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To support the continued publication of *Pachyderm* and its contribution to the conservation and management of African elephants, African rhinos and Asian rhinos, for which we would be extremely grateful; please contact the Managing Editor.

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SAVE THE ELEPHANTS

SAVE THE RHINO www.savetherhino.org

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Robert Bateman, wildlife artist

CHAIR REPORTS

African Elephant Specialist Group Chair report
Rapport du Groupe de Spécialistes de l'Eléphant d'Afrique

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Introduction

The African Elephant Specialist Group (AfESG) (hereafter 'Group') made notable advances to promote its mission through strategic initiatives and collaborative efforts from July 2023 to September 2024. The Secretariat launched a new website designed to enhance content delivery, provide dynamic updates, and serve as a comprehensive resource hub for elephant conservation. The *Data Review* working group is finalizing the African Forest and Savannah Elephant Status Reports (AFESR, ASESR), responding to feedback from the IUCN publication committee, while overcoming previous delays. Secured funding will facilitate ongoing improvements in the reporting processes starting in 2026. In 2023, the *Human Elephant Coexistence* (HECx) working group of AfESG collaborated with the Human-Wildlife Conflict and Coexistence Specialist Group (HWCC SG) of the IUCN SSC to adapt the IUCN guidelines for HWC specifically for human-elephant challenges. The proceedings of the 9th AfESG members meeting, which focused on forest elephants and human-elephant conflict (HEC), were also produced. To inform the debates surrounding the sustainable use of elephants, the AfESG established the *Sustainable Use* task

Introduction

Entre juillet 2023 et septembre 2024, le Groupe de Spécialistes de l'Éléphant d'Afrique (GSEAf) a accompli des progrès notables dans la promotion de sa mission, grâce à des initiatives stratégiques et des efforts collaboratifs. Le Secrétariat a créé un nouveau site Internet afin de faciliter la transmission de contenu et de mises à jour, et qui représente une plateforme globale de ressources pour la conservation des éléphants. Le Groupe de travail sur l'examen des données (GTED) («Data Review working group» en anglais) est dans la phase de finalisation de ses différents travaux (rapport de situation de l'éléphant de forêt d'Afrique - AFESR et rapport de situation de l'éléphant de savane d'Afrique - ASESR), tout en répondant aux remarques émises par le Comité de publication de l'UICN et en rattrapant le retard accumulé dans certaines tâches. Grâce aux financements obtenus, les avancées accomplies dans les processus de rapport pourront se poursuivre dès 2026. En 2023, le groupe de travail sur la coexistence humains-éléphants (HECx) du GSEAf («Human Elephant Coexistence working group») a collaboré avec le Groupe de spécialistes sur la coexistence et les conflits entre animaux sauvages et humains («HWCC SG») de la CSE de l'UICN («IUCN SSC») en vue d'adapter spécifiquement les lignes directrices de l'UICN aux défis engendrés par la cohabitation entre humains et éléphants. Les comptes-

force, designed to foster engagement and build evidence-based consensus. The African Elephant Database (AED) has transitioned to a modular application, improving both maintainability and functionality through modern technologies. The IUCN's new Green Status of Species protocol was initiated to assess the recovery progress of elephants.

Regular IUCN Red List assessments have been planned to ensure robust population estimates and effective conservation strategies, with reassessments of forest and savannah elephants scheduled to be completed by 2025 and 2026, respectively. The AfESG has been working with the CITES nomenclature, contributing scientific expertise through various meetings of the CITES committee. The work has led to recommendations to update nomenclature references in recognition of the two African elephant species and how to reflect these taxa in the CITES Appendices.

The AfESG task force for the *African Elephant Action Plan* (AEAP) is building an evidence base to support implementing strategies on HEC mitigation, land use planning and the restoration of connectivity. Engagements with many government authorities and their contacts are promoting stronger collaboration, increased awareness, and improved information-sharing, including survey data, for better status reporting and conservation outcomes. A recent range States dialogue meeting in Botswana aimed to harmonize trade conditions for live African elephants, where the AfESG presented the current status of elephant populations and related assessments. Additionally, grants are being secured from various donors to support ongoing AfESG initiatives.

New AfESG website

The AfESG Secretariat, in collaboration with the *Communication* task force, recognized the need for a dedicated website to allow for more comprehensive content and dynamic updates with greater control over its management. To bring this vision to life, the *Communication* task force partnered with Tenacity Works Ltd. to develop a website that showcases AfESG's work and serves as a valuable resource hub.

The website design includes key sections such as a static map of AfESG's activities,

rendus de la 9e réunion des membres du GSEAf, qui avait pour thématique l'éléphant de forêt et les conflits humains-éléphants (CHE), ont également été établis. Afin de nourrir les débats autour de l'utilisation durable des éléphants, le GSEAf a mis en place une cellule opérationnelle dédiée (« Sustainable Use task force ») pour favoriser l'engagement sur le sujet et construire un consensus basé sur des éléments factuels. La base de données sur l'éléphant d'Afrique (BDEA) est devenue une application modulaire, pour une maintenance et un fonctionnement améliorés grâce aux nouvelles technologies. Le nouveau protocole du Statut vert des espèces de l'UICN a été mis en œuvre afin d'évaluer les progrès dans le rétablissement des espèces d'éléphants.

Des évaluations régulières de la Liste rouge de l'UICN ont été planifiées pour assurer la solidité des estimations de populations et l'efficacité des stratégies de conservation. Les réévaluations des populations d'éléphants de forêt et d'éléphants de savane sont programmées et devraient être accomplies, respectivement, en 2025 et 2026. Le GSEAf a travaillé sur la nomenclature de la CITES en apportant son expertise scientifique lors de diverses sessions du Comité de la CITES, ce qui a donné lieu à des recommandations de mise à jour des références de la nomenclature afin de reconnaître les deux espèces d'éléphants d'Afrique et d'intégrer ces taxons dans les annexes de la CITES.

La cellule opérationnelle dédiée au Plan d'Action pour l'Éléphant d'Afrique (PAEA) (« task force for the African Elephant Action Plan ») est en cours d'élaboration d'un corpus de données factuelles afin d'établir des stratégies d'atténuation des CHE, d'aménagement du territoire et de restauration de la connectivité. Les collaborations engagées avec de nombreuses autorités gouvernementales et leurs contacts ont permis d'ouvrir la voie à une meilleure coopération, à une sensibilisation accrue et à un partage des informations renforcé (y compris en ce qui concerne les données de recensement), pour des rapports de situation aboutis et des résultats de conservation significatifs. Lors d'une récente réunion de dialogue des États de l'aire de répartition, qui s'est tenue au Botswana et qui visait à harmoniser les conditions commerciales des éléphants d'Afrique vivants, le GSEAf a présenté le statut actuel des populations d'éléphants et les évaluations correspondantes. En outre, le soutien de différents donateurs a été obtenu pour le financement des actions initiées par le GSEAf.

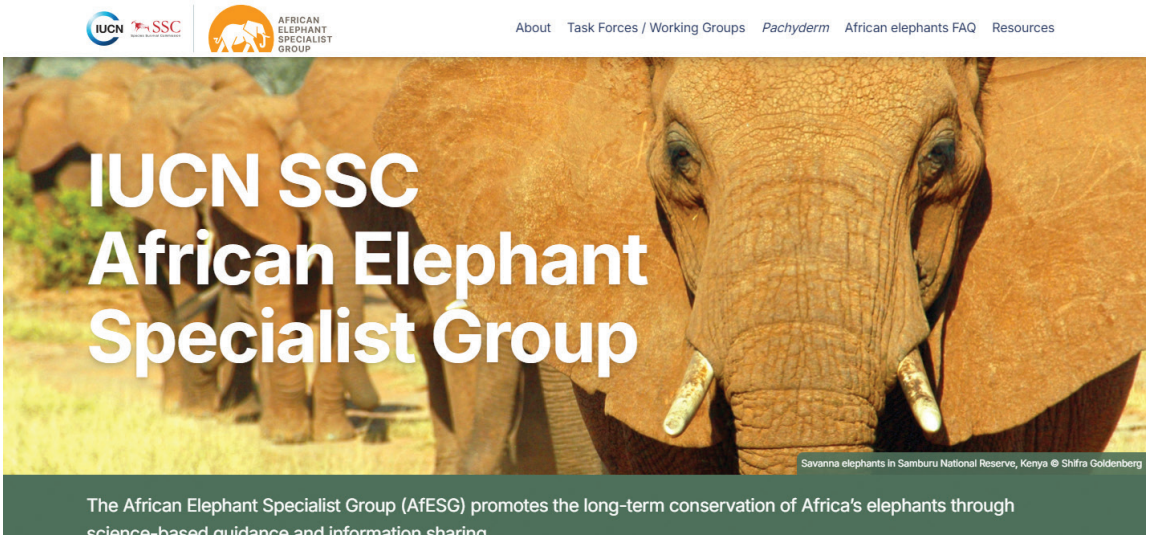

Figure 1. The revamped AfESG website home page.

Graphique 1. Page d'accueil du nouveau site Internet du GSEAf

donation links to third-party platforms, and contact information. A dedicated species section highlights the distinguishing features of elephants, comparative photos, population and distribution maps, and links to resources like the AfESG statement on elephant species classification. The site also features working groups focused on critical topics such as human-elephant coexistence (HECx), taxonomy, sustainable use, elephant movements, the AEAP, and the ivory trade.

In addition to its informative content, the website serves as a resource hub, offering access to PDFs, how-to guides, position statements, and links to partner websites. A dedicated *Pachyderm* section includes a hyperlink to the *Pachyderm* site. The development of the site was divided into two phases: Phase 1 delivered a brochure-style layout with essential content and imagery, while Phase 2 will introduce multi-language support and dynamic, data-driven content such as interactive maps.

After multiple iterations and feedback from members, the final version of the website was completed in July 2024 and launched on August 5, 2024, to coincide with World Elephant Day. The website aims to enhance communication both within and beyond the AfESG's membership and is accessible at https://www.afesg.org/.

The co-Chairs extend their deepest gratitude to Lucy Vigne, the dynamic leader of the

Création du nouveau site Internet du GSEAf

Le Secrétariat du GSEAf et l'équipe Communication sont convenus de la nécessité d'un site Internet dédié qui propose un contenu plus complet, des mises à jour dynamiques et une meilleure maîtrise de sa gestion. Dans cet objectif, l'équipe s'est associée à l'entreprise Tenacity Works Ltd afin de développer un site présentant le travail du GSEAf et constituant une précieuse plateforme de ressources.

Des sections clés y apparaissent, telles qu'une carte statique des activités du GSEAf, des liens vers les plateformes tierces de nos donateurs et des informations de contact. Les caractéristiques des éléphants, des photos comparatives et des cartes des populations et de leur répartition sont réunies sur une des pages du site, ainsi que les liens vers certaines ressources comme la déclaration du GSEAf sur la classification des espèces d'éléphants d'Afrique. Le détail des groupes de travail à l'œuvre sur les divers thèmes d'importance (coexistence humains-éléphants [HECx], taxonomie, utilisation durable, mouvements des éléphants, PAEA, commerce illégal d'ivoire) y est également disponible.

Enfin, et en plus de son caractère informatif, le site fait office de centre de ressources en offrant l'accès à plusieurs fichiers .PDF, guides pratiques, déclarations et liens vers les sites Internet de nos partenaires. Un onglet spécifique est dédié à la revue *Pachyderm*, avec un lien vers le site Internet. La conception du site se déroule en deux étapes : la phase 1 était centrée

Communication task force, and her dedicated team—Shifra Goldenberg, Lydia Tiller, Thomas Breuer, Boo (Fiona Maisels), George Wittemyer, Rose Mayienda, Mohammed Yahya, and Loki Osborn—for their invaluable contributions. Special thanks also to Lucy Osborn for her crucial support in this endeavour.

African elephant status reports

The African Forest Elephant Status Report (AFESR) subgroup of the *Data Review* working group has been meeting weekly for at least the last year. Over the course of these meetings, data, tables, maps and narratives were reviewed. The draft report was submitted for review through the IUCN process, and the subgroup reviewed and responded to the IUCN feedback and finalized the revised report at the end of September 2024 with submission to the IUCN for final review in due course. Once review feedback is received from the IUCN all recommendations and changes will be incorporated along with the copy edits made by the proofreaders and a final version will be sent for translation into French. Once the translation is complete, it will be printed in both French and English and released by the end of 2024. Preliminary population estimates were shared with African Elephant range States at CITES CoP 19 in 2022 and at the range States' dialogue meeting in Maun, Botswana in September 2024.

The African Savannah Elephant Report (ASESR) subgroup of the *Data Review* working group has also met once a week for at least the last year. The team has received, reviewed, and incorporated data on populations and ranges, with only a few information gaps; these are being pursued and the relevant authorities contacted. The team is collating data into tables and plans to initiate the narrative sections in October 2024. The ASESR is expected to be published by June 2025. Once the two reports are completed, we plan to produce a summary for policymakers which will combine and integrate information from the two reports, making them more easily comparable with previous reports.

We have experienced unforeseen challenges in data and information gathering, health challenges of team members, as well as the volunteer nature of the work of team members; all of which have

sur la création d'une présentation de type brochure, comportant les informations et imageries essentielles, tandis que la phase 2 introduira la prise en charge de plusieurs langues ainsi qu'un contenu dynamique et axé sur les données, tel que des cartes interactives.

Après de multiples itérations et commentaires de la part des membres, la version définitive a été achevée en juillet 2024 et mise en ligne le 5 août 2024, pour la journée mondiale de l'éléphant. Ce site a pour objectif de renforcer la communication au sein du groupe de spécialistes comme au-delà, et est accessible à l'adresse suivante : https://www.afesg.org/.

Les co-présidents souhaitent exprimer leur profonde gratitude envers Lucy Vigne, qui chapeaute avec dynamisme le groupe de travail dédié à la communication, ainsi que son équipe composée de Shifra Goldenberg, Lydia Tiller, Thomas Breuer, Boo (Fiona Maisels), George Wittemyer, Rose Mayienda, Mohammed Yahya, et Loki Osborn, pour leur dévouement et leur précieuse contribution. Nous adressons nos remerciements particuliers à Lucy Osborne pour son soutien crucial dans cette entreprise.

Rapports de situation de l'éléphant d'Afrique

Le groupe de travail dédié au rapport de situation de l'éléphant de forêt d'Afrique (AFESR), sous-entité du groupe de travail sur l'examen des données, s'est réuni chaque semaine, tout au long de l'année écoulée, sinon plus. Pendant ces réunions, divers documents — données, tableaux, cartes et récits — ont été analysés. Le rapport provisoire a été soumis pour révision dans le cadre des procédures de l'UICN, puis le sous-groupe a examiné les remarques émises par celle-ci et y a répondu pour ensuite parachever le rapport fin septembre 2024, lequel sera présenté à l'UICN pour étude finale. Une fois ce retour effectué et reçu, toutes les recommandations et modifications seront intégrées, ainsi que les éléments relevés par les relecteurs/rices. La version définitive sera alors envoyée pour traduction en français. Le rapport sera imprimé en français et en anglais, pour une publication avant la fin de l'année 2024. Les estimations préliminaires de population ont été partagées avec les États africains de l'aire de répartition à la 19eCdP de la CITES en 2022 et à la réunion de dialogue des États de l'aire de répartition, qui s'est tenue à Maun au Botswana en septembre 2024.

À l'instar du groupe traitant de l'éléphant de forêt, l'équipe dédiée au rapport de situation de l'éléphant

contributed to delays in finalizing the two reports. To ensure that the next set of reports is completed in good time, the AfESG has secured funding to improve the functionality of the AED in 2026.

Human Elephant Coexistence (HECx) working group

As HWC becomes more frequent, serious, and widespread throughout the world, the issues are more challenging to resolve, and many efforts to address these conflicts have made little or no progress. The IUCN Guidelines for Human-Wildlife Conflict and Coexistence (HWCC[1]) aims to provide foundations and principles for good practice with clear and practical guidance on how best to tackle conflicts and enable coexistence with wildlife. They have been developed for use by conservation practitioners, community leaders, decision-makers, researchers, and government officials, among others. Focusing on approaches and tools for analysis and decision-making, they are not limited to any species or region of the world. The purpose of these guidelines is to improve the management of HWC worldwide, supporting efforts to be pursued through well-informed, holistic, and collaborative processes that consider the underlying social, cultural, and economic drivers.

