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Evaluating the performance of conservation translocations in large carnivores across the world

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ABSTRACT

Globally, fragmented landscapes and other anthropogenic pressures are causing declines in large carnivore populations. Conservation organizations are working to counteract these trends through the translocations of large carnivores, for example by reintroducing them to their historic ranges or by reinforcing existing populations to promote gene flow and resilience. This study analyses a dataset gathered from 33 translocation projects involving 297 individual animals across 22 countries in five continents, with 18 different large carnivore (>15 kg) species surveyed. An overall success rate (survival > six months) of 66 % for all individuals was shown for large carnivores, indicating an above average success rate when compared to the translocation of other terrestrial vertebrates. While captive-born individuals still fared worse than wild-born individuals, a 32 % increase in success rates was observed for releases of captive-born individuals within the last 14 years compared to a 17 % increase in success for releases of wild-born individuals. Despite the encouraging trends in metrics of success, only 37 % of study individuals were observed engaging in reproductive behavior. While this is likely an under-count, we caution against the conflation of translocation success with population establishment. We also identified key choices in the decision tree facing those implementing translocations, and analyzed associated metrics of success. Critical decisions include whether or not to use soft-releases, choosing younger animals, selecting unfenced release locations, and sourcing wild-born individuals – all of which can lead to a higher likelihood of success. As the UN Decade of Ecosystem Restoration gets underway, we hope this information can assist decision makers and practitioners in achieving more desirable outcomes for conservation translocation of large carnivores.

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Table 1
Definition of seven fixed effect predictor variables used in the analyses.

Predictor variable	Definition
Fence	1) Unfenced: no restriction on animal movements; and 2) fenced: human-made barriers which restrict animal movements following translocation.
Release type	1) Soft-release is the acclimatization of an animal for a period before release at the release site; and 2) hard-release is the immediate release of an animal directly after translocation (Resende et al., 2021).
Origin	1) Wild-born: animals born in their natural environment; 2) period of captivity: wild-born animals with a period of captivity lasting over 10 days excluding soft-release periods; and 3) captive-born: animals born in captivity.
Sex	Male or female
Age	Adult (> 2 years) and young (≤ 2 years). This threshold was based on development across carnivore species and beginning of dispersal patterns, and while it is not uniform across species this was a clear threshold which appeared in many studies (Robinson et al., 2008; Greenberg and Holekamp, 2017).
Family	Taxonomic family (4 levels)
Year	Year in which the translocation took place

Table 2
Number of individuals and success rates for different predictor variables affecting conservation translocations. 16 individuals were deleted for no post release monitoring.

Predictor variable	Predictor variable level	Number of individuals	Success rate
Fence	Fenced	50	56 %
	Unfenced	231	71 %
Release type	Soft-release	112	82 %
	Hard-release	135	60 %
Origin	Wild-born	146	70 %
	Period of captivity	65	72 %
	Captive-born	70	64 %
Sex	Male	127	72 %
	Female	118	69 %
Age	Adult (> 2 years)	151	71 %
	Young (≤ 2 years)	56	87 %

1. Introduction

Conservation translocations are a key component for many rewilding efforts (Hayward et al., 2019; IUCN/SSC, 2013). Defined as the intentional movements of an animal to create some form of conservation net gain (Seddon, 2010), conservation translocations can pursue different purposes, such as reintroducing a species to an area where it has been extirpated (Seddon et al., 2007), or reinforcing an existing population to increase its viability (IUCN/SSC, 2013). Alternatively, it can be carried out as an assisted colonization to move a species to the periphery of its historic range in order to avoid the pressures of habitat destruction or climate change (McLachlan et al., 2007: Rozhnov et al., 2021).

The reported success rate of conservation translocations of vertebrates has been highly variable, such as 26 % (Fischer and Lindenmayer, 2000), 47 % (Resende et al., 2020), 56 % (Bubac et al., 2019), and 67 % (Wolf et al., 1996). The variability arises partly from the selection of inconsistent metrics of success and the diversity of challenges posed by the different taxa targeted in each study. Carnivores of captive-bred provenance tended to have a lower success rate in translocations compared to wild-sourced animals (32 % vs. 53 % of individuals, respectively; Jule et al., 2008). Similarly, the change in success percentages over time showed discrepancies between studies (Bubac et al., 2019; Morris et al., 2021). While the IUCN *Guidelines for Reintroductions and Other Conservation Translocations* has helped standardize this practice, discrepancies, inconsistencies and ambiguities remain with the potential to confuse managers and decision-makers assessing the evidence.

