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REVIEW

Mismatch between conservation needs and actual representation of lions from West and Central Africa in in situ and ex situ conservation

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Abstract

Mismatches between conservation action and conservation needs have been highlighted for diverse species. Lion (*Panthera leo*) conservation is no exception, raising the question of whether current conservation strategies are always adequate to ensure the long-term persistence of threatened taxa.

To investigate the representation of different lion Evolutionary Significant Units in field research, captive populations, funding allocation, and education, we carried out a literature review and sent an online questionnaire to zoos worldwide. Over 75% of the publications focused on southern and eastern African populations. Uplisting the West African lion to Critically Endangered did not change this result. We received 88 responses from zoos, which reported 346 lions in 83 zoos. Only 14 individuals have West and Central African origins. Over 70% of the respondents reported that they do not include any information on the conservation status or taxonomy of lions from West and Central Africa in their education programs. The minority of zoos funding in situ lion projects did so in Eastern and Southern Africa. We provide recommendations to encourage role-players involved in lion and other threatened species conservation to address this mismatch by shifting some of their attention and funding to West and Central Africa.

KEYWORDS

Central Africa, education, ex situ, in situ, lion, *Panthera leo*, questionnaire, review, West Africa, zoo

1 | INTRODUCTION

Conservationists require scientific data and recommendations from experts for managing habitats and populations to allow their long-term viability (Young & Clarke, 2000). Taxonomic and geographic underrepresentation can lead to ill-suited conservation strategies, which can be detrimental to threatened species (Britnell et al., 2021; Hickisch et al., 2019). However, limited conservation resources imply setting priorities and conducting a "triage" (McDonald-Madden et al., 2008). Conservationists prioritize according to different criteria: the level of vulnerability or irreplaceability for instance, on a species, area or ecosystem scale (Wilson et al., 2009). Tensen (2018) stated that conservation attention should go "towards species that are understudied, endangered, and taxonomically unique, or have a small geographic range." Preserving taxonomic uniqueness is particularly important to maintain local adaptations and evolutionary potential, ensuring adaptability and survival under environmental changes (Frankel & Soulé, 1981). The central questions to conservation are whether resources are indeed used cost-effectively and whether current conservation management strategies are built on adequate information provided through research, ensuring the long-term survival of the most threatened taxa.

West and Central Africa are rich in biodiversity and contain distinct genetic clades for many species (Bertola et al., 2016). However, these regions are under severe threat (Mallon et al., 2015), most of its charismatic species being at risk of extinction (Brugière et al., 2015). Lions (*Panthera leo*) have disappeared from *ca* 99% of their historical range in West and Central Africa, leaving only a few isolated populations (Brugière et al., 2015). The multiple distinct genetic clusters (Bertola et al., 2022) found across their range exhibit various levels of conservation needs and conservation attention. Although threatened and representing a distinct subspecies, the West and Central African lion has suffered from a lack of research and conservation attention (Bauer et al., 2003). Originating from multiple reasons, geographical biases have been reported in research efforts (Hickisch et al., 2019) and large carnivore monitoring (Strampelli et al., 2022). However, regional disparities in all lion field research topics have not been assessed.

Workshops were held in 2001 and 2006 by the International Union for the Conservation of Nature (IUCN) to upscale the conservation of lions in West and Central Africa (IUCN, 2006). The West African population was, however, only listed as Critically Endangered in 2014, following intense monitoring efforts (Henschel et al., 2014). While Bauer et al. (2015) argued that the lion populations in Central and East Africa meet the criteria to be listed as Endangered, no separate regional assessment has been undertaken since.

Aside from field research, zoos can also contribute to species conservation, by managing safety-net populations (i.e., managed captive populations that could be used to ensure the viability of populations in the wild). They can also accommodate research, provide conservation education to visitors and support in situ conservation projects (Gant et al., 2020; Mace et al., 2007; Tribe & Booth, 2003). The commitment of zoos to the latter has become a necessity for their recognition as key players in conservation and usually translates into direct financial support (Zimmermann & Wilkinson, 2007). Lions are one of the most popular species (Callahan, 2013; Woods, 2000), known to substantially garner public support (Martín-López et al., 2008). The Association of Zoos and Aquariums (AZA) SAFE (Saving Animals From Extinction) program allocates over US $2.5 million yearly to African lion conservation (AZA, 2019). Yet, the geographical distribution of funds allocated to in situ programs has not been reported. In 1989, 79% of zoo lions were of unknown origins and were called "generic lions" (Nowell & Jackson, 1996). Since then, several European zoos have performed genetic testing on their lions to determine their wild origin(s) (Bertola et al., 2018), but little is known about the representation of these different origins in zoos worldwide.