Regarding the conflict challenges related to elephants, the AfESG initiated a process in 2023, together with the Chair of the SSC HWCC Specialist Group (Alex Zimmermann), to tailor the IUCN guidelines for HWCC 2023 to the specific challenges encountered between humans and elephants and the corresponding solutions. These 2023 HWCC guidelines will undergo a thorough review of contextualization for African elephants by the AfESG *Human Elephant Coexistence* working group (HECx), with a resulting comprehensive framework then available to assist range States in preventing or mitigating HEC, and promoting HECx, consistent with the objectives contained within the AEAP.

The first meeting was held on 20 June 2024 to discuss the guidelines. Alex Zimmermann

[1]https://iucn.org/resources/publication/iucn-ssc-guidelines-human-wildlife-conflict-and-coexistence-first-edition

de savane d'Afrique (ASESR) a organisé des sessions hebdomadaires sur toute l'année au moins. Elle a reçu, examiné et intégré des données sur les populations et les aires de répartition. Seuls quelques éléments restent manquants, que les membres s'attachent actuellement à collecter en contactant les autorités concernées. Ces données sont compilées dans des tableaux et des plans afin de débuter les sections narratives en octobre 2024. La publication de l'ASESR est attendue pour juin 2025. Une fois les deux rapports effectués, nous avons pour projet de produire un résumé à destination des décideurs politiques, qui combinera et inclura des informations tirées des deux rapports pour une comparaison plus aisée avec les documents similaires précédents.

Nous avons dû faire face à des défis inattendus en termes de collecte de données et d'informations, et de problèmes de santé subis par nos membres, puis du fait de la nature bénévole du travail de nos collaborateurs – autant d'éléments qui ont contribué à des retards dans la finalisation des deux rapports. Afin de garantir une livraison des prochains rapports en temps et en heure, le GSEAf a obtenu des financements qui permettront d'améliorer la fonctionnalité de la BDEA en 2026.

Cellule opérationnelle Coexistence et conflits entre humains-éléphants (HECx)

Comme les conflits entre humains et faune sauvage (CHF) se font de plus en plus fréquents, graves et répandus dans le monde, ils représentent un défi de taille. De nombreux efforts ont été mis en place pour résoudre ces problèmes, mais n'ont donné que peu de résultats, voire aucun. Les lignes directrices de l'UICN sur les conflits entre les humains et la faune sauvage et sur leur coexistence (HWCC[1]) visent à fournir des fondements et des principes de pratiques exemplaires en présentant des conseils précis et applicables sur la meilleure façon d'aborder les conflits et de favoriser la coexistence avec la faune sauvage. Elles ont été élaborées à l'intention des praticiens de la conservation, des responsables communautaires, des décideurs, des chercheurs, des représentants gouvernementaux et autres acteurs du secteur. Axées sur des approches et des outils d'analyse et de prise de décision, elles ne se limitent pas à une espèce ou à une région spécifique

[1]https://iucn.org/resources/publication/iucn-ssc-guidelines-human-wildlife-conflict-and-coexistence-first-edition

introduced the participants to the IUCN guidelines on HWCC and the five principles that form the core thinking and structure, which the HWCC SG believes would also provide a sound base structure for the African elephant-specific document.

The elephant-specific guidelines are intended for middle- to upper-level decision-makers across Africa tasked with managing elephants in their landscape. The elephant-specific guidelines will also be an extension of Save the Elephants HECx Toolbox[2], a highly practical suite of deterrents tested in the field and intended for an audience on the ground wanting to implement HEC damage control. The elephant-specific guidelines being developed are intended to complement the Toolbox with more systems-changing guidance on how to change HEC dynamics across landscapes, countries, and policies. However, the focus needs to be on practical, clear, and actionable guidance and is not intended to be abstract or academic. This initiative is being led by Loki Osborn, the working group convenor.

Proceedings of the 9th AfESG members online meeting

The 9th members meeting of the AfESG was held online via Zoom from 13 to 14 September and from 18 to 19, October 2022. Due to ongoing concerns about Covid-19, the meeting was conducted virtually. The theme "Forest and Savannah Elephant Conservation and Emerging Challenges," focused on forest elephants and HEC. This shorter four-day meeting addressed selected topics of special interest.

The meeting aimed to update members and facilitate the exchange of scientific and technical information on various aspects of elephant research, conservation, management, education, and training. Many members gave PowerPoint presentations followed by interactive Q&A sessions. The write-up of the proceedings of the meeting has been finalized and is being formatted in readiness for circulation to members.

The co-Chairs extend heartfelt thanks to Lucy Vigne, Shifra Goldenberg, Lydia Tiller,

[2]https://www.savetheelephants.org/our-work/coexistence/hec-toolbox/

du monde. L'objectif de ces ressources est d'améliorer la gestion des CHF à l'échelle internationale, tout en soutenant les efforts actuels par un processus éclairé, holistique et collaboratif qui prend en considération la charge des facteurs sociaux, culturels et économiques.

Sur le sujet des défis que représentent les conflits avec les éléphants, le GSEAf, en collaboration avec Alex Zimmermann, président du Groupe de spécialistes des conflits et de la coexistence humains-faune sauvage de la Commission pour la Survie des Espèces (CSE), s'est engagé en 2023 dans un processus d'adaptation des lignes directrices de l'UICN aux enjeux propres aux humains et aux éléphants et aux solutions correspondantes. Un examen approfondi sera alors entrepris par la cellule opérationnelle s'occupant de la coexistence entre humains et éléphants (« Human Elephant Coexistence working group ») du GSEAf afin de conformer ces orientations au contexte des éléphants d'Afrique, ce qui donnera lieu à un cadre global destiné aux États de l'aire de répartition pour les aider à prévenir et à atténuer les CHE, ainsi qu'à promouvoir la coexistence avec les éléphants, conformément aux objectifs du PAEA.

La première réunion s'est tenue le 20 juin 2024 et avait pour objet de discuter des lignes directrices de l'UICN. Alex Zimmermann a détaillé les cinq principes fondateurs formant la base de la pensée et de la structure de ces orientations, considérés comme un point de départ satisfaisant pour l'élaboration du document spécifique aux éléphants d'Afrique par le groupe de spécialistes des conflits et de la coexistence humains-faune sauvage.

Ce cadre dédié aux éléphants d'Afrique sera destiné aux décideurs africains à un niveau intermédiaire ou supérieur de prise de décisions sur le continent et qui sont chargés de la gestion des éléphants sur leur territoire. Ces axes constitueront un prolongement de la « Boîte à outils pour favoriser la coexistence humains-éléphants », un manuel extrêmement pratique proposé par Save the Elephants et à destination d'un public sur le terrain souhaitant mettre en œuvre des actions de prévention des dommages. Le cadre spécifique aux éléphants est voué à venir compléter la Boîte à outils avec davantage de conseils à orientation systémique sur la façon de changer les dynamiques des CHE dans le paysage, les pays et les politiques. Néanmoins, l'objectif reste la création d'un guide fonctionnel, clair et concret, qui ne soit ni trop abstrait, ni théorique. Cette initiative est menée par Loki Osborn, coordinatrice de la cellule opérationnelle.

Rose Mayienda, and Mohammed Yahya for their exceptional efforts in organizing the meeting. A special note of gratitude goes to Lucy for her outstanding leadership in compiling the proceedings, ensuring the success of this important event.

A tentative in-person meeting for AfESG members has been scheduled from 7 to 12 July 2025, either in Kenya or Tanzania. Funding is being sought to support the meeting and ensure that all members can attend, and details will be generated and communicated to members in due course.

Sustainable use of Africa's elephants

Polarized debates over the sustainable use of African elephants have hindered conservation efforts both in Africa and globally. These debates stem from disagreements about the risks, benefits, and the unequal distribution of the costs and gains of elephant conservation. At the 9th members meeting (2022) it was agreed to initiate a process of engagement within the Group through the AfESG *Sustainable Use* task force. This process has been led by Duan Biggs, the task force convenor, who initiated work in July 2023.

The approach draws on best practices in conflict transformation by integrating scientific evidence with diverse moral values and perspectives to foster common ground. It involves eliciting mental models (theories of change) of Group members on the sustainable use of African elephants, identifying assumptions and knowledge gaps, and addressing them through systematic evidence synthesis (Figure 2). Community perspectives will also be incorporated through literature reviews and facilitated in-person mapping, with iterative workshops held to build consensus among stakeholders.

Initial mental mapping interviews have been conducted, with more planned to increase the sample size and geographic spread, as well as the expertise of the respondents. The next steps include expanding interviews to capture community views, strengthening ties with African governments, and holding additional workshops to find common ground.

Compte-rendu de la 9e réunion en ligne des membres du GSEAf

La 9e réunion du GSEAf a été organisée les 13 et 14 septembre et les 18 et 19 octobre 2022. Du fait des inquiétudes relatives à la pandémie de Covid 19, l'événement s'est déroulé en ligne, via la plateforme Zoom. Le thème « La conservation des éléphants de savane et de forêt et les défis émergents » se concentrait sur les éléphants de forêt et les CHE. Cette réunion plus courte qu'à l'accoutumée a abordé certains sujets spécifiques, et avait pour objectif de tenir les membres informés et de faciliter l'échange de données scientifiques et techniques sur les divers aspects de la recherche, de la conservation, de la gestion, de l'éducation et de la formation autour des éléphants. De nombreux participants ont réalisé des présentations PowerPoint, suivies de sessions interactives de questions-réponses. Le compte-rendu écrit a été finalisé et est en phase de mise en forme pour une prochaine distribution aux membres.

Les co-présidents souhaitent exprimer leur profonde gratitude envers Lucy Vigne, Shifra Goldenberg, Lydia Tiller, Rose Mayienda, and Mohammed Yahya pour leurs efforts exceptionnels déployés dans l'organisation de cette réunion. Nos remerciements tout particuliers vont à Lucy pour l'admirable entrain dont elle a fait preuve dans la compilation des comptes-rendus, garantissant par là même la réussite de cet événement important.

Une réunion en présentiel des membres du GSEAf a été provisoirement planifiée du 7 au 12 juillet 2025, et se tiendrait au Kenya ou en Tanzanie. Des financements sont recherchés afin de soutenir cette rencontre et d'assurer que tous les membres puissent y assister. Les détails leur seront communiqués en temps utile.

Discussions sur une utilisation durable des éléphants

La polarisation des débats au sujet de l'utilisation durable des éléphants d'Afrique a entravé les efforts de conservation sur le continent africain et dans le monde entier. Ces controverses proviennent de désaccords concernant les risques, les bénéfices et la répartition inégale des coûts et des gains générés par la conservation des éléphants. Lors de la 9e réunion des membres en 2022, il a été décidé de débuter un processus d'engagement au sein du groupe de spécialistes par le biais de la cellule opérationnelle

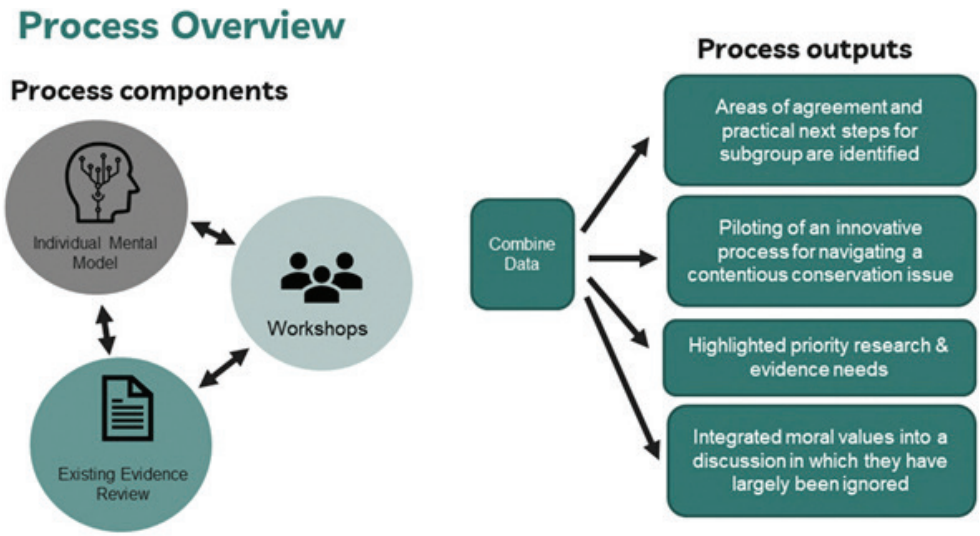

Figure 2. Overview of the Sustainable Use Process of African Elephants.

Graphique n° 2 Vue d'ensemble du processus d'utilisation durable des éléphants d'Afrique.

Revamping of the African Elephant Database

The original African Elephant Database (AED) was a large monolithic application[3]. Monolithic applications are difficult to maintain because there are many interdependencies between different parts of the code that are not usually apparent and because a software engineer must fully understand the entire application before attempting to make even a small change. The new application is modular and has different components of the overall system separated into their own "programmes". This not only makes changes less risky but also makes enhancements and new functionality much easier to develop.

The first phase focused on porting existing functionality to 'React' on the front end and 'Node JS' and '.Net Core' on the backend, while using Amazon Web Service (AWS) cloud services. This was completed in July 2024 and is currently undergoing testing. The modern

[3]**Software Development**: In this context, a monolithic application refers to a software system designed as a single, tightly connected unit where components such as the user interface, business logic, and database are all integrated into one system. This is in contrast to a microservices architecture, where different functions are divided into smaller, independent services.

dédiée à l'utilisation durable (« Sustainable Use task force »). Duan Biggs, coordinateur de la cellule, dirige le processus qu'il a entrepris en juillet 2023.

L'approche employée mobilise les bonnes pratiques en matière de transformation des conflits en intégrant la preuve scientifique aux diverses valeurs et perspectives morales afin de trouver un terrain d'entente. Il s'agit d'élaborer les modèles mentaux (théories du changement) des membres du groupe de spécialistes sur l'utilisation durable des éléphants d'Afrique, d'identifier les postulats et le manque de connaissances sur le sujet, et d'y répondre par le biais d'une synthèse systématique de la preuve. Les points de vue des communautés seront également intégrés par l'intermédiaire d'analyses documentaires et de cartographies des identités, avec des ateliers itératifs organisés afin de construire un consensus parmi les participants.

Les premiers entretiens de cartographie mentale ont été menés et d'autres sont prévus afin d'enrichir l'échantillon et l'étendue géographique, ainsi que l'expertise des personnes interrogées. Les prochaines étapes incluront la poursuite des entretiens pour recueillir la vision des communautés – le renforcement des liens avec les gouvernements africains et la tenue d'ateliers supplémentaires permettant de trouver un terrain d'entente.

technology stack allows for greater extensibility and serviceability of the system and contains improved algorithms for displaying data, uncertainty metrics, and site-level population dynamics over time. It can also now separate elephant species analysis for the first time.

The United States Fish and Wildlife Services (USFWS) will support the Phase II enhancements (enhanced features for data review and replacement and enhanced features for range mapping). These new capabilities, features, and extensions to the AED will support more dynamic updates of the database, more refined validation of data outputs, more efficient data compilation, release of intermediate summaries, and will be produced annually.

Green Status of African elephants

The IUCN recently introduced the Green Status of Species (GSS) protocol, designed to assess recovery progress of species and the impact of conservation efforts. Complementing the IUCN Red List, which evaluates the risk of extinction, the GSS uses a standardized method to assign recovery scores and categories for global species populations, from full recovery to depletion. The GSS also includes metrics such as conservation legacy, dependence, gain, and recovery potential. The IUCN AfESG has assembled a team led by the Red List coordinator (Kathleen Gobush), including three experts from African elephant range states and one intern from Ghana, to apply the GSS to the African forest elephant (*Loxodonta cyclotis*). Assessment of *L. cyclotis* is expected to conclude in early 2025, will be followed by a similar process for the African savannah elephant (*Loxodonta africana*). These assessments will provide a detailed view of each species' status across its historic range, filling knowledge gaps and offering spatially specific information to guide future conservation efforts. With these accurate and up-to-date data, stakeholders can better understand the situation and identify opportunities, gaps, and shared needs for elephant conservation, management, and governance at multiple levels.