Globally, large carnivores generally currently exist at historically low population levels within fragmented landscapes (Crooks, 2002; Crooks et al., 2017). With their critical role within ecosystems in jeopardy (Estes et al., 2011), large carnivores often need active conservation interventions, sometimes in the form of translocations, to ensure gene flow and viable populations (Zemanova et al., 2017; Farhadinia et al., 2020). Recently, translocations for the purpose of reinforcement or reintroduction have been proposed more frequently, increasingly with government support, e.g. for leopards (*Panthera pardus*) (Breitenmoser et al., 2014; Kharchenko et al., 2019; Rozhnov et al., 2019), cheetahs (*Acinonyx jubatus*) (Buk et al., 2018), tigers (*P. tigris*) (Qin et al., 2015; Chestin et al., 2017; Gray et al., 2017; Gray et al., 2020; Rozhnov et al., 2021), Eurasian lynx (*Lynx lynx*) (Ovenden et al., 2019) and wolves (*Canis lupus*) (Ditmer et al., 2022). Also, there is an interest to utilize orphaned and rehabilitated individuals obtained from the illegal wildlife trade or exhibition facilities, such as cheetahs, in these efforts (Boast et al., 2018; Warmenhove et al., 2021; Walker et al., 2022). Similarly, translocation is sometimes used to mitigate human–wildlife conflict, such as American black bears (*Ursus americanus*) (Bauder et al., 2021) and leopards (Weise et al., 2015), and human-wildlife impacts, such as puma (*Puma concolor*) (Adania et al., 2017). Globally, there is a general emphasis on rewilding associated with the UN announcement of the 2020s as the decade on ecosystem restoration (Cooke et al., 2019; UNEP, 2019). Inspired by this political opportunity, further research is desirable to enhance the success of conservation translocations, especially because carnivores can deliver cascading ecosystem effects and act as key charismatic ambassadors globally in marketing conservation and translocation efforts (Macdonald et al., 2017; Evans et al., 2022).

Following the seminal paper by Jule et al. (2008), which analyzed 2152 translocations for 17 Carnivore species (of which only 11 species were large carnivores, i.e. >15 kg (Ripple et al., 2014)) between 1990 and 2007, the field of wildlife ecology has benefitted considerably from advances in animal-tracking using a diversity of techniques (Hofman et al., 2019). These techniques enable researchers to monitor post-release success. The tracking of translocated carnivores with animal-borne electronic tags is common in areas such as southern Africa and North America (Weise et al., 2015; Bauder et al., 2021; Walker et al., 2022) and the resulting insights from these advances can further our understanding.

Here, we critically evaluated the performance of conservation translocations of large carnivores globally. We first documented the scope, in terms of both geography and species, of recent projects (2007–2021) in comparison to older initiatives (pre-2007; Jule et al., 2008). Then we quantified how management actions are associated with the success of conservation translocations in large carnivores. We hypothesized that captivity (Jule et al., 2008; Shimozuru et al., 2020) and greater age (Miller et al., 1999) would be associated with poorer survival of translocated individuals. Additionally, we tested the expectation that fenced release sites and soft-releases (i.e., with an acclimation period at the release site) would lead to higher success rates than releases in unfenced areas (Packer et al., 2013) and hard-releases (i.e., without an acclimation period) (Resende et al., 2021). Our study provides the most geographically comprehensive sample of conservation translocations for large carnivores to date, thereby providing the evidence enabling scholars and decision-makers to improve restoration practices.

2. Material and methods

2.1. Data collection

A literature review was conducted following the principles and processes suggested by Vetter et al. (2013) and Alston et al. (2019). We focused on megafaunal terrestrial carnivores defined as all terrestrial carnivore species with a maximum weight of greater than or equal to 15 kg (Ripple et al., 2014), and on translocations after 2007 to minimize