This study investigates the representation of different Evolutionary Significant Units (ESUs), with a particular focus on lions from West and Central Africa, in situ (field research) and ex situ (captive zoo populations, funding allocation, and conservation education). We define ESUs as "populations that have substantial reproduction isolation, which has led to adaptive difference" (Funk et al., 2012). ESUs are monophyletic for mitochondrial DNA alleles and divergent for nuclear DNA alleles (Moritz, 1994). We hypothesized that lions in Eastern and Southern Africa receive a different level of conservation attention than lions in West and Central Africa. We predicted a mismatch between the conservation needs of West and Central African lions and their representation in research and in zoos. We further predicted that the separate regional assessments of the IUCN Red List has had a limited effect on conservation policy and practices so far, especially in terms of increased field research publications and conservation education. To test this, we carried out a literature review of peer-reviewed scientific publications and conservation strategies focusing on wild lions and surveyed zoos worldwide through an online questionnaire.

We confirm the existence of a mismatch between conservation needs and the actual representation of ESUs in field research, zoos, and funding allocation. We urge conservation role-players to shift some of their atten-

tion and funding to more threatened, less studied and taxonomically unique populations.

2 | METHODS

2.1 | Literature review

To examine in situ lion research efforts across its range, we searched the Web of Science Core Collection and compiled peer-reviewed articles and conservation strategies published between January 2000 and December 2021. We restricted our search to articles presenting the term "*Panthera leo*" in their title, abstract, or keywords (Balme et al., 2014), as this ensured inclusiveness in terms of languages, and excluded many irrelevant articles associated with "lion" (e.g., "sea lion"). We acknowledge the possibility of a few lion articles only introducing "*Panthera leo*" later in the article being excluded, but argue that this would have had a minimal impact on our findings, as most scientific journals require the scientific name of the species to be stated at first mention in the title or the abstract. We excluded articles about captive lion populations (including lion breeding farms, sanctuaries, and zoos) and articles where lions were cited as a reference or as a comparative species. Our literature review did not include the grey literature, and therefore potential project reports, if published online, are not represented in these results.

For each article, we recorded the year of publication, the topic/category (Table S1), and the threats to lion conservation that were addressed, when relevant (Ashman et al., 2019), following the IUCN (IUCN, 2006; IUCN SSC Cat Specialist Group, 2018). Countries and the corresponding "region" were also recorded. Studies could be carried out at various scales and were assigned to the following categories: Range-wide, Africa, Asia, Southern Africa, East Africa, West & Central Africa, North Africa. These regions were delimited following the United Nations Statistics Division (www.unstats.un.org/unsd/methodology/m49). If the location of the study was unknown or different from the above categories (e.g., performed in natural history museums), the study was placed in "Other."

Studies that fitted into more than one category (for the topic, threat, country, and region) were counted once in each corresponding category, leading to a higher total than the initial number of selected publications in further analyses. Then, using the IUCN Cat Specialist Group website (www.catsg.org) and the Joint CITES/CMS/IUCN Lion Web Portal (www.cms.int/lions/en/about/joint-cites-cms-iucn-lion-web-portal), global, regional, and national action plans were added to our compilation of articles and classified in the Conservation policy category.

2.2 | Zoo questionnaire

2.2.1 | Zoo selection

We used the list of accredited institutions provided on the World Association of Zoos & Aquariums (WAZA) website (www.waza.org) and added zoos present in large cities (over 250,000 inhabitants) to increase our sample size while selecting zoos with an important local influence. We selected zoos that present an Africa-themed (or savannah) exhibit, even if they do not keep lions. Such exhibits can include mentions of lions in conservation education material and zoos can provide support to in situ lion conservation and research projects.

We then contacted zoo experts involved in lion management, including the program leader of the Lion Species Survival Plan and several regional Lion Species Coordinators of the AZA. We asked them to review a draft of the questionnaire survey to ensure questions were clear and correctly interpreted (Bhattacherjee, 2012) and requested that they share relevant contact details for targeted e-mails (Biernacki & Waldorf, 1981).

The final selection listed 275 zoos, of which only 252 could be contacted electronically. Contact details were usually provided for a specific department within the zoo (e.g., the education department), or directly for the relevant person (e.g., the mammal curator), but for some zoos, the only available option was a general e-mail address or a contact form. In addition to the 252 zoos and to optimize both response rates and international coverage, the following zoo associations were contacted to ask for the survey to be circulated within their network: the Pan-African Association of Zoos & Aquaria (PAAZA), the South East Asia Zoo Association (SEAZA), the Zoo & Aquarium Association (ZAA), and the International Zoo Educators Association (IZEA).

2.2.2 | Online survey

We sent a cover letter presenting the context and aim of our project. Information on free, prior, and informed consent and assurances of anonymity and confidentiality were also provided to the selected zoos (Bhattacherjee, 2012) (Figure S2). Questions were broadly categorized into three sections: (1) lions currently held in the zoo, (2) conservation education material pertaining to lions, and (3) funding of in situ lion conservation and research projects (including adoption schemes, another potential source of funding for in situ conservation). Lions could be assigned to either subspecies *P. leo melanochaita* or *P. leo leo*, the latter being further separated into three ESUs (i.e., Asiatic lion, Barbary lion, and West/Central African lion) (Bertola et al.,

2022). Other permitted responses were "Mixed lineages," "Not sure" or "Subspecies unknown." Conservation education material was defined as any means or resources (e.g., posters, newsletters, exhibits, hands-on experiences, presentations given by interpreters and education officers) that deliver scientific facts on lion status and conservation as part of the zoo conservation education program (Thomas, 2020). The survey was sent in English and/or French. When possible, we targeted educators and/or curators, as they were the most likely to have access to the relevant information.

