core areas. Critically endangered species are likely to have a wider influence (*e.g.*, *in-situ* conservation and education, employment such as anti-poaching initiatives and livelihood focused interventions, and international legislation against wildlife trade) in contrast to least concern species which may only achieve some localised aspects such as visitor wellbeing and tourism. Zoos can use this model to balance what species they care for and understand how these fit with the conservation zoos' role.

Level of Influence		Species & Habitat Conservation	Education & Training	Scientific Research	Public Health & Well-being	Conservation Finance	Economy	Policy
Local	Low	House threatened species onsite	Zoo has specific staff to deliver education and training.	Conduct internal evaluations (e.g., welfare assessments, education evaluations)	Zoo provides opportunities for families to connect with each other and with nature	Fund husbandry, veterinary, housing, and conservation breeding/ propagation of threatened species. Stimulate conservation donations from the public.	Provide a tourism and leisure facility in the area	Have an in-house strategy for zoo population planning
	Medium	Conservation breeding/ propagation of threatened species on site	Zoo models sustainable practices on site (e.g., no plastics/ sustainable palm oil)	Conduct peer-reviewed, published studies	Provides a programme of activities focused on wellbeing	Fund conservation staff on site (e.g., education, interpretation, research)	Employ local people (including through volunteer programmes) and use local goods and services	Local communities are consulted regarding zoo decisions and are considered stakeholders
	High	Encourage native species on site	Zoo engages with local business to develop agreed sustainable/ eco-friendly behaviours and practices	Have bespoke research staff and facilities	Works with local doctors and charities as part of local social prescribing initiatives	Fund and participate in local in situ conservation projects including in-kind support such as provision of facilities, expertise	Have a measurable impact on the local economy outside the zoo (e.g., visitors use other local services, shops, hotels, transport)	Engage with local government on local environmental and sustainability issues
National	Low	Contribute to local and national records of native species sightings and promote others to do the same	Zoo works with other education and training organisations (universities/colleges)	Contribute to national zoo studies	Works with local doctors and charities as part of national social prescribing initiatives	Fund national movements of animals/ plants for conservation breeding/ propagation	Contribute to the national economy (e.g., tourism, employment, public health, education, and upskilling)	Active member of a national zoo organisation (e.g., BIAZA)
	Medium	Actively support projects outside the zoo which encourage native species	Zoo engages with education campaigns and professional training at a national level	Conduct research across and/or in collaboration with other national zoos		Fund national projects for the in-situ protection of native species		Have staff on a committee of a national zoo organisations
	High	Have own nature reserves/ protected areas for native species	Zoo informs national curriculums and training strategies			Funding for and active participant in national species recovery projects (e.g., through assistance with reintroduction and head starting)		Engage with Members of Parliament MPs on conservation issues
Regional	Low	House species that are part of a regional plan (ESB/EEP/TAG)	Zoo engages with education campaigns and professional training at a global region level (EAZA campaigns)	Provide samples or data for global region studies		Fund conservation breeding/propagation and animal/plant movements at a global region level	Contribute to the global regions' economy (e.g., tourism, employment)	Active member of a global region zoo organisation (e.g., EAZA)
	Medium	Breed/ propagate species that are part of a regional plan (EEP/ESB/TAG)		Conduct medium scale regional focused research				Have staff on global region zoo committees (e.g., EAZA)
	High	Co-ordinate a regional species plan (EEP/TAG)						Engage with regional decision makers (e.g., EU)
Global	Low	Have own genetic biobank/ seedbank	Zoo provides education and professional training as part of in-situ projects	Provide samples or data for global studies	Works with in-situ projects in other countries to promote public health and well-being	Indirect funding of in-situ projects (e.g., funding another NGO)	Support in-situ projects in other countries through developing livelihood focused interventions	Active member of a global zoo organisation (WAZA)
	Medium	Coordinate/lead habitat management and/or species reintroduction/protection projects	Zoo engages with educational campaigns and professional training at a global level	Conduct large scale globally relevant research (field research, international comparisons)		Direct funding of in-situ projects (e.g., money given to protect habitats, cost of rescue operations, training, and maintenance)	Support the global economy through the protection of ecosystem services (biodiversity, clean water etc.)	Support in-situ projects (including supporting individuals or organisations) in other countries in achieving policy change and developing conservation strategies
	High	Have a demonstrable impact on the protection of Biodiversity and ecosystem services globally				Funding and Active participation in international in situ projects across whole landscapes, including as part of carbon offset schemes.		Have an active role in informing global policy decisions on climate and conservation (e.g., IUCN, UN)
Sustainable Development Goal		14 & 15	4, 11, 12 & 13		3		1, 2 & 8	11, 12, 13 & 17
Post-2020 Global Biodiversity Framework		2, 3, 4, 6 & 9	16	21	11 & 12	19		5

Fig. 2. Evaluation matrix: zoo sphere of influence. A suggested evaluation table for how each section of the model (Zoo Sphere of Influence) is allocated. Fulfillment of criteria within a particular section of the table relates to achieving the corresponding segment on the model. Currently, matrix criteria are only suggestions as a proof of concept. These criteria will be developed further as a crucial next step.