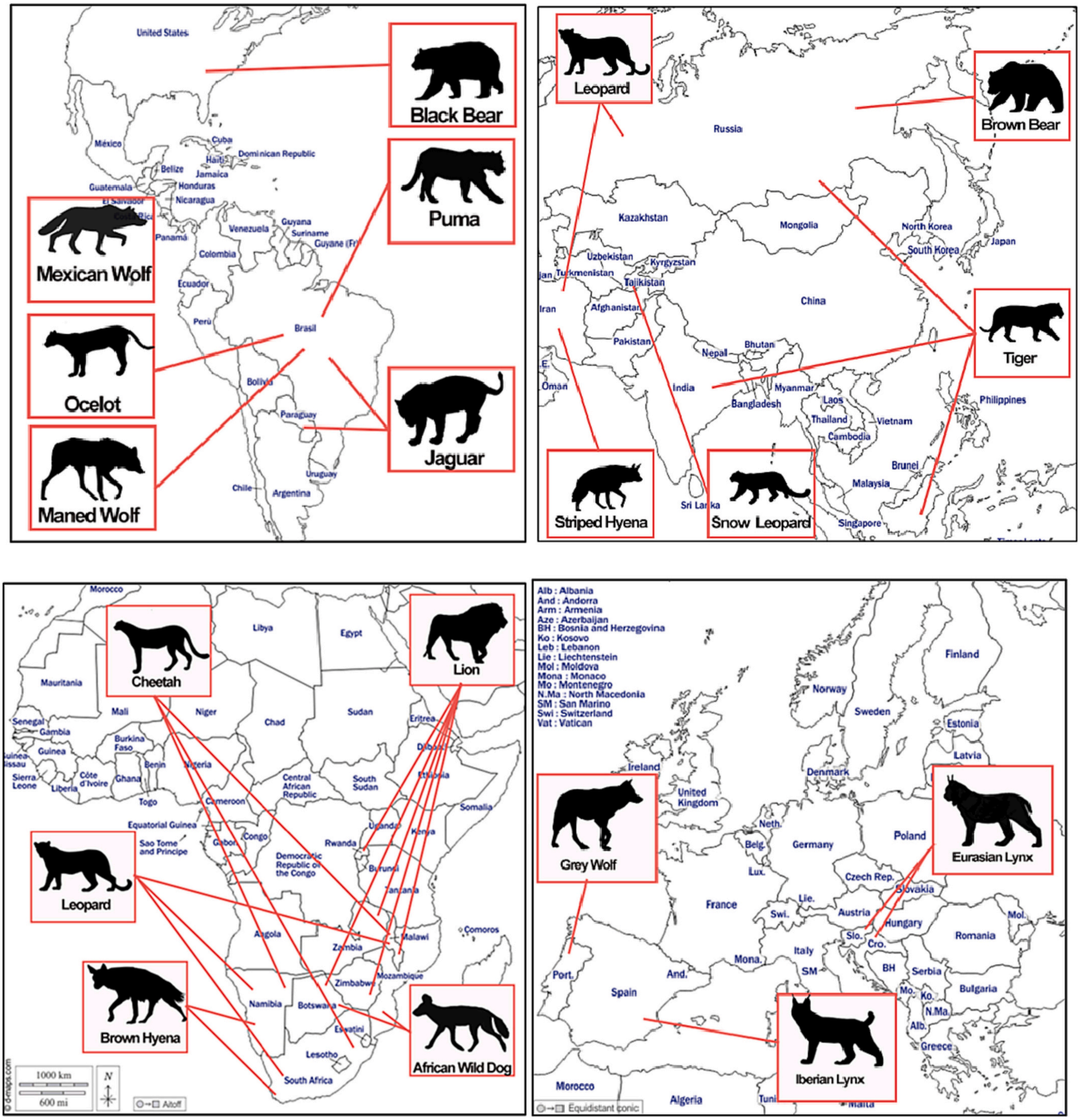

Fig. 1. Global distribution of obtained records of large carnivore translocations between 2007 and 2021 in A) the Americas, B) Asia, C) Africa and D) Europe.

overlap with previous studies such as Jule et al. (2008), while nonetheless attending to similar parameters. This facilitated the evaluation of conservation translocation projects within the context of recent advances in carnivore ecology and conservation.

The search engine Web of Science was used for primary screening and Google Scholar was utilized to supplement the original findings. Boolean string theory and wild cards were used in search term design to capture the widest variety of possible papers that would meet the required criteria while also filtering out papers not relevant to our study. Inspiration for search term selection was taken from previous reviews, such as the paper by Morris et al. (2021), which included terms like: reinforce*, reintroduc*, "assist* migration", restor*, introduc*, translocat*, and "conservation transloc*. The term rewild was added due to its rising popularity and the intention to measure its increase in use over the study period. The sections (carnivor* OR predator*) and NOT (Entomolog* OR Insect* OR Bug* OR Fish* OR marin* OR Fossil* OR Invasive* OR Bird* OR Avian* OR Rat* OR tortoise*) were added to attempt to limit our study towards its scope of large mammalian carnivores based on the initial pool of results that was generated from the search terms.

The final search terminology was: (carnivor* OR predator*) AND (reinforce* OR reintroduc* OR rewild* OR "assist* migration" OR restor* OR introduc* OR translocat* OR "conservation transloc*") NOT (Entomolog* OR Insect* OR Bug* OR Fish* OR marin* OR Fossil* OR