Once the survey was completed, participants were assigned a unique code that was used in the database and ensured anonymity throughout data processing (Andrews et al., 2007).

Statistical tests were performed in R version 4.1.0 (R Core Team, 2021). We wanted to test whether an increase in published field research on West and Central African lion populations was observed, including after the separate listing on the IUCN Red List. A chi-square goodness of fit test was used to detect significant differences between the observed and expected number of publications between time periods. Differences between the number of responses resulting from different contact methods used for zoos (categorical variables) were tested with a chi-square test of homogeneity, as we predicted that targeted e-mails would generate more responses than general e-mail addresses and contact forms. For both types of tests, we assumed our observations were independent. Expected values were above 5 and cells were mutually exclusive. Expecting that a higher number of visitors would bring more funding for zoos to invest in in situ projects, we used a rank-biserial correlation (Cureton, 1956), a nonparametric test, to assess the relationship between the number of annual zoo visitors (visitor level: 1; 2; 3; 4; 5; ordinal variable) and whether zoos funded in situ projects (dichotomous categorical variable). We calculated the rank-biserial correlation coefficient and its 95% Confidence Interval (CI). The value of the coefficient ranges from −1 (perfect negative correlation) to +1 (perfect positive correlation).

3 | RESULTS

3.1 | Overview of publications on wild lions

Our search yielded 949 results, of which 604 publications met our criteria and were selected for further analyses. The number of publications per year presented 7 times more publications in 2021 than in 2000 (Figure S1). Half of the publications focused on lion populations in Southern Africa ($n = 315$), followed by East Africa ($n = 171$, 27%). In comparison, lion populations from Central Africa, West Africa, and India represented 3% to 4% of the publications each (Figure 1). When broken down by country, most studies focused on South African lions ($n = 201$, 15%), followed by lions in Tanzania ($n = 136$, 10%; Figure 1).

Most publications belonged to the "Species Interactions" category, followed by "Human-Lion Interactions" and "Veterinary" (Figure 2). The majority of publications did not address a particular threat ("None," $n = 293$, 48%) but rather covered fundamental research questions (Figure 4). The primary threat addressed in lion research was anthropogenic killing ($n = 148$, 24%), whereas prey depletion was the least covered ($n = 20$, 3%; Figure 3).

Splitting the data into two 10-year periods revealed a significant increase in lion publications in West and Central Africa in the last decade ($n = 7$ publications in 2000–2009 versus $n = 24$ in 2010–2019, $\chi^2 = 9.3226$, $p < 0.01$). There was no significant difference ($\chi^2 = 0.16667$, $p > 0.05$) in the number of publications during the 6 years before and after the lion in West Africa was declared Critically Endangered in 2014 (Figure 4), with numbers remaining low. Although not an ideal comparison because of the different population sizes, the same analysis was performed on publications about East African (EA) and southern African (SA) lion populations, and the number of publications was found to be significantly higher after 2014 for both regions (EA: $\chi^2 = 7.0777$, $p < 0.01$; SA: $\chi^2 = 17.332$, $p < 0.01$) (Figure 4).

Most publications focusing on lions in West and Central Africa were classified as "Monitoring" ($n = 15$, 33%), followed by "Human-Lion Interactions" ($n = 7$, 13%), and "Genetics" ($n = 5$, 11%). Covered threats mirrored these categories, with 14 publications covering all threats and 9 publications covering anthropogenic killing specifically.

3.2 | Representation of lion ESUs in ex situ conservation

3.2.1 | Respondents profile

Surveys sent to targeted e-mail addresses resulted in more responses (55%) than for general addresses or through forms (27%) ($\chi^2 = 9.3338$, $p < 0.01$). Eighty-nine zoos participated (Table 1), 4 of which were not in our initial selection but were reached through zoo networks. Excluding these 4 zoos, our participation rate was 33%. All zoos but 5 hold lions in their facilities, and about 52% of them received 500,000 annual visitors or more (pre-COVID-19 records, Table 2).