Refonte de la Base de Données de l'Éléphant d'Afrique

À l'origine, la Base de Données de l'Éléphant d'Afrique (BDEA) était une application monolithe massive[3]. Les applications monolithes sont difficiles à maintenir, car il existe de nombreuses interdépendances entre les différentes parties du code, qui ne sont pas toujours visibles. La personne responsable du logiciel doit avoir une très bonne compréhension du programme dans son intégralité avant de pouvoir effectuer la moindre modification. Dans la nouvelle version modulaire, les divers composants du système global sont séparés dans leur propre programme. Non seulement les modifications sont moins risquées, mais les améliorations et nouvelles fonctionnalités deviennent bien plus faciles à développer.

La première phase s'est concentrée sur le portage des fonctionnalités existantes vers « React » pour le front-end et « Node JS et .Net Core » pour le back-end, tout en utilisant les services cloud d'Amazon Web Service (AWS). Cette étape a été achevée en juillet 2024 et est actuellement en phase de test. La pile technologique moderne permet une plus grande extensibilité et facilité d'utilisation du système, et contient des algorithmes améliorés pour l'affichage des données, des mesures d'incertitude et des dynamiques de population sur site au fil du temps. Aujourd'hui, et pour la première fois, il est possible de séparer les analyses des deux espèces d'éléphants.

Le département américain US Fish and Wildlife (USFWS) soutiendra les avancées programmées pour la phase 2 (fonctionnalités améliorées pour l'examen et le remplacement des données et fonctionnalités améliorées pour la cartographie des aires de répartition). Ces nouvelles capacités, fonctionnalités et extensions de la BDEA permettront des mises à jour plus dynamiques, une validation plus fine des données générées, une compilation plus efficace des données ainsi que la publication de résumés intermédiaires, et seront produites chaque année.

Le Statut vert de l'éléphant d'Afrique

L'UICN a récemment introduit le protocole du Statut vert des espèces (« Green Status of Species - GSS »), conçu pour évaluer les progrès de rétablissement des espèces et l'impact des actions de conservation. Venant en complément de la Liste rouge de l'UICN qui détermine le risque d'extinction, le GSS utilise

Red List assessment of the African elephant

In line with IUCN policy, the AfESG aims to produce Red List Assessments (RLA) for African elephants every 10 years, ideally, every five years, to provide comprehensive trend analyses over long temporal scales (75+ years, depending on species) at continental and species levels. Both the Red List assessments and the African Elephant status reports depend on robust population estimates, vetted in the AED. Red List reassessments typically begin after an updated status report is published.

The Red List Coordinator of the IUCN AfESG has initiated the re-assessment of the African forest elephant, given that its updated data are available from the AFESR. Work will begin on the re-assessment of the savannah elephant once the ASESR is complete. The AfESG aims to publish the forest elephant reassessment by the end of 2025 and the savannah elephant reassessment by the end of 2026.

CITES taxonomic nomenclature issues related to African elephants

The AfESG has worked with the CITES nomenclature specialist on Decision 19.276 through the 32nd and 33rd meetings of the Animals Committee, as well as the 77th meeting of the Standing Committee, to provide scientific and other information on each species to make progress on this decision.

Outcomes so far include 1) an acknowledgement (at AC32 and reconfirmed at AC33) of the scientific merit of recognizing the two species of African elephants; 2) a recommendation to update the standard nomenclature reference to Wilson and Reeder 2005 that specifies the two different elephant species as such; and 3) defer to SC78 and CoP20 considerations on how to reflect these taxa in the CITES Appendices, noting the discussions of SC77.

In addition, and relevant to taxonomic issues concerning African elephants, the Animals Committee (at AC33) agreed to propose to CoP20 an amendment to Resolution Conf. 12.11 (Rev. CoP19) on standard nomenclature related to higher taxon listings and how to handle changes

une méthode standardisée afin d'attribuer des scores et des catégories pour les populations mondiales d'une espèce, du rétablissement complet à l'extinction à l'état sauvage. Le Statut vert inclut également des indicateurs tels que l'héritage de la conservation, la dépendance envers la conservation, le gain par conservation et le potentiel de rétablissement. Le GSEAf a réuni une équipe menée par Kathleen Gobush, coordinatrice de la Liste rouge de l'UICN, et qui compte trois experts des États de l'aire de répartition et un stagiaire ghanéen, pour appliquer le Statut vert à l'éléphant de forêt d'Afrique (*Loxodonta cyclotis*). Les conclusions de l'évaluation de *L. cyclotis* sont attendues pour début 2025 et seront suivies d'un processus similaire pour l'éléphant de savane d'Afrique (*Loxodonta africana*). Ces évaluations fourniront une vue détaillée du statut de chaque espèce dans son aire de répartition historique, permettant de combler le manque de connaissances et de délivrer des informations spécifiques d'un point de vue spatial qui guideront les actions de conservation. Grâce à ces données précises et à jour, les acteurs du secteur auront une meilleure compréhension de la situation et pourront mieux identifier les opportunités, les lacunes et les besoins communs en matière de conservation et de gestion de l'éléphant, ainsi que de gouvernance à de multiples niveaux.

Évaluation de la Liste rouge pour l'éléphant d'Afrique

Conformément à la politique de l'UICN, le GSEAf a pour objectif de produire une évaluation de la Liste rouge pour les éléphants d'Afrique tous les dix ans (idéalement tous les cinq ans) afin de fournir des analyses complètes des tendances sur le long terme (75 ans et plus selon les espèces) à l'échelle du continent et des espèces. L'évaluation de la Liste rouge comme les rapports de situation de l'éléphant d'Afrique dépendent d'estimations de population solides et confirmées par la BDEA. Les réévaluations de la Liste rouge débutent en général après la publication d'un rapport de situation.

La coordinatrice de la Liste rouge auprès du GSEAf a entamé la réévaluation de l'éléphant de forêt suite à la disponibilité de données actualisées dans le rapport de situation de l'espèce (AFESR). Le travail de réévaluation de l'éléphant de savane commencera dès que le rapport de situation de l'espèce (ASESR) sera achevé. Le GSEAf prévoit de publier la réévaluation de l'éléphant de forêt fin 2025, et celle de l'éléphant de savane, fin 2026.

in taxon name (by considering whether changes in the scope of protections would occur or not with the name change).

Updating survey methods

Wildlife survey methods, particularly elephants, emphasize a combination of aerial surveys, direct ground observation, and dung count surveys to estimate population sizes and distribution. Specific methods include camera traps, passive acoustic monitoring, and GPS satellite tracking to monitor the presence, behaviour, and movements of species, especially in challenging or dense habitats. Genetic sampling and habitat assessments are conducted to understand population structure and habitat quality. The AfESG initiated a partnership with Simon Hedges to update the Wildlife Survey Manual, "Comprehensive Wildlife Survey Methods: Techniques, Applications, and Challenges in Conservation" and include other newly emerging elephant survey techniques.

Engagement with the African Elephant Action Plan

The African Elephant Action Plan (AEAP) 2023 is a contemporary framework of continental priorities and objectives for the conservation of African elephants developed, owned, and implemented by the range States. It "represents the issues identified and experienced by Africans, and the objectives that need to be addressed, in order to effectively conserve elephants in Africa across their range". The 2023 revision builds on the experience of the first 12 years of implementation of the AEAP 2010 and draws on the collective expertise and experience of range States as well as the technical support from members of the IUCN AfESG.

Across the continent, major challenges related to elephants and their socio-ecological roles include illegal killings (primarily for ivory and occasionally for meat), the damage elephants cause to communities, and habitat loss, transformation, and/or fragmentation resulting from a growing human population, impact of a changing climate and the increased human footprint.

The CITES MIKE Programme focuses on

Questions relatives à la nomenclature taxonomique de la CITES et à l'éléphant d'Afrique

Lors des 32e et 33e réunions du Comité pour les animaux (AC32 et AC33), et de la 77e session du Comité permanent de la CITES (SC77), le GSEAf a travaillé avec le spécialiste de la nomenclature sur la Résolution 19.276, afin de fournir des informations scientifiques et d'autres renseignements sur chaque espèce et de progresser sur la question.

Les résultats sont les suivants : 1) reconnaissance (lors de la 32e réunion et confirmation lors de la suivante) du mérite scientifique résidant dans le fait d'avoir identifié les deux espèces d'éléphants ; 2) recommandation d'une mise à jour de la nomenclature standard de Wilson et Reeder (2005) pour une spécification des deux espèces distinctes d'éléphants ; 3) remise à l'ordre du jour des prochaines SC78 et CdP20 les questionnements sur la façon d'inscrire ces taxons dans les appendices de la CITES, et rédaction des discussions de la 77e session.

En outre, à l'occasion de sa 33e réunion, le Comité pour les animaux s'est entendu pour proposer lors de la Cdp20 un amendement à la Resolution Conf. 12.11 (Rev. CoP19) relatif à la nomenclature standard liée aux listes de taxons supérieurs, et sur les moyens de conduire les changements dans le nom du taxon (en s'interrogeant sur la possibilité que ces changements puissent entraîner des modifications ou non dans le champ des protections).

Mise à jour des méthodes de recensement

Les méthodes de recensement de la faune sauvage, particulièrement en ce qui concerne les pachydermes, s'appuient sur des relevés aériens, l'observation directe sur le terrain et le comptage des excréments afin d'estimer la taille et la répartition des populations d'éléphants. D'autres dispositifs spécifiques incluent des pièges photographiques, la surveillance acoustique passive et le suivi GPS pour contrôler la présence, le comportement et les mouvements des espèces, notamment dans des habitats denses ou difficiles d'accès. Des échantillonnages génétiques et évaluations d'habitats sont conduits dans le but de comprendre la structure des populations et la qualité des habitats. Le GSEAf a conclu un partenariat avec Simon Hedges afin de mettre à jour le manuel intitulé *Comprehensive Wildlife Survey Methods*

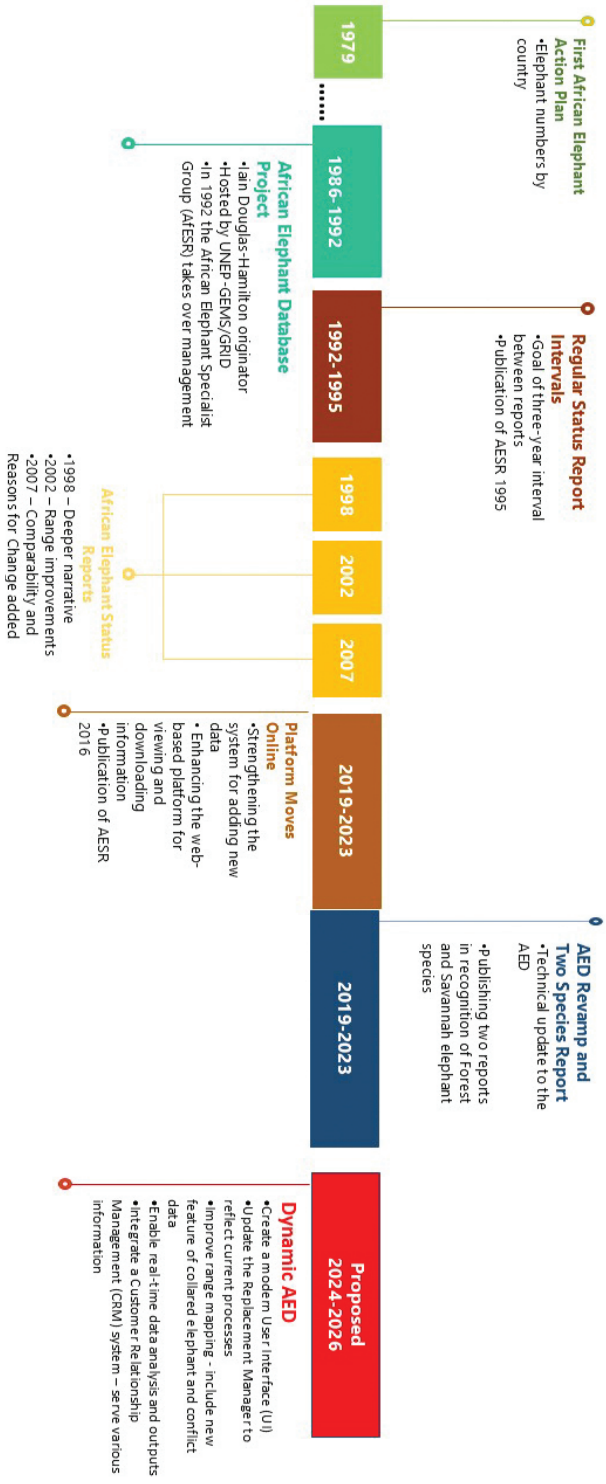

Figure 3. The history of development of the African Elephant Database and current and planned improvements.

Graphique n° 3 L'histoire du développement de la Base de Données de l'Éléphant d'Afrique et les évolutions actuelles et en prévision.

monitoring the illegal killing of elephants, and the AfESG HECx task force (see item 3 below) addresses issues related to conflict and damage. As such, and going forward, the AfESG AEAP task force (AEAP TF) seeks to contribute expertise to assist range States address some of the remaining conservation issues within the AEAP's objectives, namely habitat transformation, fragmentation, and connectivity. Specifically, the AEAP task force plans to provide an evidence base in support of range States in implementing the following AEAP strategies and activities:

Strategy 1.1: Apply adaptive management approaches in addressing HEC mitigation, ensuring capacity building for managers and local communities.

Activity 1.1.4: Undertake appropriate land use planning to minimize HEC including harmonization across sectors and among range States.

Strategy 2.1: Ensure, maintain, and restore connectivity, where possible, between elephant ranges within and between range States.

Activity 2.1.1: Identify and prioritize opportunities for range expansion and creation of connectivity corridors within the broader land use planning within and between range States.

Activity 2.1.2: Identify ways to incentivize local communities to secure, maintain and rehabilitate connectivity corridors between elephant populations.

Activity 2.1.3: Create and/or restore, where possible, the connectivity between areas of elephants within, between and among range States especially within Transfrontier Conservation Areas.

As the conditions and level of management vary throughout elephant range, there are areas where it is necessary to maintain habitats and any remaining connectivity, and in others, it is necessary to restore degraded habitat and lost connectivity. Furthermore, AEAP Strategy 2.4. highlights risks from climate change, and the work on land use planning, range expansion, connectivity corridors, etc. These can inform the management and allocation of resources envisaged in Activities 2.4.1 and 2.4.2. Some areas of elephant range require support in maintaining ecological processes, such as elephant dispersal, more so than direct habitat maintenance or restoration. Still others, especially large landscapes with varied habitat quality and water availability, may be viewed through a meta-population lens

: Techniques, Applications, and Challenges in Conservation («Méthode exhaustive de recensement de la faune sauvage : techniques, application et défis relatifs à la conservation»), et d'y intégrer des techniques innovantes de recensement des éléphants.

Implication dans le Plan d'Action pour l'Éléphant d'Afrique

Le PAEA 2023 est un cadre contemporain de priorités et d'objectifs à l'échelle du continent pour la conservation des éléphants africains, conçu, détenu et mis en œuvre par les pays de l'aire de répartition. Il «représente les problèmes identifiés et vécus par les Africains, ainsi que les objectifs devant être abordés pour une conservation efficace des éléphants d'Afrique dans leur aire de répartition». La révision qui en a été faite en 2023 s'appuie sur l'expérience acquise durant les douze premières années du déploiement du PAEA 2010 et mobilise l'expertise et l'expérience des États de l'aire de répartition et le soutien technique des membres du GSEAf.