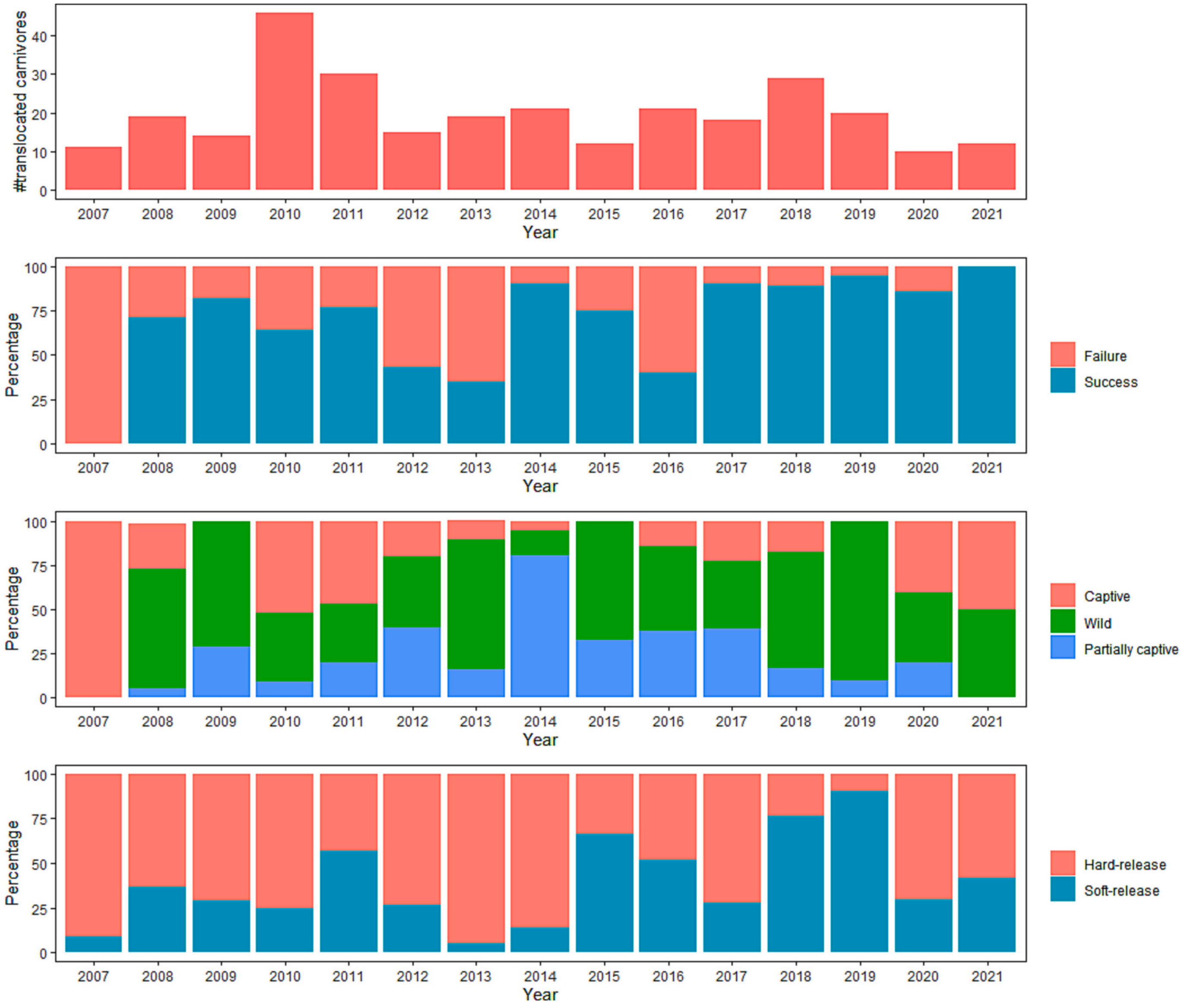

Fig. 2. Top to Bottom: A) Number of individuals translocated each year; B) individual success rates by year C) percentage of captive-born, period of captivity, and wild-born animals released per year and D) percentage of hard- and soft-releases per year.

Invasive* OR Bird* OR Avian* OR Rat* OR tortoise*). This was the format that was used in Web of Science searches, while in Google Scholar the same terms were used, but the wildcards were removed as that platform integrates these automatically into the search. We scoped our search for publications between 2007 and 2021.

In total, we obtained 1434 results on the Web of Science. After initial screening, 42 titles were extracted with 12 papers passing the final evaluation for the purposes of this study. Screening criteria were the inclusion of basic information about the translocation project, including the outcome. Three additional papers were included in our analyses based upon searches conducted on Google Scholar and collaborator input. All copies of the IUCN Global Re-introduction Perspectives reports from 2007 to 2021 were also reviewed for possible project inclusion.

Due to the lack of publicly reported carnivore translocation outcomes, it was also necessary to integrate unpublished data sets into the analysis. Through publications and connections to government projects and non-governmental organizations (NGOs), project coordinators were contacted about possible unpublished data. Through this process 11 NGO program unpublished datasets were collected using an electronic questionnaire and formatted data-entry sheet. Combined with the information garnered from the literature review and conference paper collection, this led to the inclusion of 33 different projects with 297 individual animals in the database developed for this study.

Following previous works evaluating the outcome of conservation translocation projects (Bubac et al., 2019; Jule et al., 2008; Morris et al., 2021), the response variable success rate was defined as the binary of success (survival in the wild after 6 months) or failure (death or recapture before 6 months). We chose this standard because 6 months is a common threshold that appears in other relevant literature (such as, Jule et al., 2008), and it is the most consistent minimum monitoring commitment undertaken by project managers. We also defined seven predictor variables including Age, Sex, Origin, Fence, Release style, Year, and Family. A detailed description of all predictor variables is provided in Table 1. While we measured translocation success exclusively based upon survival, we also collected data on reproduction. Reproductive behavior was defined as mating, raising a cub or accompanying the opposite sex in the case of solitary species.