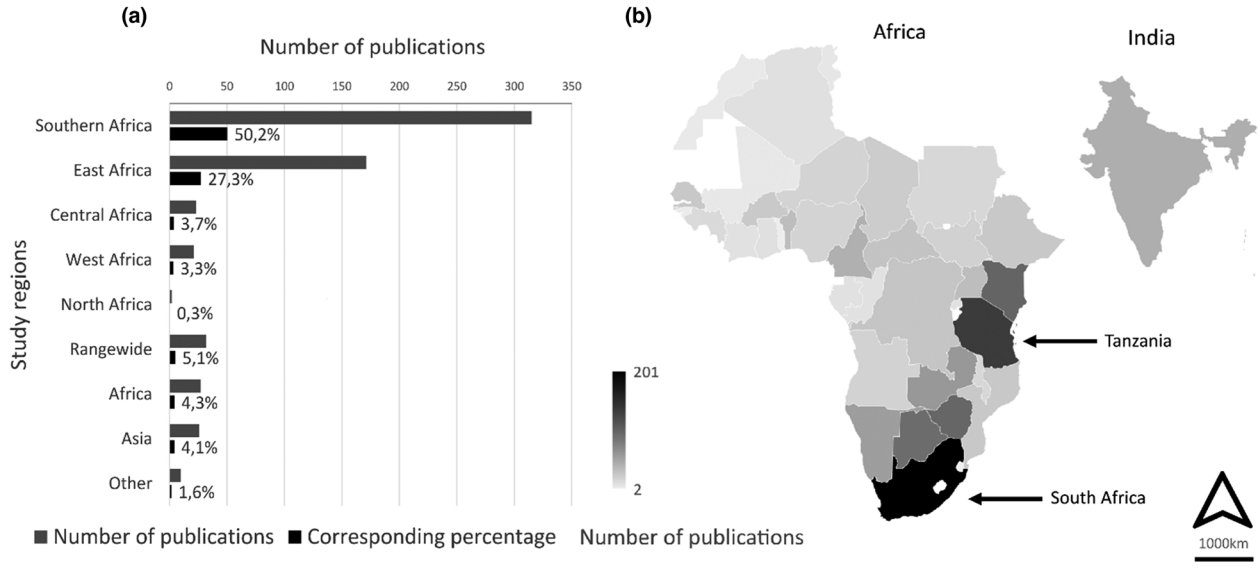

FIGURE 1 Geographical distribution of lion field research published between January 2000 and December 2021. (A) Number of publications on lions classified according to their study region ($n = 627$). (B) Number of publications on lions per country (study area) in Africa and India.

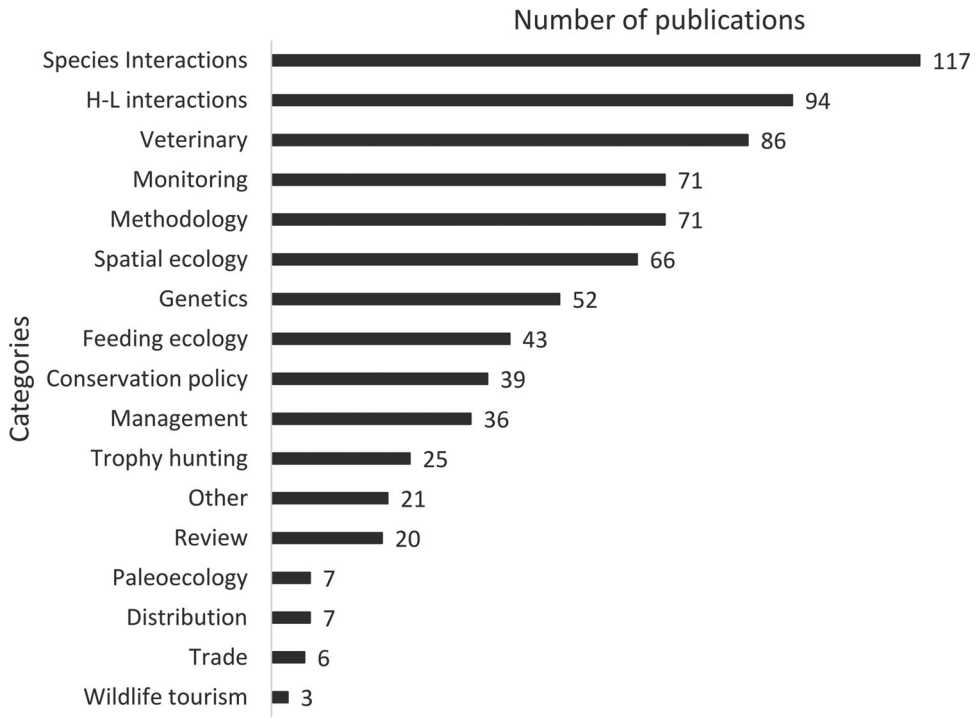

FIGURE 2 Number of publications ($n = 764$) on lion field research published between January 2000 and December 2021 according to the 17 categories we defined in Table S1. H-L = Human-Lion.

3.2.2 | Origins of lions held in zoos

We obtained 57 respondents providing clear information on the origins of lions held in their zoo (68%). A further 28 (33%) either answered that they were unsure, that the subspecies was unknown, or that their lions were of mixed origin. Out of 350 lions present in 84 zoos, only 14 held in 8 zoos were confirmed to belong to the West and Central African ESU (Figure 5).

TABLE 1 Geographical distribution of contacted zoos and respondents in our questionnaire survey about lions

	Number of zoos contacted	Number of participating zoos	Corresponding percentage (out of total participants)
Africa	12	6	6.7
Asia	41	9	10.1
Europe	111	53	59.6
North America	69	13	14.6
Oceania	13	6	6.7
South America	6	2	2.2
Total	**252**	**89**	**100**

TABLE 2 Number of annual visitors (for the year 2019) of participating zoos and whether zoos reported funding in situ lion conservation projects