3. Discussion: zoos sphere of influence

3.1. Species and habitat conservation

Zoo species and habitat conservation addresses both public (Aichi 1, 19; GBF 11, 12) and biodiversity targets [SDG 14 (life below water), 15 (life on land); Aichi 4, 6, 12, 13, 14; GBF 2, 3, 4, 6, 9]. Zoos, therefore, have the potential to influence at all levels (local – global, low-high) in this category. For example, although accessibility to exotic species has increased (*e.g.*, cheap air travel and the internet), for most people, the zoo remains their only first-hand exposure to wildlife. These close encounters build a connection to species (Clayton et al., 2009, 2011) necessary for developing the foundations of pro-environmental action.

At least 17 species would not exist without zoo breeding programmes (Conde et al., 2011). Established "success stories" include the golden lion tamarin (*Leontopithecus rosalia*) (Kierulff et al., 2012), Przewalski's horse (*Equus ferus przewalskii*) and California condor (*Gymnogyps californianus*) (Marcy, 2022). In addition, numerous species releases feature amongst zoo internal literature such as: Blandings turtle (*Emydoidea blandingii*), Bermuda (*Poecilozonites spp.*) and Partula (*Partulidae spp.*) snails, golden mantella frogs (*Mantella aurantiaca*), black rhino (*Diceros bicornis michaeli*), and Mauritius pink pigeon (*Nesoenas mayeri*).

However, managing zoo populations is neither straightforward nor globally consistent. Space in zoos is limited. Zoos balance housing charismatic animals, which attract the public (necessary for generating funding), against housing highly endangered species. The public expectation for certain animals, in addition to a historic legacy of showcase species, has led to a bias towards large bodied, charismatic, and often less threatened species (Bowkett, 2009; Conde et al., 2013; Fa et al., 2014; Martin et al., 2014; Mooney et al., 2020). As such, the current global zoo population is no more representative of threatened species than if it were selected at random (Conde et al., 2013). A solution is to re-focus existing zoo populations towards a wider variety of threatened and smaller species which occupy less space (Keulartz, 2015; Mooney et al., 2020). For example, whilst 18 % of Vietnam's extant and 28 % endemic amphibian species are classified as threatened, only a fraction (8 % and 3 % respectively) are kept in zoos worldwide (Krzikowski et al., 2022).

Another key objective for zoos is ensuring populations are self-sustaining. Broadly speaking, to achieve this, zoos aim to maintain approximately 90 % genetic diversity for at least 100 years (Powell, 2019); as the genetics of the founders are often unknown, most population management relies on zoo pedigree knowledge. Sustainability requires target populations of 50–250 individuals (Conde et al., 2013; Powell, 2019); however, only 27 % of Species360 member zoos house >50 individuals (Conde et al., 2013).

Globally zoo population targets are organised within regions for example: the American Association of Zoos and Aquariums (AZA) targets zoo population sustainability (Silver et al., 2022), the Zoo and Aquarium Association Australasia (ZAA) uses the One Plan Approach with a focus on native species (ZAA Zoo Aquarium Association Australasia, 2022), and the European Association of Zoos and Aquariums (EAZA) defines the role of each individual species (with some not focused on population sustainability but rather on conservation education, research, or training (EAZA, 2022)). There are a handful of globally managed programs, Global Species Management Plans (GSMPs) (WAZA, 2019), and a growing desire to shift from a regional to a global population management framework.

Zoos also play a critical role in species reintroduction, providing both zoo-bred populations and staff expertise (Gilbert et al., 2017). Determining what counts as reintroduction "success" is important. As long-term data is required, it may take decades before a species is deemed successfully reintroduced. Many of the established "success stories" still require extensive funding and management (Finkelstein et al., 2012). Understanding long-term impact is vital to improving survival chances. Personality trait selection pre-release (Allard et al., 2019) and maintaining wild characteristics (Passos et al., 2021) may influence survival chances post-release. The IUCN conservation translocation specialist group claims that 24 % of the 418 species release projects reported were highly successful (Soorae, 2021). However, these projects are of varying degrees of quality and lack overarching criteria for measuring success. Although there have been more systematic attempts to measure reintroduction and translocation success amongst North American zoos (Brichieri-Colombi et al., 2019), a comprehensive global analysis of reintroduction efforts is urgently needed.