Sur tout le continent, s'agissant des éléphants et de leur rôle socioécologique, les défis majeurs portent sur les abattages illégaux (en premier lieu pour l'ivoire, parfois pour la chair), les dommages causés par les animaux aux communautés et la perte, la transformation et/ou la fragmentation des habitats, conséquences d'une population humaine grandissante, des impacts du dérèglement climatique et de l'accroissement des activités humaines.

Le programme MIKE de la CITES se concentre sur la surveillance des abattages illégaux des éléphants et l'équipe du GSEAf en charge de la coexistence humains-éléphants (voir le paragraphe n° 3 ci-dessus) se penche sur les problématiques relatives aux conflits et aux dommages. À ce titre, le GSEAf, par le biais de sa cellule opérationnelle pour le PAEA («AEAP task force»), souhaite apporter son expertise aux États de l'aire de répartition lorsque sont abordées certaines des problématiques actuelles de conservation au cœur des objectifs du PAEA : la transformation, la fragmentation et la connectivité des habitats. Plus spécifiquement, la cellule vise à fournir un corpus de données factuelles qui vienne soutenir les États dans la mise en œuvre des stratégies et activités suivantes dans le cadre du PAEA :

Stratégie 1.1 : Appliquer des approches de gestion adaptatives pour l'atténuation des CHE, en garantissant le renforcement des compétences du personnel en charge et des communautés locales.

for elephant conservation. A consequence of improved elephant range and elephant movement could be an increase in conflict with communities depending on how they use such landscapes, and if they are growing and expanding their footprint. As such, efforts to improve habitat and connectivity must go hand in hand with the work of the IUCN AfESG HECx task force (item 3 above) and both require thoughtful, collaborative, inclusive planning and dialogue.

Engagements with governments

During this reporting period, the AfESG Secretariat undertook significant engagements with African elephant range States to promote the mission of the Group and improve collaboration on elephant conservation efforts. Visits were made to government authorities in Ethiopia, Ghana, Malawi, Mozambique, Tanzania and Zambia, to strengthen partnerships on conservation issues. The IUCN East and Southern African Regional Office (ESARO) and the West African Regional Office (WARO) played key roles in organizing and coordinating these regional engagements. Additionally, online engagements were conducted with government contacts in Botswana, Côte d'Ivoire, Eswatini, Guinea, Kenya, Namibia, Rwanda, Somalia, South Africa, Togo and Zimbabwe. These interactions promote stronger collaboration, increase awareness and improve information-sharing, including survey data, to improve status reporting and conservation outcomes.

African Elephant dialogue meeting

Persuant to Decision 19.167 on 'Trade in Live African Elephants (*Loxodonta africana*)', at its 77th meeting (SC77; Geneva, November 2023), the Standing Committee called for a CITES dialogue meeting for African elephant range states as per Resolution Conf. 14.5 on dialogue meetings and welcomed the offer by Botswana Government's to host the meeting; in consultation with the Chair of the Standing Committee and the range States. The meeting took place from 23 to 26 September in Maun Botswana.

The dialogue discussed the harmonization of the conditions to trade in live African elephants and propose relevant changes to CoP 20 as well

Activité 1.1.4 : Entreprendre un aménagement du territoire approprié afin de minimiser les CHE, dont des politiques d'harmonisation entre secteurs et entre États.

Stratégie 2.1 : Garantir, maintenir et restaurer la connectivité, dans la mesure du possible, entre les aires de répartition des éléphants à l'intérieur des États et entre eux.

Activité 2.1.1 : Identifier et classer par ordre de priorité les possibilités d'extension d'aire de répartition et de création de corridors de connectivité au sein des politiques d'aménagement du territoire au sens large, à l'intérieur des États et entre eux.

Activité 2.1.2 : Identifier les moyens d'inciter les communautés locales à sécuriser, maintenir et réhabiliter les corridors de connectivité entre les populations d'éléphants.

Activité 2.1.3 : Créer et/ou restaurer, si possible, la connectivité entre des zones habitées par les éléphants à l'intérieur des États et entre eux, en particulier dans les zones de conservation transfrontalières.

Du fait que les conditions et les niveaux de gestion varient dans l'aire de répartition, il est nécessaire dans certaines zones de maintenir les habitats et les connectivités encore existantes, tandis que d'autres espaces requièrent une restauration des habitats dégradés et des connectivités perdues. En outre, la Stratégie 2.4 du PAEA met en lumière les risques liés au changement climatique ainsi que le travail à effectuer en termes d'aménagement du territoire, d'extension des aires de répartition, de corridors de connectivité, etc. Ces problématiques peuvent avoir une influence sur la gestion et l'allocation des ressources envisagées dans les Activités 2.4.1 et 2.4.2. Certaines zones de l'aire de répartition demandent un soutien dans la gestion de processus écologiques tels que les actions de dispersion d'éléphants, plutôt qu'une aide directe à la maintenance et à la restauration des habitats. D'autres espaces, notamment les vastes étendues présentant des variations dans la qualité des habitats et la disponibilité en eau, peuvent être considérés dans une optique de métapopulation pour la conservation des éléphants. L'amélioration de l'aire de répartition des éléphants et de leurs mouvements pourrait entraîner un accroissement des conflits avec les communautés, selon l'usage qu'elles ont de ces mêmes environnements et de l'augmentation ou non de leurs activités humaines. Les efforts à réaliser pour de meilleurs habitats et une plus grande connectivité doivent aller de pair avec le travail de la cellule opérationnelle pour la coexistence entre humains et

as relevant changes to annotation 2 (after CoP19, footnote annotation A10), including changes to streamline and simplify the annotation. In accordance with the draft terms of reference (Notification to the Parties 2024/078), the African elephant range States agreed at SC77 that participation in this dialogue meeting should include the IUCN SSC AfESG for technical experts and resource persons. Representation at the meeting included thirty-one of the 37 African elephant range States, as well as two IUCN AfESG members, a representative of the UNEP African Elephant Fund, and several staff from the CITES Secretariat. It was chaired by the CITES Standing Committee Chair; and was a closed meeting with confidentiality established as a ground rule. Representatives of the AfESG presented information relating to the current status of African elephant populations, the range of the two species, and related assessments specifically the Red List and Green status. The report was noted, its scientific independence was acknowledged, and the AfESG was requested to establish a mechanism to ensure that relevant government authorities in African elephant range States share survey information and are consulted before status reports and population estimates are published. A communique (https://cites.org/eng/node/141108) as the main output of the meeting summarizing the agreements will be presented and discussed at the 78th Standing Committee in February 2025.

Strategic interventions for financial sustainability

The Paul G. Allen Family Foundation/Vulcan three-year grant will conclude in December 2024. This grant has significantly advanced the AED technology stack and supported the production of the AFESR and ASESR. Furthermore, the grant was critical in establishing key relationships to develop a circle of funders, including Save the Elephants, the International Fund for Animal Welfare, WWF–US, and WWF–International. Together, the first two organizations have committed to providing an annual financial contribution of USD 100,000 for specified AfESG activities. Grants from this circle of funders have supported a variety of initiatives, including the development of elephant-specific guidelines for

éléphants (voir le paragraphe n° 3 ci-dessus) – des tâches qui nécessitent réflexion, collaboration et inclusion dans la planification et le dialogue.

Rencontres avec les gouvernements

Ces derniers mois, le Secrétariat du GSEAf s'est engagé dans une série de rencontres importantes avec divers États de l'aire de répartition, en vue de promouvoir la mission du groupe de spécialistes et d'améliorer la collaboration sur les actions de conservation de l'éléphant. Des visites ont été organisées auprès des autorités gouvernementales d'Éthiopie, du Ghana, du Malawi, du Mozambique, de Tanzanie et de Zambie afin de renforcer les partenariats sur les questions de conservation. Le bureau régional de l'UICN an Afrique australe et orientale (ESARO) ainsi que le bureau régional pour l'Afrique de l'Ouest (WARO) ont joué un rôle crucial dans la préparation et la coordination de ces engagements régionaux. En outre, des rendez-vous en ligne ont eu lieu avec des contacts des gouvernements du Botswana, de Côte d'Ivoire, d'Eswatini, de Guinée, du Kenya, de Namibie, du Rwanda, de Somalie, d'Afrique du Sud, du Togo et du Zimbabwe. Ces interactions sont vectrices d'une meilleure collaboration et d'une plus grande sensibilisation, mais elles améliorent également le partage d'informations, dont les données de recensement, afin de perfectionner les processus de rapports de situation et les résultats de conservation.

Rencontres de dialogue relatives à l'éléphant d'Afrique

Conformément à la décision 19.167 relative au «Commerce d'éléphants d'Afrique vivants (*Loxodonta africana*)» prise lors de sa 77e session (SC77, Genève, novembre 2023), le Comité permanent a appelé à une réunion de dialogue CITES pour les États de l'aire de répartition de l'éléphant d'Afrique, conformément à la résolution Conf. 14.5 sur les réunions de dialogue, et a souscrit favorablement à la proposition du gouvernement du Botswana d'accueillir la réunion, en consultation avec le président du Comité permanent et les États de l'aire de répartition. Le dialogue devait s'articuler autour de l'harmonisation des conditions relatives au commerce d'éléphants vivants et introduire la proposition à la CdP20 de modifications pertinentes des résolutions ainsi que de l'annotation #2 (depuis la CoP19, annotation de bas de page A10), y compris des modifications visant

HECx, the Green Species Status processes, the sustainable use initiative, engagement with the AEAP, and updating the survey manual.

The four-year EU–MIKE CITES grant ended in October 2024, with plans for a subsequent five-year phase. This grant continues to support the maintenance and enhancement of the AED, which enables ongoing monitoring of Africa's elephant populations and informs the reporting to the Standing Committee of CITES on the conservation status of African elephants.

In June 2024, AfESG was awarded a three-year grant of USD 669,253 from the USFWS–African Elephant Conservation Fund. This funding will support the management and optimization of the AED, the analysis of elephant population trends, and the development of a baseline for HEC risks. The grant will also contribute to the creation of HEC toolkits, guidelines, and training resources for practitioners, support the Green Species Status process for both elephant species and the reassessment of the Red List Status of both species, and provide evidence to inform decision-making and policy development by range States and CITES. Importantly, this funding will also provide support to initiate the next revision of the status reports for both species.

In this issue

There is increasing evidence of compromised ethical concerns for captive African savannah elephants managed in confined spaces, with the trend for zoos and captive facilities to close due to public pressure. The manuscript by Eggeling and Roos et al. entitled *African elephant reintegration from captivity to wild living: quantifying the detailed behavioural changes* is an important and timely paper that describes the integration of captive elephants into a free-roaming system in South Africa and documents how elephant behaviour changes during the rehabilitation process. The authors recommend continual monitoring of behaviour to assess the success of reintegration operations after rehabilitation (pp. 70–83).

In this issue, we publish two of Parker's articles on tusk metrics. The first: *Tusk metrics and pair symmetry in savannah elephants* contributes comprehensive historical data with an in-depth

à rationaliser et simplifier l'annotation. En accord avec le projet de mandat (Notification aux Parties 2024/078), les États de l'aire de répartition de l'éléphant d'Afrique ont décidé à la 77e session du Comité permanent que le GSEAf du CSE de l'UICN devait participer à cette réunion en qualité d'experts techniques et de personnes-ressources. La rencontre a eu lieu du 23 au 26 septembre 2024 à Maun, au Botswana. Trente-et-un des trente-sept pays de l'aire de répartition de l'éléphant d'Afrique étaient présents, ainsi que deux membres du GSEAf, un représentant du Fonds pour l'éléphant d'Afrique du Programme des Nations Unies pour l'environnement (PNUE), et plusieurs membres du Secrétariat de la CITES. Le président du Comité permanent a assuré la présidence de la réunion, laquelle s'est tenue à huis clos et en suivant les règles établies de confidentialité. Les représentants du GSEAf ont présenté des données relatives au statut actuel des populations d'éléphants d'Afrique, à l'aire de répartition des deux espèces et aux évaluations correspondantes (la Liste rouge et le Statut vert). Il a été pris acte de ce rapport, son indépendance scientifique a été reconnue et le GSEAf a été mandaté pour mettre en place un mécanisme permettant de garantir que les autorités compétentes des pays de l'aire de répartition de l'éléphant d'Afrique partagent les informations de recensement et qu'elles soient consultées avant que les rapports de situation et les estimations de populations soient publiés. Le communiqué (https://cites.org/eng/node/141108), principal résultat de la réunion et résumant les accords importants, sera présenté et discuté à la 78e session du Comité permanent en février 2025.

Interventions stratégiques en vue d'un financement durable

La donation de la Fondation Paul G. Allen Family/Vulcan, qui courait sur trois ans, s'achèvera en décembre 2024. Elle aura permis des avancées de taille quant à la pile technologique de la BDEA et aura soutenu la production des rapports de situation de l'éléphant d'Afrique et de l'éléphant d'Asie. De plus, elle aura joué un rôle crucial dans la formation de relations clés qui ont ouvert la voie au développement d'un cercle de donateurs, dont Save the Elephants, le Fonds international pour la protection des animaux et WWF (antenne États-Unis et International). Save the Elephants et le Fonds international pour la protection des animaux se sont, à elles deux, engagées à hauteur de 100 000 $ pour des activités précises du GSEAf.

analysis of tusk symmetry. The increase in tusk weights and lengths with age is reconfirmed to be exponential in males and more linear in females up to their fifth decade. Between the right and left tusks, five metrics were symmetrical on average and predictive of age and each other. Interestingly, pair-length symmetry is less within the alveoli, where growth takes place, than between their corresponding external parts, where the tusks are essentially dead tissue (pp. 39–47).

Parker's second paper: *Further observations on savannah elephant tusks*, presents some fresh and interesting interpretations of important historical data on the growth of elephant tusks. Parker explains that the longest tusk pairs have a tight curvilinear relationship to average shoulder height, rising evenly from 24% (females) and 26% (males) under 6.5 years, rising to 58% and 76%, respectively, in the oldest age classes. Therefore, they relate to the height of an elephant (pp. 48–69).

Stiles' review of 'The political, economic, and institutional context of wildlife trafficking networks in Africa and a description of how they operate' is the second of two parts; the first was published in *Pachyderm*, Vol. 63/2022. The second part furthers our understanding of how large-scale wildlife trade crime is organized. The article explores the movement of ivory and rhino horn along the trade chains from acquisition to end-use market consumers using case studies of two of the main syndicates and the structure of the networks: the Kromah network (from 2010 to 2017) and the Xaysavang network (2005 to the present). It is framed between two UN developments to address transnational organized crime and corruption, and then demonstrates how badly we are losing this battle on these two critical fronts despite the substantial investment over the last decade or so. The review highlights how IWT constitutes a very significant criminal sector, and it can only be effectively challenged if both the demand and supply chains are targeted, encompassing elements of transparency, legal clarity, enforcement and the development of alternative livelihoods (pp. 142–159).

There are two papers on Gonarezhou National Park (NP), Zimbabwe. Mandinyenya et al.'s paper entitled *Sex differences in home range and habitat use by savannah elephants in Gonarezhou*

Les financements venus de ce cercle de donateurs ont soutenu diverses actions, dont l'élaboration de lignes directrices spécifiques à l'éléphant sur les conflits entre les humains et la faune sauvage et sur leur coexistence, le processus du Statut vert des espèces, l'initiative pour une utilisation durable des éléphants, les engagements avec le PEAP et la mise à jour du manuel de recensement.

Les donations sur quatre ans de l'Union européenne via CITES MIKE prendront fin en octobre 2024 et les perspectives d'une phase supplémentaire de cinq ans se profilent. Ces ressources sont toujours dédiées à la maintenance et l'amélioration de la BDEA, laquelle permet le suivi continu des populations d'éléphants d'Afrique et sert de base pour les rapports à destination du Comité permanent de la CITES sur la conservation de ces espèces.