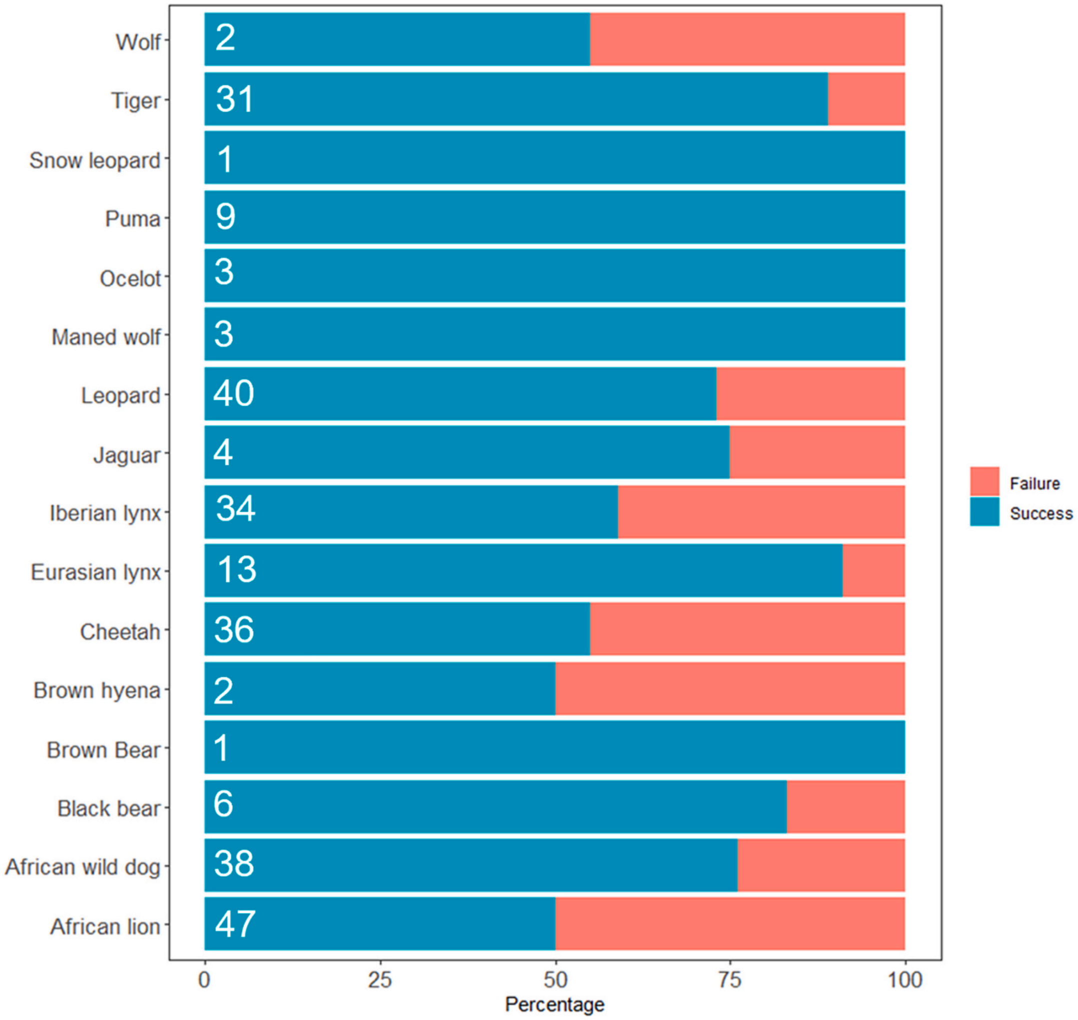

Fig. 3. Success rate by species for translocated animals based on 267 individual carnivores monitored post-translocation between 2007 and 2021. The numbers in each bar indicate the total number of individuals considered for each species. Numbers on the left indicate sample size.

2.2. Data analysis

We conducted a chi-square test to measure associations between the categorical variables on the success or failure outcome. We fitted 19 generalized linear mixed models (GLMM) with a binomial distribution and logit link, and the success rate as the binary response variable was success or failure. Seven categorical predictor variables (Table 1) were included as fixed effects while species was used as a random effect. Interactions between variables were also tested to see which combination could create the model with the best predictive capacity. All statistical analyses were run in RStudio 1.4.1103 (R core team, 2021). The “lme4” package (Bates et al., 2015) was used to fit all these models with the default Laplace Approximation for estimating maximum likelihood and the “bbmle” package (Bolker et al., 2021) was used to weight all models based on Akaike's information criterion (AIC). This enabled examination of several competing models or hypotheses simultaneously to identify the best set of models via information criteria such as the AIC (Burnham and Anderson, 2002). Models within <2 of the ΔAIC score were examined. We also calculated the R^2 as a measure of the goodness-of-fit of a model, summarizing the amount of variance explained in a model using the package “MuMIn” (Bartoń, 2009). Also, the package “effects” (Fox et al., 2016) was used for graphical effect displays of the model variables. Finally, we calculated the odds ratio as the exponentiated coefficient for the value of the intercept as the odds of a success.

3. Results

We obtained data on 297 translocated individual large carnivores between 2007 and 2021, representing 18 species from four families: Felidae, Canidae, Ursidae and Hyaenidae (Table 2 and Fig. 1). We excluded 5.7 % (n = 17) of translocated individuals because of a combined lack of post-release monitoring and reported outcomes. This resulted in the inclusion of 280 individuals, ranging between 1 and 47 individuals per species and differing between 6 and 46 individuals per year during the period 2007–2021 (Fig. 2A). Our records span 22 countries on five continents (Fig. 1), with Africa the provenance of 50.8 % of the data (n = 151). The inclusion of post-release reproduction information following translocations revealed that reproductive behavior was recorded in 37 % (n = 109) of cases.

The overall success rate of translocations for all individuals irrespective of species was 66 %, varying between 94 % in South America (n = 19) and 62 % in Africa (n = 151). Translocations of canids and felids yielded high success rates (73 %; n = 53 and 67 %, n = 219, respectively), although it was the highest for ursids (86 %; n = 7; Fig. 3). However, there was no evidence that the success rate significantly differed among families (the family as a predictor variable in GLMM models was non-significant; Table 3). Wild-born carnivores were translocated more often, comprising 49.1 % of individuals translocated comparing to those that had experienced a period of captivity (21.8 %) and captive-born individuals (27.6 %; $X^2 = 15.97$, $df = 2$, $P < 0.05$;

Table 3
Results of 19 GLMM models testing the relationship between covariates and the success rate of 297 large carnivore translocations between 2007 and 2021. Species was included in all models as the random effect.