3.2. Education and training

Zoos potentially influence education and training at all levels (local to global), with the greatest influence at local and regional levels. Zoos provide a multitude of learning opportunities from formal school sessions and training programmes to informal learning during a visit (Collins et al., 2019; Godinez and Fernandez, 2019; Moss and Esson, 2013). The interdisciplinary opportunities offered at a zoo site mean that educational themes are wide-ranging and go beyond biological sciences. Vast numbers of student research projects are conducted at zoo sites, in addition to vocational skills training, as part of university and college programmes.

Focus has moved from conveying facts about animals to providing targeted conservation education aimed at environmental actions and fulfilling SDG 4 (quality education) and 12 (responsible consumption) (Thomas, 2020). International studies have demonstrated that zoos are able to meet global biodiversity targets (Aichi Target 1) around raising awareness and knowledge of biodiversity (Jensen et al., 2017; Moss and Esson, 2013; Moss et al., 2015; Moss et al., 2017) and influence some conservation behaviors (Counsell et al., 2020; Mann et al., 2018; Pearson et al., 2014; Smith et al., 2008). However, there is still an abundance of single-site studies which measure limited educational or behavioural outcomes and as yet no meta-analysis of conservation education impacts.

3.3. Scientific research

Zoos are valuable locations for research (Hutchins et al., 2019; Lina et al., 2020) and provide a unique environment with real-world application of techniques. This is especially important for veterinary, welfare, reproduction, plant sciences, and understanding social behaviors of both animals and humans.

Zoo research is need-driven and informs practice (Kendall and Bergl, 2019); it extends beyond the zoo site using its unique scientific skills in the field. Consequently, research influences all levels from local to global. For example, understanding impact of *in-situ* conservation education initiatives, or physiological drivers of fencing African bush elephants (*Loxodonta africana*) in Kenya (Morrison, 2019), or the wildlife endocrinology skills developed in zoos and used to conserve Black Rhino (*Diceros bicornis michaeli*) (Edwards et al., 2020). Zoos are also developing and implementing novel techniques in welfare assessment, biobanking, genetic analysis, and sampling. Often these techniques have previously only been used on a few domestic species.

Zoos also are a diverse source of biological and genetic resources, supporting research in disease, population management and the wider GBF Target 4. Biological sampling is especially important for future conservation efforts as techniques may exist in the future which are not yet available in the present (Finieg et al., 2021; Nature's SAFE, 2020). In working together, zoos can collate findings and already are building biobanks of genetic material for future use (Bolton et al., 2022).

The range of different specialists means that zoo research is often highly interdisciplinary. Unlike the university sector, zoo research is driven in response to a situation with the purpose of directly informing practice. As such, zoo research often features in professional conferences or conservation plans and are sometimes never published in peer-reviewed sources. However, zoo-led peer reviewed publications do

feature in the published literature and continue to increase in number. Between 1998 and 2018 EAZA members contributed 3345 peer-reviewed publications (Hvilsom et al., 2020) and between 1993 and 2013, AZA institutions contributed 5175 peer-reviewed publications (Loh et al., 2018).

3.4. Public health and wellbeing

Climate change poses a range of threats to mental and physical health (Lawrance et al., 2021). The benefits to mental health of nature-based recreation were already recognized (Lackey et al., 2019) and the Covid-19 pandemic has further emphasized the importance of nature in maintaining and improving mental health (Pouso et al., 2020). In providing nature-based recreation and connecting plant and animal species with society, zoos fulfil a role in promoting positive wellbeing and addressing SDG 3 (good health and well-being).

Physiologically, a link has recently been established between immersive experiences as part of a zoo visit and reduction in stress, assessed by measuring salivary cortisol and blood pressure, showing just how effectively zoos and aquariums can be in helping restore mental health (Coolman et al., 2020). Nature engagement is important for wellbeing and has been prescribed as an alternative treatment for mental health (known as Social or "Green" Prescribing) (Leavell et al., 2019). Trial mental health and wellbeing programmes held within zoos have shown early successes (Burton Mallott, 2021; Coolman et al., 2020; Public Perspectives Ltd. et al., 2012; Sumner and Goodenough, 2020). Additionally, volunteering programmes offered by zoos have been shown to help individuals develop key skills such as self-confidence and communication which can in turn help them find employment (Smith et al., 2018). Whilst most of the health and wellbeing benefits are at the local and national levels, zoos potentially influence global health as part of field projects.

3.5. Conservation finance

In an assessment of conservation funding in 2011, zoos were stated as the third largest provider of species conservation funding globally (Gusset and Dick, 2011). This includes funding spent on conservation management and resourcing. Although charity and local authority zoos receive some state support (*e.g.*, tax-breaks), most funds are generated through visitor entry prices and donations. Zoos with a large variety of animals and which are dissimilar to other zoos have been found to have the largest numbers of visitors and are therefore able to contribute more to *in-situ* conservation (Mooney et al., 2020). Unlike other funding bodies who contribute relatively short-term projects, zoos have the potential to provide continuous sustainable funding for long-term conservation (BIAZA et al., n.d.).