Annual visitors	Number of respondents	Corresponding percentage	Number of zoos funding in situ lion projects	Number of zoos not funding any in situ lion projects	Number of zoos that did not answer the question about funding in situ lion projects
Less than 100,000	6	6.7	1	5	0
Between 100,000 and 499,999	36	40.4	12	20	4
Between 500,000 and 999,999	23	25.8	7	11	5
Between 1 and 3 million	20	22.5	6	14	0
Over 3 million	3	3.4	1	2	0
Not specified	1	1.1	0	0	1
Total	**89**	**100**	**27**	**52**	**10**

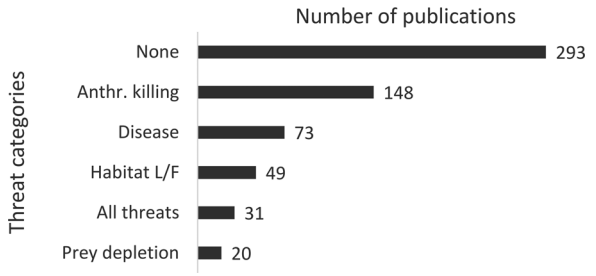

FIGURE 3 Number of publications on lion field research published between January 2000 and December 2021 per threat type ($n = 614$). Anthr. = Anthropogenic and L/F = Loss/Fragmentation.

3.2.3 | Education material about lions

Out of 89 participants, 64 (72%) answered that their conservation education material did not include the separate IUCN regional assessment for West African lions. Fifteen participants confirmed its presence in their material, whereas 10 were unsure of its presence. Five of the 8 zoos keeping lions from West or Central African origins mentioned the presence of the subspecies in their educational material.

When asked whether zoos provided specific information about the lion populations in West and Central Africa (i.e., their updated scientific name, phylogeny, regional population numbers, specific regional range, threats, or conservation status), 72% indicated that none of these elements were mentioned. At least one of these elements (average: 2–3) was mentioned by 23% of the respondents, and only one presented all six of them. Among these elements, phylogeny (i.e., explaining that these lions were more closely related to Asiatic lions than other African lions) was the least mentioned in conservation education material.

Despite the current lack of specific information on these populations, most zoos were interested ($n = 52$, 58%) or potentially interested ($n = 18$, 20%) in addressing this gap.

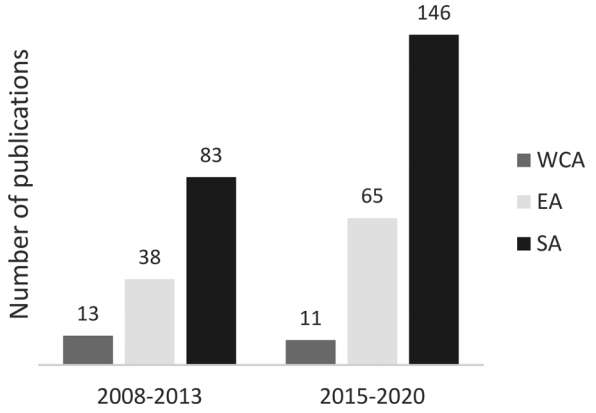

FIGURE 4 Number of publications on lion field research published per study region (WCA: West-Central Africa, EA: East Africa, SA: Southern Africa) for the 6 years before (2008–2013) and after (2015–2020) the lion in West Africa was declared Critically Endangered (2014) by the IUCN.

3.2.4 | Funding aspects

There was no link between the level of annual visitors and its funding for in situ lion projects (Table 2) (rank-biserial correlation coefficient = $4.27e^{-03}$, 95% CI [−0.26, 0.27]). Most of the respondents did not fund in situ lion projects, but when they did, they mostly funded eastern and southern African projects (Figure S3).

Out of the 89 participating zoos, 76% offered adoption schemes (a fundraising technique where visitors or organizations contribute financially to "adopt" a chosen animal, for its upkeep, for example). Among those, 51 propose to "adopt a lion," although actual lion adoptions represented a small percentage of total adoptions (median of 0.6%, IQR = 0.0–2.6) and were not necessarily used to fund in situ lion projects.

4 | DISCUSSION

Our study showed an unequal representation of ESUs both in in situ and ex situ conservation efforts, as well as funding allocation, preventing effective lion conservation across its range. These results could have been influenced by the grey literature that was not included in our data because of the chosen methodology. Indeed, conservation actions are sometimes preferred over research (McDonald-Madden et al., 2010) and obtaining information on these actions can be difficult if not confidential. The regional listing of the lion in West Africa as Critically Endangered on the IUCN Red List in 2014 did not significantly affect research efforts in the region. We recognize the relatively short timeframe considered, but still think the change in conservation status could have induced a sense of urgency, resulting in quicker action, funding and research productivity. Although Jarić et al. (2017) found similar results in research efforts on Critically Endangered species, accounting for other metrics (i.e., increase in the number of field conservation programs or funding allocation) could lead to a different conclusion (Betts et al., 2020). However, investigating these programs would involve sensitive funding information and a separate survey. Therefore, we decided this was outside the scope of this study.

4.1 | Biases in publications on wild lions

Bauer et al. (2003) and the IUCN/SSC Cat Specialist Group IUCN (2006) prompted the need for increased attention on lions from West and Central Africa. The number of publications on those taxa is still an order of magnitude less than for lions in other regions of Africa, which can partly be due to there being less lions in West and Central Africa. The lack of knowledge of local variations in several ecological parameters induces generalizations based on knowledge acquired from a subset of taxa from different geographic origins, resulting in conservation decisions that lack robustness (Britnell et al., 2021; Hickisch et al., 2019).