Model number	Model	df	AIC	ΔAIC	AIC weight
1	~ Sex * Age + Fence + Release + Origin	9	195.94	0.00	0.69
2	~ Sex * Age + Fence + Release + Origin + Family	12	198.46	2.52	0.20
3	~ Sex * Age + Fence + Release + Origin + Family + Year	13	199.67	3.72	0.11
4	~ Age	3	210.85	14.91	0.00
5	~ Sex + Age	4	212.57	16.62	0.00
6	~ Age * Origin	7	212.81	16.86	0.00
7	~ Sex * Age + Year	6	213.89	17.95	0.00
8	~ Sex * Age	5	214.44	18.50	0.00
9	~ Fence + Release + Origin	6	260.20	64.26	0.00
10	~ Fence + Release + Origin + Family	9	261.62	65.68	0.00
11	~ Fence * Release	7	263.73	67.79	0.00
12	~ Release	3	264.98	69.03	0.00
13	~ Sex	3	278.99	83.05	0.00
14	~ Year	3	316.49	120.55	0.00
15	~ Year + Family	6	320.93	124.99	0.00
16	~ 1	2	326.26	130.31	0.00
17	~ Fence	3	327.20	131.26	0.00
18	~ Origin	4	329.30	133.35	0.00
19	~ Family	5	331.26	135.32	0.00

Table 4
Maximum likelihood estimates corresponding to the best performing GLMM model: Success rate ~ Sex * Age + Fence + Release + Origin. Only significant variables are reported.

Parameter	Estimates from best performing model		*P* value
	Coefficient estimate	Standard error	
Age (young)	1.24	0.71	0.08
Fence (unfenced)	2.37	0.67	< 0.05
Release type (soft-release)	2.49	0.70	< 0.05
Origin (captive-born)	−1.54	0.78	0.04

Fig. 2C). Similarly, hard-release marginally dominated the release type, accounting for 57.4 % of translocations ($X^2 = 2.90$, $df = 1$, $P = 0.09$; Fig. 2D). Adults (71.8 %, n = 153) dominated the age structure of the translocated carnivores ($X^2 = 21.36$, $df = 1$, $P < 0.05$) whereas both sexes contributed almost equally to the translocations (F: 48.2 % vs. M: 51.8 %; $X^2 = 0.16$, $df = 1$, $P = 0.68$). In Table 2, the success rate for all levels of the predictor variables is reported. African lion and cheetah translocation accounted for 92 % (n = 46) of releases into fenced areas.

The highest ranked model (ΔAIC <2) for predicting success rate for all individuals irrespective of species contained the effects of Fence, Release, Origin, Sex and Age, the latter two interactively with the AIC weight = 0.69 (Table 3). We found evidence for relationships between four predictor variables and the success rate (Table 4; Fig. 4). However, our linear model had limited explanatory power ($R^2 = 0.49$), suggesting that relationships, although general, were moderately strong. Surprisingly, individuals with a period of captivity had a higher rate of success in translocations ($\beta = -1.54 \pm$ SE 0.78, $P = 0.04$) than wild-born large carnivores. Translocations which were conducted in unfenced areas were associated with higher success rate ($\beta = 2.37 \pm$ SE 0.67, $P < 0.05$) than those in fenced areas. Translocating younger individuals tended to achieve a marginally higher success rate ($\beta = 1.24 \pm$ SE 0.71, $P = 0.08$) than adults. Release type was also associated with the success rate, with soft-release accounting for a higher success rate ($\beta = 2.49 \pm$ SE 0.70, $P < 0.05$; Table 4; Fig. 4). Sex showed no evidence of difference in the success rate.

Finally, regarding the provenance of translocated individuals, we found that using captive-born large carnivores decreased the odds of success by a factor of 1.5-times (CI 95 % 0.0–3.1) while releasing in unfenced areas increased the odds of success by 2.7-fold (CI 95 % 1.0–3.7) and soft-release increased the odds of success by a factor of 2.5-times (CI 95 % 1.1–3.9).

4. Discussion

Our study revealed that, the overall success of translocations was 66 % across the 18 species of large carnivores, a markedly higher rate than that documented for all species (54 %; Bubac et al., 2019). We also recorded higher success rate for conservation translocation of large carnivores between 2007 and 2021 comparing to the past, i.e., pre-2007. For example, the success rate was 70 % for wild-born carnivores whereas it was 53 % documented pre-2007 (Jule et al., 2008). Similarly, the success rate for captive-born large carnivores doubled from 32 % in pre-2007 (Jule et al., 2008) to 64 % in our data. The geographical spread of large carnivore translocation has also doubled from 11 countries pre-2007 (Jule et al., 2008) to 22 countries in our study.