En juin 2024, le GSEAf a bénéficié d'une donation sur trois ans de 669 253 $ de la part du Fonds pour la conservation de l'éléphant d'Afrique du département américain US Fish and Wildlife (« USFWS–African Elephant Conservation Fund »). Ce financement permettra de soutenir la gestion et l'optimisation de la BDEA, les analyses de tendances des populations d'éléphants et le développement d'une base de référence pour les risques liés aux CHE. Il contribuera également à la création d'outils pour prévenir les CHE, de lignes directrices et de ressources de formation à destination des acteurs de la conservation et il accompagnera le processus du Statut vert et de la réévaluation de la Liste rouge pour les deux espèces d'éléphants. En outre, il représentera un appui pour fournir des données concrètes aidant les prises de décisions et le développement des politiques des États de l'aire de répartition et de la CITES. Enfin, il sera un atout essentiel dans le lancement de la prochaine révision du rapport de situation des deux espèces.

Dans ce numéro

Il est de plus en plus évident que les éléphants de savane d'Afrique gérés dans des espaces confinés posent des problèmes éthiques. La tendance est à la fermeture de ces zoos et structures d'accueil en captivité sous la pression de l'opinion publique. Le manuscrit produit par Eggeling, Roos et al. intitulé *African elephant reintegration from captivity to wild living: quantifying the detailed behavioural changes* (« Quantifier en détail les changements de comportement des éléphants d'Afrique vivants dans des conditions de captivité

National Park, is an interesting piece of research on an understudied population of elephants. The study details seasonal and sex-linked variation in the home range dynamics of elephants; adding to the body of literature on elephant behaviour concerning environmental heterogeneity, and has implications for the effective management of elephant populations not only in Gonarezhou NP but elsewhere (pp. 104–118).

The second paper from research in Gonarezhou NP supports studies elsewhere that have found high drought mortality among immature elephants. Hundreds of elephants died during a severe drought in Gonarezhou NP in southeast Zimbabwe during 1992. The following year, entire female herds comprised of 670 female and juvenile elephants were captured and translocated elsewhere. Dunham presents his findings on the effect of drought on population age and sex structure from drought to 2023. Data from elephant herds culled in Gonarezhou NP during 1972–1987 were factored in (pp. 84–93).

The purpose of Von Hagen et al.'s paper *Five strategies to mitigate human-elephant conflict in the Kasigau Wildlife Corridor of Kenya*, is to convey how the findings of previous studies were incorporated into community workshops to convey and discuss strategies for the mitigation of HEC. The manuscript describes the development of the workshop structure and the five strategies presented. for reducing HEC. This stakeholder process is useful and it is important to have reflected in the literature (pp. 132–141).

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pendant leur réintégration à la vie sauvage») est une publication importante et opportune qui s'attache à décrire l'intégration d'éléphants, auparavant en captivité, dans un contexte sauvage en Afrique du Sud. Les auteurs documentent les changements de comportement pendant le processus de réintroduction, et recommandent un suivi continu des comportements afin d'évaluer la réussite de ce type d'opération après réintroduction (pp. 70–83).

Nous publions dans ce numéro deux articles de Ian SC Parker sur les dimensions des défenses. Le premier, intitulé *Tusk metrics and pair symmetry in savannah elephants* («Mesures et symétrie des paires de défenses de l'éléphant de savane»), apporte des données historiques exhaustives ainsi qu'une analyse détaillée de la symétrie des défenses. La croissance des défenses au fil des années, en poids et en dimensions, a été confirmée de nouveau comme étant exponentielle chez les mâles et plus linéaire chez les femelles jusqu'à leurs cinquante ans environ. Les cinq mesures sont en moyenne symétriques entre les défenses droites et gauches et s'avèrent prédictives de l'âge de l'individu et de la façon dont serait constituée la deuxième défense. Il est toutefois frappant de constater que la symétrie des paires en longueur est moindre à l'intérieur des alvéoles, où a lieu la croissance, qu'entre les parties externes correspondantes, où les défenses sont essentiellement composées de tissus morts (pp. 39–47).

Le second article, *Further observations on savannah elephant tusks* («Observations supplémentaires sur les défenses des éléphants de savane»), présente des interprétations nouvelles et intéressantes de la croissance des défenses d'éléphant à partir de données historiques importantes. Parker explique que les paires de défenses les plus longues ont une relation curvilinéaire étroite avec la hauteur moyenne des épaules, passant uniformément de 24 % (femelles) et 26 % (mâles) en dessous de 6,5 ans, à, respectivement, 58 % et 76 % dans les classes d'âge les plus élevées. En somme, leur longueur est relative à la hauteur de l'animal (pp. 48–69).

L'article *The political, economic, and institutional context of wildlife trafficking networks in Africa and a description of how they operate* («Contexte politique, économique et institutionnel dans lequel s'inscrivent les réseaux de commerce illégal des espèces sauvages et description de leur mode de fonctionnement»), proposé par Stiles, est la suite d'un premier document publié dans le volume n° 63 de Pachyderm (2022). Les éléments contenus dans le présent numéro

approfondissent notre compréhension de l'ampleur de la criminalité relative au commerce d'espèces sauvages. Grâce à l'étude de deux des principales organisations criminelles (le réseau Kromah de 2010 à 2017 et le réseau Xaysavang de 2005 à nos jours) et des structures des réseaux, nous explorons le mouvement de l'ivoire et de la corne de rhinocéros tout au long de la chaîne commerciale, depuis l'acquisition jusqu'aux marchés ciblant le consommateur final. L'article s'inscrit dans le cadre de deux initiatives des Nations unies visant à lutter contre la criminalité organisée transfrontalière et la corruption, et montre à quel point nous sommes en train de perdre la bataille sur ces deux fronts essentiels, malgré les investissements substantiels consentis au cours des dix dernières années environ (pp. 142–159).

Deux papiers sont consacrés au parc national de Gonarezhou au Zimbabwe. L'un, écrit par Mandinyenya et al., s'intitule *Sex differences in home range and habitat use by savannah elephants in Gonarezhou National Park*, («Le sexe des éléphants de savane du parc national Gonarezhou détermine des variations dans les domaines vitaux et l'utilisation des habitats») et représente une recherche intéressante sur cette population d'éléphants peu étudiée. L'analyse détaille les variations, selon les saisons et le sexe de l'animal, dans les dynamiques de domaine vital. Elle s'ajoute au corpus de littérature sur le comportement des éléphants par rapport à l'hétérogénéité environnementale et affecte l'efficacité de la gestion des populations d'éléphants, non seulement à Gonarezhou, mais également ailleurs (pp. 104–118).

Le second article issu d'une recherche dans le parc national de Gonarezhou vient appuyer de précédentes études qui avaient établi un fort taux de mortalité dû à la sécheresse chez les éléphants juvéniles. Des centaines d'éléphants sont morts lors d'une grave sécheresse qui a touché en 1992 le parc national de Gonarezhou, au sud-est du Zimbabwe. L'année suivante, des hardes entières comprenant 670 femelles et éléphants juvéniles ont été capturées et transférées en d'autres lieux. Dunham présente ses conclusions utiles des effets de la sécheresse sur la répartition des âges et des sexes depuis cet épisode jusqu'à nos jours. Les données tirées de hardes d'éléphants abattus dans le même parc national entre 1972 et 1987 sont prises en compte (pp. 84–93).

L'objectif de l'article écrit par Von Hagen et al., *Five strategies to mitigate human-elephant conflict in the Kasigau Wildlife Corridor of Kenya* («Cinq stratégies pour atténuer les conflits humains-éléphants dans le corridor de Kasigau au Kenya»), est de relater l'intégration des conclusions de précédentes études au sein d'ateliers communautaires dans le but de transmettre des stratégies d'atténuation de CHE et d'en discuter. Le manuscrit décrit la façon dont la structure des ateliers a été pensée et développée. Ce processus est utile et il est important qu'il résonne dans la littérature (pp. 132–141).

Remerciements

Le travail sans relâche et l'engagement des membres du GSEAf impliqués dans les diverses cellules opérationnelles et autres groupes de travail sont hautement appréciés et nous les en remercions. Nous sommes très reconnaissants pour le soutien financier de l'Union européenne via le projet MIKE de la CITES, de la Fondation Paul G. Allen Family/Vulcan inc., de Save The Elephants, du Fonds international pour la protection des animaux, de WWF (antenne États-Unis et International) et du fonds pour la conservation de l'éléphant d'Afrique du département américain US Fish and Wildlife. Nos remerciements particuliers sont adressés au bureau ESARO de l'UICN pour son soutien lors des rencontres régionales. Nous tenons à témoigner notre sincère gratitude au secrétariat du GSEAf (Mohammed Yahya, Rose Mayienda and Rachel Sharon) pour son soutien inestimable.

African Rhino Specialist Group Chair report
Rapport du Groupe de Spécialistes du Rhinocéros d'Afrique

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Introduction

The Vision of the African Rhino Specialist Group (AfRSG) is to promote thriving wild African rhinoceroses (rhinos) which are valued by people. The AfRSG strives to guide and facilitate the conservation of viable African rhino populations across their natural range. Increasingly the expectations of African citizens are that rhino conservation makes a broader contribution to the well-being of people who share landscapes with rhinos. In this report, we reflect on the progress towards achieving the AfRSG objectives in relation to black rhinos (*Diceros bicornis*) and white rhinos (*Ceratotherium simum*).

Achieving global rhino conservation

Over the past year, the AfRSG was requested to comment on proposals for rhino introductions and the expansion of the range of both species of African rhino. These proposals centered on translocations of rhinos to sites within and beyond the historical range of the identified species. Proposals within the historical range of the focal species included restocking of the Zambezi Valley in Zimbabwe with a founder population of south-central black rhino (*Diceros bicornis minor*), and the feasibility of expanding the current range of the south-central black rhinos to Nsumbu and Kafue National Parks (NP) in Zambia. Requests dealing with rhinos

Introduction

La vision du Groupe de Spécialistes du Rhinocéros d'Afrique (GSRAf) est de promouvoir des rhinocéros sauvages vigoureux et estimés à leur juste valeur. Le groupe s'attache à guider et à faciliter la conservation de populations de rhinocéros sauvages viables dans leur aire de répartition naturelle. Les citoyens africains ont de plus en plus d'attentes quant à la conservation des rhinocéros : elle doit contribuer davantage au bien-être des habitants qui partagent le paysage avec eux. Dans ce rapport, nous analyserons les progrès accomplis dans la réalisation des objectifs que le GSRAf s'est fixés pour le rhinocéros noir (*Diceros bicornis*) et le rhinocéros blanc (*Ceratotherium simum*).

Assurer la conservation des rhinocéros à l'échelle mondiale

L'année dernière, le GSRAf a été mandaté afin de faire part de ses observations quant à des propositions d'introductions de rhinocéros et d'extension des aires de répartition des deux espèces africaines. Ces propositions portaient sur des translocations vers des sites se trouvant à l'intérieur et au-delà des aires de répartition historiques des espèces identifiées, comme dans le cas suivant : le repeuplement la vallée du Zambèze au Zimbabwe avec une population fondatrice de rhinocéros noirs du centre-sud (*Diceros bicornis minor*). Les discussions s'intéressaient également à la faisabilité d'étendre l'aire de répartition actuelle des rhinocéros noirs aux parcs nationaux de Nsumbu

outside their historical range included guidance on the management of a single southern white rhino (*Ceratotherium simum simum*) in Côte d'Ivoire, the introduction of a founder population of southern white rhino into the Ngorongoro Crater in Tanzania, and the supplementation of the out-of-range (introduced) southern white rhino population at Ziwa Rhino Sanctuary in Uganda. An important emerging issue in continental rhino conservation is the 'rewilding' of rhinos, i.e. release into a free-ranging or wild context of rhinos that were housed for a period, or bred, within captive breeding facilities. This issue is of particular relevance for the African Parks Network that acquired approximately 2,000 intensively managed southern white rhinos through their purchase of the Platinum Rhino facility in South Africa.

These initiatives have challenged the AfRSG to consider the detail in the IUCN guidelines for reintroductions and other conservation translocations (IUCN 2013) as well as the rhino specific guidelines (Emslie et al. 2009). Motivations for releasing rhinos outside of their historical range vary, but commonly aspirations seek to increase the number of the specific rhino species or enhance the socio-ecological role of rhinos in a range State.

Recent research suggests the existence of a distinct structure in the geographic distribution of black rhino genetics (Sánchez-Barreiro et al. 2023; Moodley and Robovsky 2024) across the species range, and it is necessary to consider this when making rhino translocation decisions for conservation purposes. This is a topic that the AfRSG will be tackling in more detail with the intention of developing guidelines for decision-makers. Until such guidelines are developed the current subspecies categorization will remain in place with an emphasis on source and target populations being as geographically close as is pragmatic. Furthermore, when a subspecies has gone extinct, an ecologically equivalent subspecies can be introduced as a substitute (IUCN 2013). Out-of-range introductions irrespective of the purpose, will require substantially more risk aversion in both initial consideration and when establishing or managing the populations.

The AfRSG contributed to the review of the Kenyan Ecological Carrying Capacity guidelines.

et Kafue en Zambie. Pour ce qui est des rhinocéros vivant en dehors de leur aire de répartition historique, plusieurs demandes étaient étudiées, notamment en ce qui concerne la gestion du dernier rhinocéros blanc (*Ceratotherium simum simum*) de Côte d'Ivoire, ainsi que l'introduction d'une population fondatrice de rhinocéros blancs du sud dans le cratère du Ngorongoro en Tanzanie et le renforcement d'un effectif de la même espèce introduit (hors de son aire de répartition) dans le sanctuaire de Ziwa Rhino en Ouganda. Parmi les sujets importants à aborder dans le cadre de la conservation à l'échelle du continent figure le « réensauvagement » des rhinocéros, soit le fait de réimplanter — dans des conditions de liberté ou à l'état sauvage — ces animaux qui ont été élevés en captivité ou recueillis pendant une période donnée. Cette question revêt une dimension particulière pour le réseau African Parks Network, qui a acquis environ 2 000 rhinocéros blancs du sud gérés de manière intensive suite à son rachat des installations de Platinum Rhino en Afrique du Sud.

Ces initiatives ont poussé le GSRAf à prendre en compte dans le détail les lignes directrices établies par l'UICN en ce qui concerne les réintroductions et autres translocations de conservation (UICN 2013), ainsi que les recommandations propres aux rhinocéros (Emslie et al. 2009). Les motivations avancées pour implanter des rhinocéros hors de leur aire de répartition historique sont variables, mais elles visent généralement à augmenter l'effectif d'une espèce spécifique ou à renforcer leur rôle socioécologique dans les États de l'aire de répartition.

De récentes recherches ont indiqué l'existence d'une structure distincte dans la distribution géographique de la génétique des rhinocéros noirs (Sánchez-Barreiro et al. 2023 ; Moodley et Robovsky 2024) sur la surface de l'aire de répartition de l'espèce. Il convient de prendre cela en compte lors des démarches de translocations à des fins de conservation. Ce sujet sera abordé en détail par le GSRAf, avec l'intention de développer des lignes directrices destinées aux décisionnaires. D'ici là, la catégorisation actuelle des sous-espèces restera la règle et les populations sources et cibles devront être aussi proches que possible du point de vue géographique. En outre, lorsqu'une sous-espèce est éteinte, une sous-espèce équivalente au niveau écologique pourra être introduite comme substitut (UICN 2013). Des introductions hors de l'aire de répartition, quel qu'en soit l'objectif, nécessiteront un degré d'aversion au risque nettement plus élevé lors

This was done through the Chair and Scientific Officer, as well as other AfRSG members, who participated in a workshop to review existing thinking around the ecological concepts. As part of the workshop, members focused on considering different models for rhino density management and the underlying ecological basis for decision-making. The process required consideration of the alignment between existing Kenyan policy prescripts and ecological fundamentals. The resulting framework, particularly when considering the establishment of a new site, adopted a two-step approach that encourages a national assessment of possible new sites likely to have the ecological potential to carry more than 50 individual rhinos; and once a founder population is established to use dispersal and colonization dynamics as well as a fixed harvesting rate tactic (through translocation) to manage the rhino population density. This approach, coupled with a monitoring programme that tracks population growth parameters, should enable the Kenyan management team to effectively navigate the challenges of managing the density of the rhino population at a site.