Within Africa, the South African and Tanzanian predominance in research and conservation was demonstrated by Di Marco et al. (2017) and further highlighted in Bauer et al. (2021). This was then confirmed for lion research in particular (Braczkowski et al., 2020; Sargent et al., 2021; Sobratee & Slotow, 2019), and for other large carnivores (Balme et al., 2014; Strampelli et al., 2022). Our study confirms that this extends to all research topics. The mismatch between research attention and conservation needs is not uncommon and has been observed across multiple carnivore species (Tensen, 2018), including leopard (Jacobson et al., 2016) and cheetah (Durant et al., 2017). Regional disparities can be explained by important barriers such as insecurity due to local conflict or terrorism, poverty, and corruption (Lhoest et al., 2022; Transparency International, 2016). These regions appearing riskier for investments (Dickman et al., 2015), scientific capacity is reduced by the lack of training opportunities and infrastructure of field sites (Hickisch et al., 2019). Difficulties of access, language barriers and permits further contribute to making these regions a low priority for conservation (Amano & Sutherland, 2013; Bauer et al., 2021). Recognizing these obstacles, we argue that these regions still need urgent support in conservation and research, under certain conditions outlined in our recommendations.

In West and Central Africa, human presence in and around unfenced protected areas encompasses several substantial direct and indirect threats (Henschel et al., 2016)

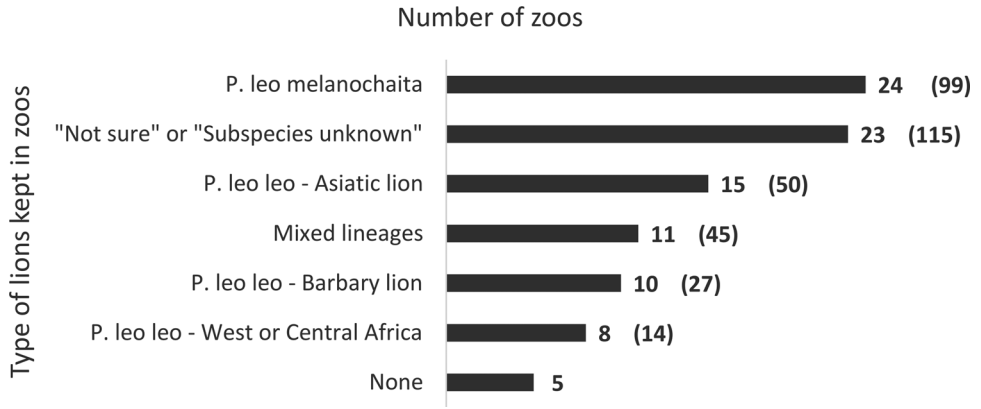

FIGURE 5 Number of participating zoos keeping each type of lion out of a total of 84 zoos. Some participants kept more than one taxon. The number of individual lions reported for each type is given in parentheses.

that are barely known and rarely studied. Few studies have specifically focused on evaluating mitigation methods for both lions and local communities. However, one publication included the results of several projects scattered throughout West and Central Africa (Bauer et al., 2010). This publication was also the only one including an outreach aspect, using local radio channels. Bauer et al. (2020) identified the two primary threats to lions throughout Africa to be retaliatory killing and prey depletion, but except for (Vinks et al., 2021), almost no article addressed or studied the latter.

Although many studies could indirectly contribute to lion conservation, almost 45% of the papers we reviewed did not clearly address one or more of the threats faced by lions. Balme et al. (2014) contradicted the perception that applied conservation research corresponds to less robust science, more logistical challenges and lower impact publications, but fundamental studies remain advantageous and accessible to academics.

Most national action plans (NAP) included in the "Conservation Policy" category were over 10 years old have not been updated since their publication, and have not had any follow-up monitoring and/or evaluation of conservation measures. All relevant countries had not developed a NAP.

4.2 | West and Central African lion populations lack conservation attention from ex situ institutions

Conde et al. (2011) reported a low representation of Critically Endangered species in the Species 360 database (online database on captive wildlife worldwide). We showed that this mismatch between species is also noticeable between subspecies of varying conservation statuses. Few individuals from West and Central African origins were reported in zoos. This can be explained by the combined effects of the fairly recent taxonomic change (distinguishing the northern and the southern subspecies (Kitchener et al., 2017), the logistical challenges involved in genetic testing, resulting in few zoos having proceeded to such testing as of yet (Bertola et al., 2018), the mixing of individuals which were previously considered as "generic" African lions (Bertola et al., 2018), and perhaps a difficulty in originally sourcing wild lions from these regions (lower population densities, political instability) compared to sourcing lions from Eastern or Southern Africa. A larger captive population would not necessarily contribute to the survival of wild populations through reintroductions (utilizing captive lions for in situ population supplementation has been discouraged for many reasons; see Hunter et al., 2013), but their presence in zoos remains important for fundraising and educational purposes.