A criticism of this is that the majority of zoo generated funds are spent onsite and a much smaller percentage of funds are spent on field projects, however, this must be considered in relation to local costs as relative value varies between conservation locations. In addition, the One Plan approach requires a more holistic implementation that blurs the boundaries between *in-situ* and *ex-situ*. Zoos, therefore, contribute across all levels including providing global level conservation finance.

More recently, zoos are engaging with the concept of carbon credit or payment for ecosystem services schemes, whereby businesses can offset their carbon usage or meet sustainability targets (such as SDG 12 – responsible consumption and production and SDG 13 - climate action) through investing in zoo conservation projects (*e.g.*, Durrell's re-wild carbon scheme (Durrell, 2022)). This has enormous potential for fund generation, however, it is somewhat controversial if companies try to buy their way out of polluting instead of investing in sustainable production. Additionally, as demonstrated by the Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) carbon credit scheme, very careful management is required to ensure that funds are directed in the right place and that there are net overall benefits (Mahanty et al., 2013; West et al., 2020).

3.6. Economy

Zoos are hugely valuable to the economy as businesses and tourist destinations. They address SDG 8 (decent work and economic growth) by employing local people, using local suppliers, and bringing people into an area. A report conducted on the economic contribution of eight UK charity zoos found that they contribute at least £200 million *per annum* to the national economy (BIAZA et al., n.d.)

On a global scale, further economic benefit is achieved through protecting biodiversity and ecosystem services. Although there has been no assessment of the economic value of this for a zoo to date, natural capital audit methodology is available that could enable this to be quantified in future (DEFRA, 2020) and zoos have begun to test natural capital assessments for global regions (Chauvenet et al., 2014).

3.7. Policy

To support the work of conservation zoos, politicians need to fully understand zoos' integrated role in society. As experts in a wide range of fields, zoos are well-placed to advise governments on conservation policy. They can potentially fulfil the SDG targets 3 (good health and wellbeing), 4 (quality education), 8 (decent work and economic growth), 11 (sustainable cities and communities), 12 (responsible consumption and production), 13 (climate action), 14 (life below water), 15 (life on land), and, 17 (working in partnership). Where politicians have worked with zoos, significant pro-environmental progress has been made, for example, introducing a no deforestation standard by the international Round Table on Sustainable Palm Oil (RSPO) in 2018 (Chester Zoo, 2022b). Zoos have also impacted local business such as The Deep Aquarium's campaign to stop the use of plastic straws in the city of Hull, UK (The Deep, 2022). Through their trade associations, and through WAZA in particular, zoos are also starting to influence policy at the global level through participation in the formulation of international treaties such as CITES and the CBD. Zoos, therefore, have the potential to influence at all levels in this category.

Zoos must work collectively and share skills and resources if they are to fulfil their potential and this is a key component of new zoo strategies (DEFRA, 2021). This is easier where zoos all fall under the same legislation such as in the American Association of Zoos and Aquariums (AZA) and are not subject to different cultures, languages, and legal systems as is the case for EAZA member zoos.

4. Summary

The historic 'pillars' model is out-of-date and unrepresentative of conservation zoos' role. Without a new model, zoos are being undervalued and viewed as separate to society. This means they are not always considered in conservation decision making, despite the wealth of expertise and resources that they have to offer.

Our new model (Fig. 1) reflects the conservation zoos' role for species and society by placing zoos at the centre of a network. It reflects the varying levels of influence that zoos can have as well as the core areas that zoos can work across. Currently our new model represents an initial framework for evaluation. Further research is needed to test model suitability and generate measures of zoos' value. We have suggested evaluation markers which zoos could use to assess themselves against (Fig. 2) however, these must now be developed and tested further.

Evidence is needed such as systematic evaluations and meta-analyses to understand the extent zoos collectively meet these objectives. This is a critical next step as without a credible, evidenced argument for the future of conservation zoos they risk being ignored by politicians and misunderstood by the public. Armed with such evidence, however, conservation zoos will be able to realise their full potential in making a significant contribution to the global environmental crisis.

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Sarah L. **Spooner**: Methodology, Writing – Original draft preparation, Visualization. **Susan** L. **Walker:** Conceptualisation, Writing – Review & Editing, Supervision. **Simon Dowell:** Writing – Review & Editing. **Andrew Moss:** Conceptualisation, Writing – Review & Editing, Supervision.

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All authors were employees of Chester Zoo, a large not-for-profit zoo, at the time of submission.

Data availability

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