4.1. Management corollaries of success

Previous research had suggested that the translocation of captive-born large carnivores tended to be less successful than translocating wild-caught animals (Jule et al., 2008; Weise et al., 2015; Boast et al., 2018). Although this tendency is weakly apparent in our more contemporary sample, it is much less pronounced and reveals confounding effects on the survivorship of released animals. Surprisingly, wild-born animals that had experienced a period in captivity (excluding holding in soft-release enclosures) had a very minor difference in likelihood of survival after the translocation than other wild-born individuals. This could be due to the increased temporal availability of ideal release dates for partially captive animals (Facka et al., 2016).

Although our results do not offer a definitive conclusion on the relative merits of soft- and hard-release, our conclusion aligns with Resende et al. (2021) who found in a study of 17 species (primarily mammals, but also including reptiles and birds) that soft-releases led to a higher likelihood of success. One component which could influence this increase in success for large carnivores is pre-release training, but this methodology is not often reported in the literature regarding individual translocations (Houser et al., 2011; Walker et al., 2022). It is noteworthy that soft-releases are likely to incur substantially greater costs than hard-releases (Weise et al., 2014).

We report a marginal effect of age on the success rate of large carnivores following translocations, skewing towards young animals. While age must be considered relative to lifespan, large carnivores have longer lifespans than small carnivores allowing for a larger period in which this differential success can materialize (Holliday, 2006). Younger animals have greater behavioral plasticity allowing them better to adjust to new environments (Gross et al., 2010) and younger animals may lack the homing tendencies that are characteristic of older carnivores within the 1–2 year age-group (that being a common age-group for dispersal in large carnivores (Bradley et al., 2005)). Young adults within this 1–2 year age ranged are likely the best candidates for translocation (Tetzlaff et al., 2019).

Contrary to our expectation, translocations to unfenced areas fared better than those to fenced areas. Fencing allows carnivores to persist at higher population densities (Packer et al., 2013) and it ensures site fidelity and prevents homing, which are major concerns for translocated and introduced carnivores (Bradley et al., 2005). Higher carnivore densities supported by fencing were beneficial (Packer et al., 2013), notwithstanding any risks associated with living close to carrying capacity (Packer et al., 2013).

The fenced reserve system in southern Africa (which is well organized and financed), where most of these fenced translocations took place (92 %), includes multiple large carnivore species and often had