The educational potential of zoo exhibits and their diverse array of conservation education material have been demonstrated and discussed thoroughly (Falk et al., 2007; Gippoliti, 2011; Moss et al., 2017), with evidence of a positive relationship between knowledge of a species and attitudes toward it (Godinez & Fernandez, 2019). In the present study, however, we highlighted that few zoos present information on lions in West and Central Africa, with only 10 participants mentioning the most up-to-date information on their conservation status. This lack of visibility to (inter)national visitors is an important missed opportunity to improve public awareness and support for lions in these regions.

Many disparities in financial support have been observed between zoos for in situ conservation (Miller et al., 2004). Accredited zoos (registered with WAZA) show an effort to increase in situ support, with more than US $230 million distributed to field conservation annually by AZA zoos (AZA, 2019) versus over US $22.5 million by EAZA zoos (EAZA, 2019). According to EAZA

(2019), a third of this amount is directed to conservation and research projects located in Africa. Yet, we found that less than half of the interviewed zoos reported funding in situ lion conservation projects, and similarly to Mallon et al. (2015), mostly in Eastern and/or Southern Africa.

4.3 | Eight recommendations for a more effective conservation practice

The intensity of research and conservation observed in Eastern and Southern Africa leads by example. If we want to improve the status of all ESUs and preserve genetic diversity, we encourage role-players involved in conservation to shift some of their efforts and funding to the regions and taxa that most need it. We highlight some steps that could be taken in lion conservation in Figure 6 and believe these could be helpful for other species' conservation.

4.3.1 | Expanding research capacity in West and Central Africa

Representation of all different ESUs and threats is crucial for developing appropriate conservation strategies. Producing more inclusive research outputs can be achieved by strengthening partnerships with local research institutions and researchers in West and Central Africa, for example by providing training opportunities (scholarships) for students and early-career researchers or funding for research facilities (Blicharska et al., 2017). Training opportunities in Africa have been listed in the Guidelines for the Conservation of Lions in Africa (IUCN SSC Cat Specialist Group, 2018), which could be extended to these regions.

It is important that any relevant reports from conservation projects in West and Central Africa are made available to local managers and wildlife authorities. To help maximize access and readership, we encourage the publication of titles and/or abstracts in English, French and/or Portuguese (Amano et al., 2016), and popularizing scientific findings in local and social media (Wilson et al., 2016).

4.3.2 | Filling the gap in research topics

Applied research that directly informs conservation practices and policy has been encouraged (Balme et al., 2014; Game et al., 2015), and addressing threats to wildlife is ever more needed for efficient conservation strategies. We strongly recommend a continued expansion of research topics (Figure 6), particularly those pertaining to human dimensions of wildlife, as well as epidemiological studies (Croes et al., 2008) for a better understanding of local threats and how to mitigate them (Bauer et al., 2020).

4.3.3 | Updating, implementing, and monitoring conservation efforts

We identified a need for updated regional and/or national conservation action plans. Such plans guide national priorities and define specific actions required to ensure long-term healthy populations. To ensure the implementation and monitoring of conservation actions, experts recommend appointing a National Coordinator for accountability and oversight of project actions (IUCN SSC Cat Specialist Group, 2018). Maintaining survey efforts will be important, especially in regions that have not yet been systematically surveyed for lion presence if/when the local security context allows it (e.g., parts of Guinea, Mali, Burkina Faso, Nigeria, the Central African Republic; Henschel et al., 2010).

4.3.4 | Supporting in situ conservation projects in West and Central Africa

Establishing stronger connections and expanding capacity-building opportunities between zoos and in situ projects will directly impact species conservation in the wild. This would be facilitated not only by monetary support but also staff expertise (Ancrenaz et al., 2018; Olive & Jansen, 2017), collaborations with locals, and outreach programs (Figure 6).

4.3.5 | Updating educational material

We urge zoos to include more information on the conservation status of and threats to biodiversity in West and Central Africa in particular, in line with the World Zoo and Aquarium Conservation Education Strategy (Thomas, 2020), which promotes educating the public for "social change for conservation."

4.3.6 | Strengthening cooperation between zoos keeping lions from West and Central African origins

Maintaining viable captive populations with a reduced number of founders is challenging and calls for effi-