A subsequent workshop in Zimbabwe, attended by the Chair and Scientific Officer, sought to address some of the challenges in managing a number of medium-sized and many small populations of black and white rhinos in the country. Of particular importance is the fact that many of the populations have been isolated (i.e. no movement of individuals in or out of the population) for some time with potential for reduced fitness or at least inbreeding. The removal, exchange or supplementation of individual rhinos could address risks. Managing a metapopulation through translocations, however, could build ecological robustness in fragmented landscapes by mimicking colonization and dispersal dynamics between two areas. This approach should reduce genetic risk management.

Fostering the value of rhinos

Rhinos play key ecological roles in natural ecosystems (Waldram et al. 2008) and can contribute to the well-being of people (Morais et al. 2018). An external review process for the African Rhino Conservation Framework emphasized

de l'examen initial de la proposition, comme pendant l'établissement ou la gestion des populations.

Le GSRAf a contribué à l'examen des directives relatives aux capacités d'accueil du Kenya (« Kenyan Ecological Carrying Capacity guidelines » en anglais). Cette étape a été réalisée par le biais du président, du directeur scientifique ainsi que d'autres membres du GSRAf, qui ont participé à un atelier visant à repenser les approches actuelles autour des concepts écologiques. Durant cette table ronde, les membres se sont attachés à considérer différents modèles de gestion de la densité de rhinocéros et l'assise écologique permettant les prises de décisions. Le processus a demandé de prendre en compte l'alignement entre les prescriptions de la politique kenyane existante et les principes écologiques fondamentaux. Le cadre qui en est ressorti, tout particulièrement en ce qui concerne l'établissement d'un nouveau site, a privilégié une approche en deux étapes : encourager une évaluation nationale de nouveaux sites éventuels portant un potentiel environnemental d'accueil de plus de cinquante rhinocéros, puis, une fois la population fondatrice établie, utiliser des dynamiques de dispersion et de colonisation ainsi que des tactiques de taux de prélèvement fixe (par translocation) afin de gérer la densité de population des rhinocéros. Cette approche, associée à un programme de suivi des paramètres de croissance de population, devrait permettre à l'équipe kenyane dédiée de piloter avec efficacité les défis posés par la gestion de la densité sur un site donné.

Un second atelier s'est tenu au Zimbabwe, auquel le président et le directeur scientifique du GSRAf ont assisté, afin de discuter de diverses problématiques liées à la gestion de plusieurs populations de rhinocéros noirs et blancs dans le pays (quelques-unes de taille moyenne et de multiples petits groupes). Il est particulièrement important de noter que nombre de ces populations ont été isolées depuis un certain temps (autrement dit, qu'aucun mouvement d'individu n'a été effectué depuis ou vers la population), impliquant un risque de valeur adaptative réduite ou, à tout le moins, de consanguinité. Le retrait, l'échange ou l'ajout de rhinocéros constituerait une réponse dans ces circonstances. Gérer une métapopulation par le biais de translocation pourrait en outre établir une résilience écologique dans des paysages fragmentés en imitant les dynamiques de colonisation et de dispersion entre deux zones. Cette approche devrait restreindre les besoins de gestion du risque génétique.

the need to address the emerging social context and the changing societal expectations related to rhinos in Africa. Six key themes are identified in the framework (ecological roles, safety and security, organized crime, rhino markets, inequality, and the multiple values of rhinos), and these need to be supported by enabling flexible funding, technical capacity, and appropriate rights and laws. Efforts are currently underway to publish the framework under the IUCN label.

In the reporting period, the AfRSG contributed to an assessment of the Green Status (Grace et al. 2021) of black rhinos. Additionally, the AfRSG published a study on 'The measures of conservation legacy, conservation dependence, conservation gain and recovery potential for black rhino' (Ferreira et al. 2024a). The analysis highlighted that various global change drivers could lead to habitat for 21,770 black rhinos being available by 2122 (that is in 100 years), but only 20,951 would occupy that space when based on the predicted growth. Given this, the recovery potential from what was present in 2022 was 14,483. To fully realize the potential, however, the introduction of ecologically equivalent subspecies into available habitat within ranges of extinct subspecies is needed.

Synthesizing the available information at the CITES CoP19 in Panama and additional insights from recent publications, the AfRSG distilled four insights that are useful for informing rhino conservation decision-making.

- First, was the identification of a generalized poaching threshold (Ferreira et al. 2022): when rhino populations experience poaching losses of less than 3.5% of rhinos per annum, the population numbers will increase despite poaching.
- Secondly, it appears that size does matter: smaller reserves on average recorded lower poaching rates (Ferreira and Dziba 2021). This is most likely due to more cost-effective access control, situational awareness, maintenance of staff integrity, and detailed monitoring of rhinos at an individual level.
- Thirdly, cost-effective access control, situational awareness, staff integrity and rhino monitoring are hard to achieve when localities where rhinos live are

Promouvoir la valeur des rhinocéros

Les rhinocéros jouent un rôle écologique essentiel dans les écosystèmes naturels (Waldram et al. 2008) et peuvent contribuer au bien-être des populations locales (Morais et al. 2018). Un processus d'évaluation externe du Plan de conservation du rhinocéros d'Afrique a mis en lumière la nécessité de tenir compte des contextes sociaux nouveaux et des attentes sociétales en pleine mutation à l'égard des rhinocéros d'Afrique. Dans ce plan, six thèmes clefs ont été identifiés — rôle écologique, sécurité, crime organisé, le rhinocéros sur le marché noir, inégalités et les valeurs multiples du rhinocéros — qui doivent pouvoir s'appuyer sur un financement flexible, des capacités techniques ainsi que des droits et des lois adaptés. Des efforts sont actuellement déployés pour une publication sous le label de l'UICN.

Le GSRAf a contribué à l'évaluation du Statut vert (Grace et al. 2021) du rhinocéros noir. En outre, le groupe a publié une étude sur les mesures relatives à l'héritage des initiatives de conservation, à la dépendance à la conservation, aux gains en matière de conservation et au potentiel de rétablissement du rhinocéros noir («The measures of conservation legacy, conservation dependence, conservation gain and recovery potential for black rhino») (Ferreira et al. 2024a). Cette analyse a mis en exergue le fait que plusieurs facteurs de changements à l'échelle mondiale pourraient conduire à la disponibilité d'un habitat pour 21 770 rhinocéros à l'horizon 2122 (soit dans 100 ans), mais que seuls 20 951 de ces individus occuperaient cet espace si l'on se base sur la croissance prévue. Dans ces conditions, le potentiel de rétablissement par rapport à la situation en 2022 est de 14 483. Cependant, afin d'atteindre pleinement ce potentiel, il est nécessaire de mener à bien l'introduction de sous-espèces, équivalentes d'un point de vue écologique, dans des habitats disponibles au sein des aires de répartition de sous-espèces éteintes.

Grâce à la synthèse réalisée depuis les informations exposées à la 19e CdP de la CITES qui s'est tenue au Panama et d'après des perspectives extraites de récentes publications, le GSRAf a compilé quatre éclairages utiles lors des prises de décisions relatives à la conservation des rhinocéros.

- En premier lieu, un seuil global de braconnage a été identifié (Ferreira et al. 2022) : lorsque les populations de rhinocéros subissent, du fait du braconnage, des pertes inférieures à 3,5 % des individus par an, leur nombre augmente malgré le préjudice.

abutted by areas experiencing high levels of criminality (Rademeyer 2023).
- Lastly, site level rhino conservation and particularly population growth, irrespective of species or subspecies, tend to perform better when management of the site is conducted by partnering organizations as opposed to state only (Ferreira et al. 2022).

Challenges and opportunities

Although there has been much focus on the rewilding of rhinos through the 'Rhino Rewild' initiative of African Parks, there are other important opportunities related to rhinos living in zoos. At the end of 2023, up to 20% of all eastern black rhinos (*D. b. michaeli*) were in zoo facilities across the globe, with a concentration in Europe (AfRSG, Unpublished data). Additionally, various global environmental change drivers, including climate change impact on rhinos (e.g. Mamba and Randhir 2024) and ecosystems, are imposing new thinking and requirements for adaptive capacity of ecosystems (Malhi et al. 2022) and how rhinos can contribute to that, including contributions as novel elements fulfilling a specific trophic role (Cromsigt et al. 2018). We have already noted the need for pragmatic considerations given new genetic insights. When there is the need to ensure that rhinos are protected from nearby criminality, the management of fragmented habitats increases considerably in complexity.

Fostering the values of rhinos across the complete suite of conditions within which rhinos live could benefit from implementing meta-population frameworks (Olivier et al. 2009). In meta-population dynamics, rhino populations can occur in discontinuous units across their range; vital rates can differ between these units; and there should be occasional dispersal events. In the contemporary world, these dispersal events can be assisted through translocations between populations (sites). The approach reflects an ecological process, but dispersal dynamics support robust genetic outcomes across the meta-population.

- La deuxième donnée révèle que la taille des réserves a son importance : les plus petites d'entre elles enregistrent en moyenne des taux de braconnage plus faibles (Ferreira et Dziba 2021). Cela est très probablement lié à plusieurs facteurs : un contrôle de l'accès à ces zones efficace et rentable, une connaissance solide de la situation, l'intégrité préservée du personnel sur place et un suivi détaillé des rhinocéros à l'échelle individuelle.
- Troisièmement, il est souligné que les éléments cités ci-dessus sont difficiles à mettre en œuvre lorsque les régions habitées par les rhinocéros sont attenantes à des territoires souffrant de niveaux de criminalité élevés (Rademeyer 2023).
- Enfin, il a été relevé que la conservation des rhinocéros au niveau du site, et plus particulièrement la croissance des populations (quelle que soit l'espèce ou la sous-espèce), tend à de meilleurs résultats lorsque la gestion du lieu est conduite par des organisations partenaires plutôt que par l'État seul (Ferreira et al. 2022).

Défis et opportunités

Bien que le réensauvagement des rhinocéros ait connu une attention conséquente suite à l'initiative d'African Parks « Rhino Rewild » (« Le retour à l'état sauvage des rhinocéros »), d'autres projets d'importance en lien avec les rhinocéros vivant en zoos existent. Fin 2023, jusqu'à 20 % des rhinocéros noirs de l'est (*D. b. michaeli*) se trouvaient dans des zoos de par le monde, dont un certain nombre en Europe (GSRAf, données non publiées). De plus, divers facteurs de changements environnementaux à l'échelle mondiale, dont l'impact du dérèglement climatique sur les rhinocéros (voir Mamba et Randhir 2024) et sur les milieux naturels, imposent de nouvelles réflexions et exigences en matière de capacité d'adaptation des écosystèmes (Malhi et al. 2022). Il faut également prendre en compte la façon dont ces animaux peuvent participer à cette adaptation, y compris leur contribution en tant qu'éléments nouveaux jouant un rôle trophique spécifique (Cromsigt et al. 2018). Nous avons déjà évoqué la nécessité de perspectives pragmatiques compte tenu des données génétiques inédites. Lorsqu'il faut garantir la sécurité des rhinocéros face à la criminalité environnante, la complexité de la gestion d'habitats fragmentés augmente considérablement.

Promouvoir la valeur des rhinocéros, et ce,

Communicating about rhinos

The Scientific Officer and Chair contributed or provided responses to media enquiries. Media engagements were largely restricted to responses by the Chair or Scientific Officer to enquiries related to the translocation of white rhinos from the facility managed by African Parks who purchased the Platinum Rhino initiative—now known as 'The Farm'.

The chair has established a process of updating the membership regularly on activities and key developing aspects with regards to rhino conservation. Three webinar sessions focused on: 1) innovative funding mechanisms for biodiversity credits; 2) the implantation of radioactive beads into rhino horns to increase detection in transit at customs posts; and 3) an introduction to the Rhinomics initiative which seeks to legalize rhino horn trade.

The AfRSG published the measures of conservation legacy, conservation dependence, conservation gain and recovery potential for black rhinos, which was a key requirement for the Green Status assessment. The assessors worked step by step through the requirements with the IUCN Green Status Team.

The *Communications* Working Group completed a stakeholder analysis. Most stakeholders require communication beyond knowledge provision to improve awareness including providing opportunities to further their understanding. This requires a diversity of approaches to identify messages and mechanisms to deliver messages that are specific to the needs of each stakeholder.

Guiding rhino conservation

Following the completion of some work and some rationalization, the AfRSG is left with four task forces and eight working groups.

The *Data Access and Use* task force has been discontinued after delivering a data-use policy—which the AfRSG is implementing, and the *Co-chair Process* task force was disbanded once the new chair was appointed. The *Range State Representatives and AfRSG Activities* task force reported on the survey they conducted, and in which range State representatives participated.

The *Community Participation* task force has been dormant and has made no progress on collating information and lessons from the

en parcourant tout le spectre des conditions dans lesquelles ils vivent, pourrait bénéficier de la mise en œuvre de cadres métapopulationnels (Olivier et al. 2009). Dans les dynamiques de métapopulations, les groupes de rhinocéros sont parfois scindés en unités discontinues dans leur aire de répartition. Les taux démographiques peuvent différer entre ces unités et des événements de dispersion occasionnels devraient se produire. Dans le monde contemporain, ces événements de dispersion peuvent être soutenus par des translocations entre populations (ou sites). Cette approche est manifeste d'un processus écologique, mais les dynamiques de dispersion permettent d'obtenir des résultats génétiques robustes sur l'ensemble de la métapopulation.

La communication autour des rhinocéros

Le directeur scientifique et le président du GSRAf ont donné suite à des demandes émises par les médias, ou ont contribué à leur apporter une réponse. Ces contacts se sont strictement limités aux questions relatives aux translocations de rhinocéros blancs depuis l'installation gérée par African Parks — désormais connue sous le nom de « The Farm » (la Ferme) — qui a racheté le projet Platinum Rhino.

Le président a mis en place un processus d'information régulière des membres à propos des activités et des aspects clefs en cours de développement concernant la conservation. Trois sessions de webinaires ont eu lieu, sur les sujets suivants : 1) les mécanismes de financement innovants pour les crédits biodiversité ; 2) l'implantation de microsphères radioactives dans les cornes de rhinocéros afin d'en accroître la détection aux postes de douane ; 3) l'introduction à l'initiative Rhinomics qui vise à légaliser le commerce de corne de rhinocéros.

Le GSRAf a publié les mesures relatives à l'héritage des programmes de conservation, la dépendance à la conservation, les gains en matière de conservation et le potentiel de rétablissement du rhinocéros noir, ce qui était une condition essentielle pour l'évaluation du Statut vert. Les membres assesseurs ont travaillé sur chacune des modalités en collaboration avec l'équipe du Statut vert de l'UICN.

Le *Communications* Working Group (« Groupe de travail dédié à la communication ») a conduit une analyse des parties prenantes, qui, pour la plupart, et afin d'améliorer leur sensibilisation, demandent

Conservation Clinic of the AfRSG at the African Protected Area Congress. As the focus of the task force is important, there will be ongoing discussions to find ways of revitalizing the work of developing guiding principles for enhancing meaningful participation in various levels of decision-making associated with rhinos.

The *Rewilding Rhinos* task force completed the work of developing a guiding document for the rewilding of African rhinos. A key element of this work is the manner in which the interpretation of 'suitable and appropriate destinations' is handled according to CITES decisions (CITES 2022).

The *African Rhino Conservation Framework* task force is nearing completion of the process and is preparing the framework (see above) for publication consistent with IUCN guidelines (CPSG 2020).

Working groups tackle activities that are less focused than task forces. Although the *African Rhino Data Management* working group developed a work process, two joint applications for funding a data management system in collaboration with TRAFFIC have been unsuccessful. As an interim measure, the Secretariat has established an online data storage facility. The working group will continue to guide the use and management of data. The *Population Rating Systems* working group made little progress in finalizing a rhino population rating system, but the working group was able, with assistance from the IUCN Secretariat, to complete a Green Status assessment team for black rhinos. The assessment is expected to be published before the end of 2024.