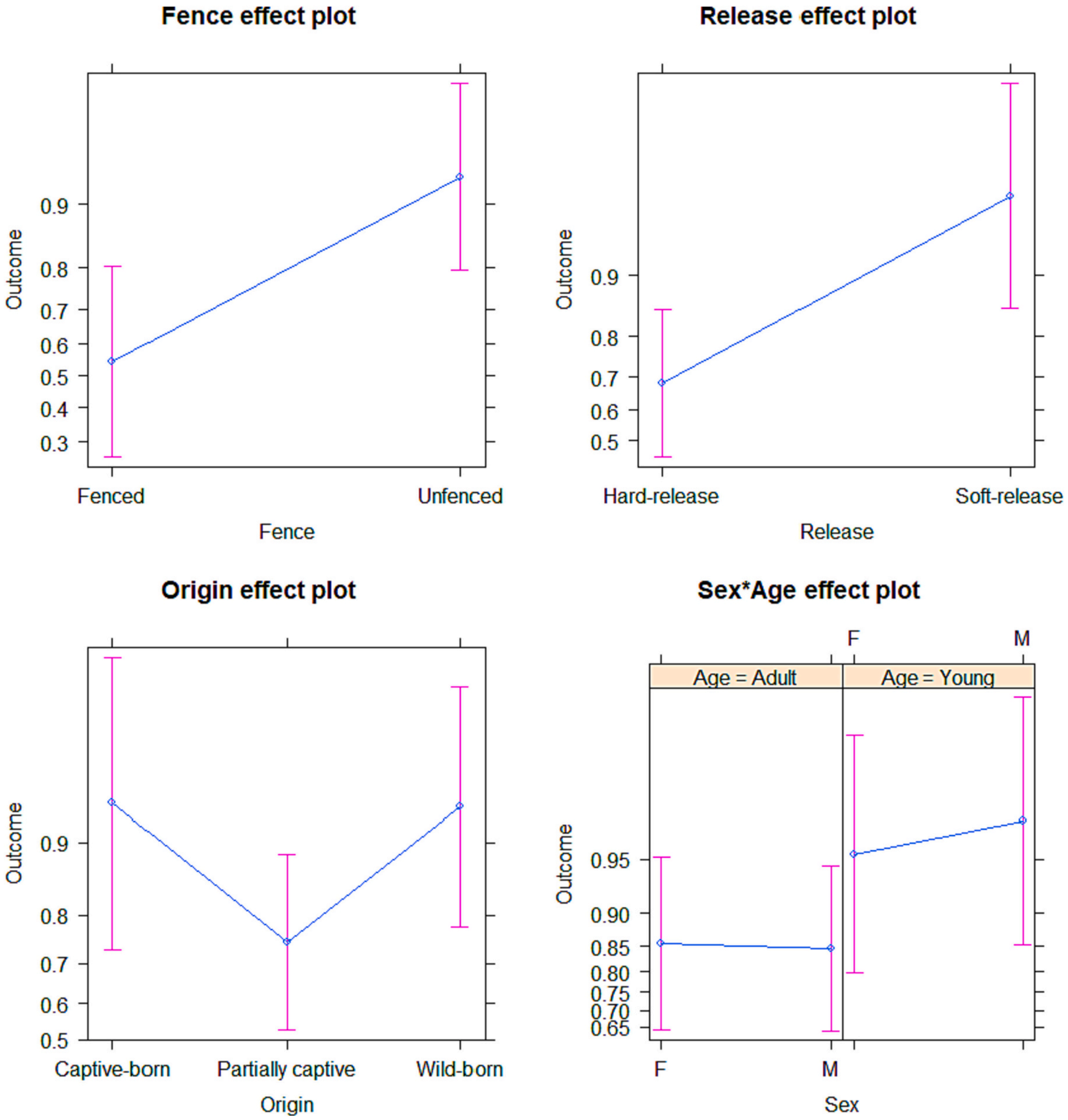

Fig. 4. Effect displays for the best performing GLMM model: Success rate ~ Sex * Age + Fence + Release + Origin.

high densities of conspecifics (Swanson et al., 2014; Miller et al., 2015; Davies-Mostert et al., 2015). Research on the ways in which African lions depress African wild dog populations has shown that prey depletion may exceed the effect of direct conflict (Goodheart et al., 2021). Similarly, cheetahs in fenced reserves with higher densities of large carnivores fared worse than those in fenced reserves without large carnivores (Bissett and Bernard, 2011).

This co-existence in close proximity leads to spatio-temporal resource partitioning by the large carnivores as well as possible aggressive intra-specific interactions, which could influence translocation success and depress populations due to the competition (Bissett and Bernard, 2011; Wolf and Ripple, 2016; Evers et al., 2022). Evidence of the negative influence of interspecific competition on survival rates has been recorded for captive-born leopards released into the Russian Caucasus (Hernandez-Blanco et al., 2021). Therefore, in fenced settings with finite resources available and higher carnivore densities, outcomes are likely to be affected by these added pressures.

Three limitations to understanding are that many studies do not report the duration of captivity prior to release, the densities of conspecifics at release sites, or the specific circumstances of the animal's transport and potential period of captivity. That duration in captivity clearly impacts an animal's habituation to human interactions and thus affects its likely survival in the wild (Jule et al., 2008). Densities and sex ratios of conspecifics at a release site probably affect not only the survival of the translocated individual, but also its reproductive success. Individuals released into reintroduction sites may benefit from reduced competition in the absence of resident conspecifics and therefore breed at a younger age than normal (Hunter, 2007; Boast et al., 2018). Implementing baseline surveys of resident conspecific populations prior to release could help with individual selection and improving success rates in translocation projects.

Reproductive success is the ultimate measure of the success of release efforts (Hayward and Somers, 2009; Walker et al., 2022). Encouragingly, post-release reproductive behavior, such as mating, raising a cub or accompanying the opposite sex, was recorded in >1/3 of translocation efforts (an increase over the previous era at least partly attributable to the greater availability of tracking technology which had enabled post-release monitoring of 89.9 % individuals included in this study).

While the successes of carnivore translocations have multiplied since Jule et al. review in 2008, 34 % of translocation efforts failed. This is a high mortality rate in the context of the limited population sizes, fragile genetic assemblages, and shrinking ranges of many large carnivore species (Ripple et al., 2016), not to mention the considerable expense of translocations (Weise et al., 2014). Local stakeholders must also be consulted and considered in order to ensure the long-term success of these translocated large carnivore populations (Bavin et al., 2020). Nonetheless, the improvements achieved in the last 14 years are noteworthy, and encourage further research and refinement for the coming decade.

5. Conclusion

As the UN decade of ecosystem restoration gets underway, our findings inform decisions regarding large carnivore translocation programs globally. We discover a marked increase in translocation success relative to that prevailing at the time of Jule et al. (2008) historic review. This increases optimism that large carnivores held in zoological collections may realistically serve as repositories for translocations around the world (Farhadinia et al., 2020). Orphaned and rehabilitated animals contributed to the successes reviewed here, with successful roles documented in 10 countries. New post-release monitoring using tagging techniques (Hofman et al., 2019) and pre-release population surveys will importantly inform the adaptive management of the translocated individuals and the receiving population (Canessa et al., 2016; Bubac et al., 2019). As the UN decade on ecosystem restoration unfolds, improvements in carnivore translocation have the potential to make a substantial contribution to biodiversity conservation.

CRediT authorship contribution statement

Seth Thomas: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition, Resources, Investigation, Software, Validation. **Vincent van der Merwe:** Data curation, Writing – review & editing. **William Douglas Carvalho:** Data curation, Writing – review & editing. **Cristina Harumi Adania:** Data curation, Writing – review & editing. **Rok Černe:** Data curation, Writing – review & editing. **Tomislav Gomerčić:** Data curation, Writing – review & editing. **Miha Krofel:** Data curation, Writing – review & editing. **Jeffrey Thompson:** Data curation, Writing – review & editing. **Roy T. McBride:** Data curation, Writing – review & editing. **Jose Hernandez-Blanco:** Data curation, Writing – review & editing. **Anna Yachmennikova:** Data curation, Writing – review & editing. **David W. Macdonald:** Writing – review & editing. **Mohammad S. Farhadinia:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Project administration, Resources, Investigation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Data availability

Data will be made available on request.

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