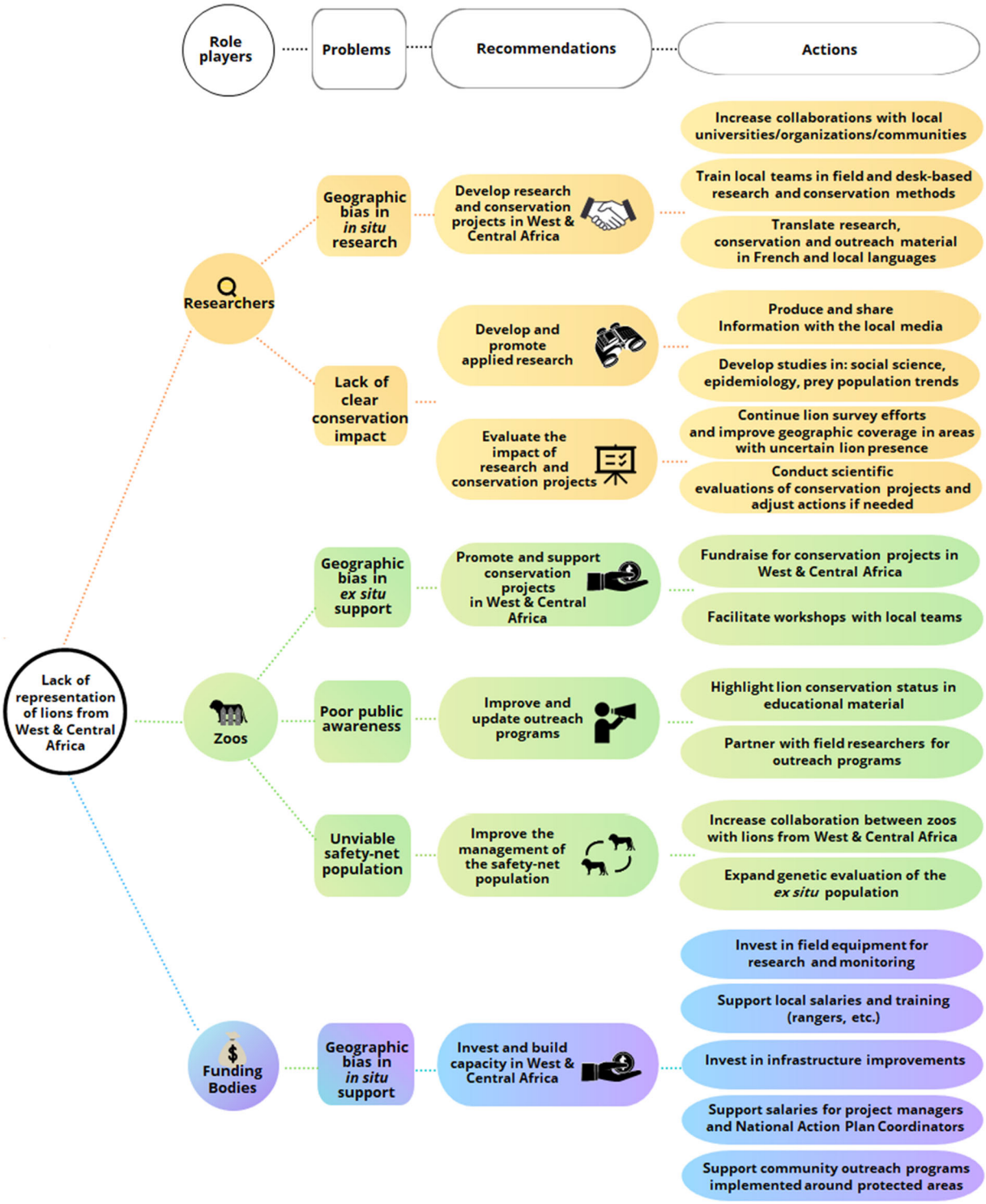

FIGURE 6 Recommendations to adapt conservation efforts for a more inclusive conservation of lion across its range.

cient and cooperative ex situ population management plans (Conde et al., 2013), which could form part of a One Plan Approach (Byers et al., 2013). The geographical proximity between zoos would be ideal for potential exchanges (Conde et al., 2013). As of yet, France appears to be a hotspot for such zoos. This "specialization" could be further developed for future practicalities.

4.3.7 | Genetic testing of captive lions

Zoos are encouraged to do genetic testing on their lions when their genetic cluster is unknown. This could lead to the identification of additional individuals belonging to the West and Central African genetic clade. Improved genetic information could result in alternative management decisions in terms of breeding and exchanges between zoos. The scale and methodology of such efforts could be replicated from the project on the captive population of Eurasian lynx (*Lynx lynx)* in European zoos (Lengger et al., 2021).

4.3.8 | Directing more funding to conservation projects in West and Central Africa

Rethinking investments in research and biodiversity conservation is of critical importance in West and Central Africa. Increasing funding from governments, NGOs, zoos, or businesses into these regions could have positive effects on biodiversity conservation (Mallon et al., 2015; Scholte, 2022), especially if allocated to protected area management (Henschel et al., 2016; Henschel et al., 2014; Lindsey et al., 2017, 2018; Riggio et al., 2013) (Figure 6). Governments can attract more funding by improving the sociopolitical landscape and increasing their conservation agenda (Bruner et al., 2004). Additionally, funding bodies could insist on collaborations with local institutions and the inclusion of monitoring of conservation actions in their requirements (Bruner et al., 2004). Emerging solutions involving carbon credits, such as the Lion Carbon program, a partnership developed between Lion Landscapes and BioCarbon Partners, could be a source of funding, particularly in lion range countries in Central Africa (Tear et al., 2021).

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DATA AVAILABILITY STATEMENT

The data generated or analyzed during this study are publicly available in the figshare repository (https://figshare.com/s/fa32029ac3aac13a9d72).

ETHICS STATEMENT

Ethics approval for the online survey was obtained from the Natural and Agricultural Sciences Ethics Committee from the University of Pretoria (NAS291/2020).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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