The *Governance* working group provides advice and guidance to the Chair in governance and functions of the AfRSG as and when required. The *AfRSG Membership* working group has been integrated into the Governance working group. The *Capacity* working group did not achieve its objectives after most of the members resigned from the working group. The AfRSG will now pursue a modified approach to mentor and grow African rhino expertise. Two additional working groups were also merged—these are the *Value of Rhinos* and *Adequate Finance* working groups. The new *Values of Rhinos* working group identified information requirements and the Secretariat facilitated webinars to explore and discuss innovative funding models such as

à bénéficier d'une communication plus exhaustive qu'une simple transmission d'informations, dont des éléments de compréhension et les moyens de mieux saisir la situation. Cela nécessite l'emploi de diverses approches pour identifier les messages à diffuser et les mécanismes permettant de les délivrer, qui sont spécifiques aux besoins de chaque partie prenante.

Guider la conservation du rhinocéros

Après avoir œuvré sur le sujet et réalisé des efforts de rationalisation, le GSRAf centralise désormais quatre cellules opérationnelles (CO) et huit groupes de travail (GT).

La CO *Data Access and Use* («Accès aux données et utilisation») a pris fin après la livraison de sa politique d'utilisation des données (que le GSRAf est en train de mettre en place) et la CO *Co-chair Process* («Processus de co-présidence») a été dissoute une fois le nouveau président nommé. La CO *Range State Representatives and AfRSG Activities task force* («Représentants des États de l'aire de répartition et activités du GSRAf») ont fait part de l'étude qu'ils ont réalisée, à laquelle des représentants d'États de l'aire de répartition ont collaboré.

La CO *Community Participation* («Communautés engagées») est en suspens et n'a pas progressé dans la collecte d'informations et d'enseignements auprès de la «Conservation Clinic» (atelier de conservation écologique) du GSRAf au Congrès des zones protégées d'Afrique. L'objectif de cette cellule étant important — l'élaboration de principes directeurs permettant une participation significative aux différents niveaux de prises de décisions — les discussions vont se poursuivre afin de trouver les moyens de raviver les efforts en ce sens.

La CO *Rewilding Rhinos* a accompli la tâche qui lui incombait : concevoir un document de référence pour le réensauvagement des rhinocéros africains. Un des éléments clef de ce travail réside dans l'interprétation qui est faite des «destinations appropriées et adaptées», conformément aux décisions de la CITES (CITES 2022).

La CO *African Rhino Conservation Framework* («Plan de conservation du rhinocéros d'Afrique») est sur le point d'achever sa mission et prépare actuellement la publication du plan (voir plus haut), selon les termes fixés dans les lignes directrices de l'UICN (CPSG 2020).

Les groupes de travail prennent en charge des activités moins spécifiques que les cellules

the wadappt (https://wadappt.io/) and Rhinomics (https://rhinomics.com/) initiatives.

The *Protection, Law Enforcement, Investigations and Intelligence* working group held one online meeting and decided that it would be better if they channelled their energies and worked with the security structures of other IUCN and Specialist Groups. The most active working group is the *Biological Management* working group, which after integrating the *Technical Mediation and Facilitation of Important Processes and Actions*, continued to provide reviews and comments on proposals and policy documents. The total for the year exceeds six.

According to the annual reporting requirements of the IUCN SSC 2023 (Grace and Long 2023) for the 2021–2025 quadrennium, the AfRSG had set itself 31 goals for the quadrennium. These targets are grouped into the *Assess, Plan, Act, Network and Communicate* thematic areas. By 2023, the AfRSG had completed 11 of the targets (36%), 15 targets were on track (48%) and 5 targets (16%) had not been initiated. The completed targets included: submission of a joint IUCN/TRAFFIC report for CoP19; review range State proposals for IUCN TRAFFIC analyses in preparation for CITES CoP19 in 2022; review at least two scientific papers per year. On-track targets include publish[ing] at least two articles in SPECIES by 2024; attend[ing] the next IUCN–SSC Leaders meeting; develop a strategy for capacity building of young rhino conservationists in 2021.

Improving knowledge and understanding

Members of the AfRSG continued to engage in developing and increasing scientific understanding to inform rhino conservation through research under the auspices of various institutions. The status of black rhinos and contributing factors highlighted the impacts of conservation action on the future of black rhinos (Ferreira et al. 2024a). Following concerns of selective pressures linked to offtakes (Wilson et al. 2022), the AfRSG emphasized how public debate, scientific evidence, policy making, and management, should focus on the causal reasons for poaching and horn trafficking (Ferreira et al. 2024b).

There has been an increase in genetic work done on African rhinos. Leaving individuals restricted to

opérationnelles. Bien que le GT *African Rhino Data Management* (« gestion des données relatives au rhinocéros d'Afrique ») ait élaboré un processus de travail, deux demandes conjointes de financement d'un système de gestion des données en collaboration avec TRAFFIC n'ont pas abouti. En guise de mesure provisoire, le Secrétariat a mis en place un service de stockage des données en ligne. L'équipe continuera d'accompagner l'utilisation et la gestion des données. Le groupe de travail *Population Rating Systems* (« Système d'évaluation des populations ») a peu avancé dans sa tâche de finalisation d'un système d'évaluation de la population de rhinocéros, mais est parvenu, avec l'aide du Secrétariat de l'UICN, à constituer une équipe pour l'examen du Statut vert des rhinocéros noirs. La publication de cette évaluation est attendue avant la fin de l'année 2024.

Le GT *Governance* (« Gouvernance ») fournit des conseils et des orientations au président, sur demande de ce dernier, en termes de gouvernance et de fonctions du GSRAf. Le GT *AfRSG Membership* (« Membres du GSRAf ») a été intégré au groupe *Governance*. Le GT *Capacity* (« Compétences ») n'a pas atteint ses objectifs du fait de la démission de la plupart de ses membres. Le GSRAf va désormais s'attacher à trouver une approche différente afin d'encadrer et développer l'expertise autour du rhinocéros. Deux groupes supplémentaires — *Value of Rhinos* (« Valeur du rhinocéros ») et *Adequate Finance* (« Financement approprié ») — ont fusionné sous le nom *Values of Rhinos* en vue d'identifier les besoins en matière d'information. Le Secrétariat a animé des webinaires traitant de modèles de financement innovants tels que les projets wadappt (https://wadappt.io/) et Rhinomics (https://rhinomics.com/).

Le groupe de travail *Protection, Law Enforcement, Investigations and Intelligence* (« Protection, application de la loi, investigations et renseignement ») a tenu une réunion en ligne et a décidé que canaliser leur énergie et travailler avec les structures de sécurité d'autres groupes de spécialistes et de l'UICN serait plus constructif. L'équipe la plus active est le groupe *Biological Management* (« Gestion biologique ») qui, après avoir intégré en son sein le groupe *Technical Mediation and Facilitation of Important Processes and Actions* (« Médiation technique et facilitation des processus et des actions d'importance »), a continué de fournir des comptes-rendus et des commentaires sur diverses propositions et documents d'orientation. Ils en ont produit plus de six sur l'année.

small, isolated populations can carry an increased risk of extinction. Across the extant black rhino subpopulations in Tanzania, translocated populations did not share haplotypes with native populations, indicating successful restoration of previous diversity to the region. Authorities could enhance the utilization of previous translocations focusing on the natural movements of individuals between subpopulations within a large area, which could be less costly than the alternative of using genetic data to target specific animals for translocation (Mellya et al. 2023).

Larger populations such as in Kruger NP in South Africa resulted from several lineages, (one from KwaZulu-Natal, South Africa, and the other from the Zambezi River, Zimbabwe), introduced in the 1970s. Understanding the genetic implications of mixing gene pools can help avoid the risk of outbreeding depression, and maximize translocation effectiveness. Kruger's black rhinos were more diverse than those from KwaZulu-Natal, and more like those of the Zambezi Valley. There was an increase in the Zimbabwean lineage, suggesting a possible selective advantage. Multiple sources may enhance the adaptive capacity of individuals in newly established populations (Stanbridge et al. 2023).

A better understanding of how rhinos respond to changing conditions and adapt can help enhance conservation outcomes. When food resources are limited, rhinos may switch to lower-quality forage. The breadth of the Eastern black rhino diet increased with vegetation productivity but was also associated with less *Vachellia* and *Senegalia* spp. and more with grasses (Harvey Sky et al. 2024). This unanticipated finding has piqued interest and will receive attention from black rhino diet specialists. Importantly, larger dietary shifts are associated with longer inter calving intervals.

Improved techniques to measure rhino demographics including fecundity schedules can enhance the evaluation of the responses of rhinos to various stressors. Analysing longitudinal faecal progestogen metabolite (fPM) concentrations in breeding female Eastern black rhinos at Ol Jogi (Kenya) suggests that irregular ovarian activity and isolated bouts of anoestrus do not have negative impacts on reproductive performance (Kamau et al. 2023).

The health of individual rhinos is an important conservation consideration in small populations,

Conformément aux exigences de l'UICN CSE 2023 en matière de rapports annuels (Grace et Long 2023) pour le quadriennat 2021-2025, le GRSAf s'est fixé 31 objectifs à atteindre sur la période. Ces perspectives sont réunies dans les thématiques *Assess, Plan, Act, Network and Communicate* (« Évaluer, Planifier, Agir, Travailler en réseau et Communiquer »). En 2023, le GSRAf avait accompli 11 de ses missions (soit 36 %), 15 d'entre elles (soit 48 %) étaient en cours de réalisation et 5 (soit 16 %) restaient à entreprendre. Parmi les objectifs atteints, on peut citer : la soumission d'un rapport conjoint de l'UICN et de TRAFFIC pour la CdP19, l'évaluation des propositions des États de l'aire de répartition pour les analyses TRAFFIC de l'UICN en vue de la CdP19 de la CITES en 2022, et l'examen d'au minimum deux articles scientifiques par an. Les dossiers en cours de réalisation concernent la publication, à l'orée 2024, d'au moins deux articles dans la revue SPECIES, la participation à la prochaine réunion des dirigeants de la CSE (« IUCN SSC Leaders ») et le développement en 2021 d'une stratégie de renforcement des compétences pour les jeunes impliqués dans la conservation du rhinocéros.

Pour une connaissance et une compréhension plus vastes

Les membres du GSRAf poursuivent leur entreprise de développement et d'amélioration de la compréhension scientifique, qui vient soutenir la conservation du rhinocéros grâce à la recherche, sous les auspices de diverses institutions. Le statut du rhinocéros noir et les facteurs qui y contribuent ont mis en lumière les impacts des interventions de conservation sur l'avenir de l'espèce (Ferreira et al. 2024a). Suite aux inquiétudes relatives à la pression sélective exercée par les prélèvements (chasse ou braconnage) (Wilson et al. 2022), le GSRAf a souligné combien le débat public, les preuves scientifiques, l'action politique et la gestion de conservation devaient se pencher sur les raisons menant au braconnage et au trafic de corne (Ferreira et al. 2024b).

Les recherches en génétique effectuées sur les rhinocéros d'Afrique se sont accrues. Les individus vivant dans de petites populations isolées peuvent courir un risque plus élevé d'extinction. Dans l'ensemble des sous-populations encore existantes en Tanzanie, les groupes issus de translocations ne partagent pas leurs haplotypes avec les populations natives, ce qui indique un rétablissement réussi d'une

particularly when considering interventions such as translocation. A small sample of three South-western black rhinos in Namibia did not find any presence of flatworms (*Echinococcus* spp.) (Aschenborn et al. 2023). Translocations of rhinos expose animals to many factors (e.g. prolonged fasting, confinement, novel environment, etc.) that may change the composition of gut microbiota with a potential impact on health and welfare. Faecal samples of 16 captured rhinos and 7 after a >30–hour road transport (n=7) noted that capture and transport lead to an imbalanced faecal microbiota composition in southern white rhinos. This could result in potentially infectious intestinal disorders, most likely due to the recrudescence of normally harmless pathogens, increased shedding of pathogens, or increased vulnerability to new pathogens (Pohlin et al. 2023).

The poaching of rhinos for their horn not only reduced black and white rhino numbers, but also contracted their distribution within Kruger NP. However, the population growth within priority conservation zones exceeded the population growth beyond these zones for both black and white rhinos in the reporting period 2023 to 2024. Priority conservation zones offer an opportunity to combat rhino poaching in a more tactical manner, concentrating resources on key areas for rhino survival (Ferreira et al. 2024c).

Zoos hold a substantial number of rhinos globally (Knight et al. 2023). Assessing the novel *in vitro* fertilization programme in white rhinos of both subspecies highlighted 65 procedures in 22 females that resulted in an efficiency of 1.0 ± 1.3 blastocysts per ovum pick-up, generating 22 Northern white rhinos (*C. s. cottoni*), 19 Southern white rhinos and 10 hybrid blastocysts for the future generation of live offspring (Hildebrandt et al. 2023). Advances in enhancing reproduction go hand in hand with zoo animal husbandry improving individual survivorship over time. Through improved zoo husbandry, the survival of the critically endangered black and near-threatened white rhino improved significantly over time, whereas that of the vulnerable greater one-horned rhino (*Rhinoceros unicornis*) rhino stagnated. This requires research to understand specific factors underlying stagnation (Wittwer et al. 2023).

A systematic review of trade restrictions implemented to protect wild species threatened

diversité antérieure dans la région. Les autorités pourraient améliorer les stratégies précédentes de translocations en privilégiant les mouvements naturels des individus entre sous-populations dans une vaste zone — méthode probablement moins coûteuse que l'alternative consistant à utiliser des données génétiques afin de cibler des animaux spécifiques éligibles à la translocation (Mellya et al. 2023).

Des populations plus importantes, telles que celles du parc national Kruger en Afrique du Sud, sont issues de plusieurs lignées : l'une provenant du KwaZulu-Natal en Afrique du Sud et l'autre de la région du fleuve Zambèze au Zimbabwe, introduites dans les années 1970. La compréhension des enjeux associés au mélange des patrimoines génétiques peut permettre d'éviter le risque de dépression de consanguinité et d'optimiser l'efficacité des translocations. Les rhinocéros noirs de Kruger présentent une diversité supérieure à ceux du KwaZulu-Natal et ressemblent davantage à ceux de Zambezi Valley. On relève un accroissement de la lignée zimbabwéenne, ce qui indique un probable avantage sélectif. La multiplicité des sources peut renforcer la capacité adaptative des individus dans des populations nouvellement établies (Stanbridge et al. 2023).

Une meilleure compréhension de la façon dont les rhinocéros réagissent et s'acclimatent à des conditions changeantes peut contribuer à améliorer les résultats en matière de conservation. Lorsque les ressources alimentaires sont limitées, les rhinocéros peuvent se tourner vers un fourrage de qualité inférieure. L'étendue du régime alimentaire du rhinocéros noir de l'est augmente avec la productivité de la végétation, mais l'on constate par ailleurs une consommation moindre de *Vachellia* et de *Senegalia* spp. et une ingestion accrue de graminées (Harvey Sky et al. 2024). Ces résultats inattendus ont suscité l'intérêt des spécialistes du régime alimentaire du rhinocéros noir, qui se pencheront sur la question. En outre, il est important de souligner que les variations dans l'alimentation sont associées à des intervalles plus longs entre les naissances.

Les techniques de mesure de la démographie des rhinocéros, dont les plannings de fécondité, ont été améliorées et sont susceptibles d'affiner l'évaluation de leur réponse à divers facteurs de stress. L'analyse longitudinale des concentrations de métabolite progestatif fécal, chez des femelles rhinocéros noirs de l'est en âge de procréer à Ol Jogi (Kenya), suggère qu'une activité ovarienne irrégulière et des épisodes isolés d'anœstrus n'ont pas d'impact négatif sur leurs performances reproductives (Kamau et al. 2023).

by overexploitation, and in which rhinos were highlighted, was used to evaluate effectiveness as reflected by: 1) the direct conservation impact at species or population level; 2) the indirect impact by human behaviour or at attitude level; and 3) the socioeconomic impact on rural livelihoods and well-being, as well as national economies. Most research focused on the effects of trade restrictions and law enforcement on crime-related behaviour, with gaps in socioeconomic impacts, local livelihoods and attempts to disrupt criminal networks. The effectiveness of trade restrictions depends on a range of aligned interventions in countries of origin, transit, and consumption (Hiller and 't Sas-Rolfes 2024).

Trade policy remains strongly contested. A thematic analysis using elephants (*Loxodonta* spp.), rhinos and lions (*Panthera leo*) examined the evolution of international trade policy debates from 2016–2019, and submissions to a national policy review in South Africa during 2020. Debates focussed on cognitive cause-and-effect relationships and elements based on normative values that resulted in three narratives aligning with: 1) broader environmental policy and political narratives; having 2) different ethical interpretations; and 3) perceptions of risk and precaution. Wildlife trade policy conflict links somewhat to competing ideological visions most likely entrenched in the CITES listing system ('t Sas-Rolfes and Gooden 2024).

Conflicting ideologies also transcends into national policies with unknown risks and opportunities. The Parliament of the United Kingdom discussions relating to the Hunting Trophies (Import Prohibition) Bill between 2022 and 2024 prompted an assessment to determine whether hunting, including that of rhino, designated as 'trophy hunting' is 1) a major threat increasing concern for a species; 2) causes localized declines; 3) not a threat; and 4) contributes benefits for a species and/or people. As much as 79% of imports from 2015 to 2021 into the United Kingdom were from countries where the hunted species are stable, increasing or abundant. Hunting posed a local threat to nine species, while it benefited 20 other species (Challender et al. 2023).

The consequences of policies for conservation outcomes carry importance for authorities to help reflect and adapt. Rhino conservation performance has varied with geography and over time. Good outcomes relate to greater institutional diversity

La santé des rhinocéros au niveau individuel est un sujet important à prendre en considération dans les populations de taille modeste, notamment lorsque sont envisagées des interventions telles que des translocations. Un petit échantillon pris sur trois rhinocéros noirs du sud-est en Namibie n'a pas montré de présence de vers plats (*Echinococcus* spp.) (Aschenborn et al. 2023). Les translocations des rhinocéros exposent ces derniers à de nombreux facteurs (jeûne prolongé, confinement, nouvel environnement, etc.) qui peuvent modifier la composition de leur microbiote intestinal, avec un éventuel impact sur leur santé et leur bien-être. Des échantillons fécaux de 16 rhinocéros capturés ont été prélevés avant leur transport, puis la même procédure a été effectuée sur 7 individus après un transport de plus de 30 heures ($n=7$). Il en ressort que la capture et le transport entraînent un déséquilibre dans la composition du microbiote fécal des rhinocéros blancs du sud. Des troubles intestinaux potentiellement infectieux pourraient en résulter, sans doute dus à une recrudescence de pathogènes généralement inoffensifs, à une augmentation de l'excrétion de pathogènes ou à une vulnérabilité accrue à l'exposition à de nouveaux pathogènes (Pohlin et al. 2023).

Le braconnage n'a pas seulement réduit le nombre de rhinocéros noirs et blancs, mais a également limité leur répartition dans le parc national Kruger. Cependant, sur la période 2023-2024, la croissance de la population au sein des zones de conservation prioritaires est supérieure à celle des populations de rhinocéros, noirs comme blancs, se trouvant à l'extérieur de ces périmètres. Ces espaces de conservation prioritaires offrent l'opportunité de combattre le braconnage de manière plus tactique, en concentrant les ressources sur des secteurs clés pour la survie des animaux (Ferreira et al. 2024c).

Au niveau international, les zoos abritent un nombre important de rhinocéros (Knight et al. 2023). L'étude du nouveau programme de fécondation in vitro chez les rhinocéros blancs des deux sous-espèces a montré que 65 procédures pratiquées sur 22 femelles ont obtenu une efficacité de 1,0 à 1,3 blastocyste par ponction ovocytaire, qui ont produit 22 rhinocéros blancs du nord (*C. s. cottoni*), 19 rhinocéros blancs du sud et 10 blastocystes hybrides pour de futurs descendants (Hildebrandt et al. 2023). Les progrès réalisés dans l'amélioration de la reproduction vont de pair avec l'élevage des animaux en zoos, qui augmente la survie des individus au fil du temps. Grâce à l'évolution des conditions d'élevage en zoo, la survie

within countries including when non-state actors play a meaningful role in rhino management. Decentralization is a sensible conservation strategy for rhinos but carries risks of unintended consequences such as domestication and in some instances increased opportunity for corruption (Rademeyer 2023; t' Sas-Rolfes and Emslie 2024).

The status of rhinos

Across the continent, 586 rhinos were lost to poaching in Africa during 2023, an increase on the 551 reported in 2022. The poaching losses continued to be concentrated in South Africa (499, 85.2%) increasing from 438 recorded in 2022. Namibia reported 63 poached rhinos, a decrease from 93 in 2022. Botswana reported nine, Zimbabwe six, Zambia five, Kenya four and the Democratic Republic of Congo, one. The nine remaining range States did not report figures on detected poached rhinos for 2023. Averaging across the continent, and considering both species, the loss of rhinos to poaching in 2023 was 2.51% of the total population. This is lower than the 3.4% threshold, above which populations are predicted to decline (Ferreira et al. 2022).

If the continental poaching rate remains below the 3.4% threshold, continental rhino numbers are anticipated to increase. The most recent available numbers (end of 2023) indicate that there are 23,885 rhinos in Africa, an increase of 2.4% from the 23,321 reported for the end of 2022 (Knight et al. 2023). The estimates for 2023 comprised 6,421 black rhinos (a decrease of 1.0% from 6,487 in 2022) and 17,464 white rhinos (an increase of 3.7% from 16,834 in 2022).

The drop in black rhino numbers is of concern and is understood to be largely a result of the loss of south-western black rhino (*D. b. bicornis*) numbers in Namibia which reported 2,195 in 2022 and 2,113 in 2023. Added to this South-central black rhino (*D. b. minor*), numbers in South Africa declined from 2,205 to 2,065 over the same time period. Increases in other range States and the continental increase in Eastern black rhinos (*D. b. michaeli*) only partially offset the declines in Namibia and South Africa. Across the continent, however, the first annual increase in total rhino numbers since 2012 was reported at the end of 2022 (Knight et al. 2023). This is a positive, albeit small, step in the right direction.

du rhinocéros noir (en danger critique d'extinction) et du rhinocéros blanc (quasi menacé) a progressé de manière significative, tandis que celle du rhinocéros indien est restée au même niveau. Des recherches sont nécessaires afin de comprendre les facteurs spécifiques à l'origine de cette situation (Wittwer et al. 2023).

Un examen systématique des restrictions commerciales mises en œuvre pour protéger les espèces sauvages menacées par la surexploitation (desquelles le rhinocéros fait partie) a été effectué afin d'en évaluer l'efficacité, selon les critères suivants : 1) l'impact direct en termes de conservation sur les espèces ou la population ; 2) l'impact indirect du comportement ou des attitudes des humains ; 3) l'impact socio-économique sur les moyens de subsistance et le bien-être des populations rurales, ainsi que sur les économies nationales. La plupart des recherches se sont concentrées sur les effets des restrictions commerciales et de l'application de la loi sur les comportements criminels, mais ont omis les impacts socio-économiques, les moyens de subsistance locaux et les tentatives de démantèlement des réseaux criminels. L'efficacité des restrictions commerciales dépend de tout un panel d'interventions alignées dans les pays d'origine, de transit et de consommation finale (Hiller et 't Sas-Rolfes 2024).

Les politiques commerciales demeurent fortement contestées. Une analyse thématique s'appuyant sur les éléphants (*Loxodonta* spp.), les rhinocéros et les lions (*Panthera leo*) a observé l'évolution des débats traitant de politique commerciale internationale entre 2016 et 2019, ainsi que les soumissions en vue d'un examen de la politique nationale en Afrique du Sud au cours de l'année 2020. Les discussions ont ciblé les relations cognitives de cause à effet et les éléments fondés sur des valeurs normatives, et trois types de récits s'en sont dégagés : 1) un récit qui s'aligne avec des discussions plus vastes sur les politiques environnementales et les narratifs politiques ; 2) un récit qui présente des interprétations éthiques différentes ; 3) un récit qui s'intéresse aux perceptions du risque et aux mesures de précautions. Les conflits relatifs à la politique commerciale des espèces sauvages sont quelque peu liés à des visions idéologiques concurrentes, qui prennent très probablement leurs sources dans le système de liste de la CITES ('t Sas-Rolfes et Gooden 2024).

Les divergences idéologiques se répercutent également sur les politiques nationales, avec des opportunités et des risques incertains. Les discussions quant à la proposition de loi visant à interdire l'importation de trophées de chasse («Hunting

Outside of Africa, 33 South-central black rhinos and 317 eastern black rhinos were reported from zoos around the world. China reported 14 black rhinos of unknown origin. In addition, 930 southern white rhinos were reported within zoo collections and a further 332 southern white rhinos were reported from facilities in China.

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Trophies Import Prohibition Bill»), qui se sont tenues au Parlement du Royaume-Uni entre 2022 et 2024, ont fait l'objet d'un examen afin de déterminer si la chasse, dont celle du rhinocéros, désignée comme «chasse aux trophées» : 1) représente une menace majeure et une préoccupation croissante pour une espèce ; 2) est un facteur de déclin localisé ; 3) ne constitue pas une menace, 4) contribue à des avantages pour une espèce et/ou les habitants. Entre 2015 et 2021, 79 % des importations britanniques provenaient de pays dans lesquels les espèces chassées montrent des chiffres stables, en hausse ou élevés. La chasse constitue une menace au niveau local pour neuf espèces, tandis qu'elle bénéficie à vingt autres (Challender et al. 2023).

Les conséquences des politiques sur les résultats en matière de conservation sont pertinentes pour les autorités, afin de les accompagner dans la réflexion et l'adaptation. Les performances de la conservation du rhinocéros connaissent des variations selon la géographie et la période donnée. Les effets positifs sont associés à une plus grande diversité institutionnelle au sein des États, y compris lorsque des acteurs non étatiques jouent un rôle significatif dans la gestion des rhinocéros. La décentralisation est une stratégie de conservation judicieuse, mais elle peut avoir des répercussions involontaires telles que la domestication des rhinocéros et, parfois, des fenêtres d'opportunités pour la corruption (Rademeyer 2023 ; t' Sas-Rolfes et Emslie 2024).

La situation du rhinocéros d'Afrique

Sur le continent africain, 586 rhinocéros ont été victimes de braconnage en 2023 — un chiffre en hausse par rapport aux 551 signalés en 2022. Ces pertes continuent d'advenir principalement en Afrique du Sud (499 soit 85,2 %), où elles ont augmenté depuis les 438 individus braconnés recensés en 2022. La Namibie a relevé 63 cas, une baisse par rapport aux 93 rhinocéros braconnés en 2022. Le Botswana a fait état de 9 cas, le Zimbabwe, de 6, la Zambie, de 5, le Kenya, de 4, et la République Démocratique du Congo, d'un seul. Les neuf autres États de l'aire de répartition n'ont pas rapporté de chiffres pour 2023. En moyenne sur le continent pour les deux espèces, les pertes dues au braconnage en 2023 s'élèvent à 2,51 % de la population totale, taux sous le seuil des 3,4 % (au-dessus duquel un déclin des effectifs est attendu) (Ferreira et al. 2022).

Si le taux de braconnage à l'échelle du continent reste inférieur à ce seuil des 3,4 %, le nombre de

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rhinocéros d'Afrique devrait augmenter. Les données les plus récentes (fin 2023) indiquent l'existence de 23 885 rhinocéros en Afrique, soit une hausse de 2,4 % par rapport aux 23 321 annoncés fin 2022 (Knight et al. 2023). L'estimation effectuée en 2023 comportait 6 421 rhinocéros noirs (une baisse de 1,0 % par rapport aux 6 487 en 2022) et 17 464 rhinocéros blancs (une augmentation de 3,7 % par rapport aux 16 834 en 2022).

La chute du nombre de rhinocéros noirs est inquiétante et se comprend comme étant largement le résultat de la perte de 82 rhinocéros noirs du sud-ouest en Namibie (*D. b. bicornis*), selon les chiffres communiqués par le pays (2 195 en 2022 contre 2 113 en 2023). En outre, la population de rhinocéros noirs du centre sud (*D. b. minor*) a décliné de 2 205 à 2 065 individus sur la même période. Les hausses répertoriées dans d'autres États de l'aire de répartition ainsi que la croissance des effectifs du rhinocéros noir de l'est (*D. b. michaeli*) à l'échelle du continent ne compensent que partiellement les baisses constatées en Namibie et en Afrique du Sud. Toutefois, la première augmentation annuelle du nombre total de rhinocéros africains depuis 2012 a été signalée à la fin de l'année 2022 (Knight et al. 2023). Bien que modeste, c'est le signe positif que nous nous dirigeons dans la bonne direction.

En dehors de l'Afrique, 33 rhinocéros noirs du centre-sud et 317 rhinocéros noirs de l'est ont été comptés dans des zoos à travers le monde. La Chine a fait état de 14 rhinocéros noirs d'origine inconnue. De plus, 930 rhinocéros blancs du sud et 332 individus de cette même espèce ont été répertoriés respectivement dans des collections de zoos et dans des installations en Chine.

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Asian Rhino Specialist Group Chair report
Rapport du Groupe de Spécialistes du Rhinocéros d'Asie

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The conservation and management of three species of Asian rhinos, the greater one-horned rhinos (GOH), Javan rhinos, and Sumatran rhinos, continue to present some extreme challenges in the range States of Asia, especially Sumatran and now Javan rhinos as well. While the population of the GOH has steadily increased over recent years, the critically endangered Sumatran rhino continues to face poor breeding opportunities due to population isolation, and the Javan rhino is in an even more dire predicament due to poaching for the illegal trade in rhino horn, this is elaborated below.

Current status of the greater one-horned rhinos in India and Nepal

Estimates of the population of GOH rhinos in India and Nepal are generally carried out over three- to four-year intervals, relying on the expertise and operational coordination of the people necessary to carry out this exercise. Currently, there are approximately 4,018 GOH rhinos in India and Nepal according to 2022 estimates; of which 752 are found in Nepal and 3,266 in India.

In Nepal, two GOH rhinos were introduced to Koshi Tappu Wildlife Reserve (WR) in September 2023 to build a new population, having been translocated from Chitwan National Park (NP), Nepal. With this latest rhino translocation, Koshi Tappu WR has become the fifth rhino-bearing area in Nepal after Chitwan NP, Bardia NP, Suklaphanta NP and Parsa National Park.

GOH rhinos have returned to Assam's Laokhowa-Burhachapori Wildlife Sanctuary (WLS). In December 2023 three (or four) rhinos from Orang NP moved south-east towards Laokhowa-Burhachapori WLS, dispersing

La conservation et la gestion des trois espèces de rhinocéros d'Asie (le rhinocéros indien, le rhinocéros de Java et le rhinocéros de Sumatra) continuent de représenter des défis extrêmement relevés au sein des États de l'aire de répartition d'Asie, en particulier en ce qui concerne les rhinocéros de Java. Alors que la population de rhinocéros indiens a augmenté de façon régulière ces dernières années, le rhinocéros de Sumatra, en danger critique d'extinction, subit toujours le peu d'opportunités d'accouplement et de reproduction existantes du fait de l'isolement des populations. Le rhinocéros de Java est dans une situation plus précaire encore en raison du braconnage dont il fait l'objet pour le commerce illégal de sa corne. Ces problématiques sont développées ci-dessous.

État actuel du rhinocéros indien en Inde et au Népal

Les estimations de population du rhinocéros indien en Inde et au Népal sont généralement effectuées tous les trois à quatre ans et reposent sur l'expertise et la coordination opérationnelle des personnes nécessaires à la mise en œuvre de cette opération. Selon les estimations menées en 2022, on dénombre actuellement autour de 4 018 rhinocéros indiens sur les deux pays, dont 752 au Népal et 3 266 en Inde.

Au Népal, deux individus ont été introduits en septembre 2023 dans la réserve naturelle de Koshi Tappu depuis le parc national de Chitwan, dans le but de fonder une nouvelle population. Grâce à cette translocation, la réserve naturelle de Koshi Tappu est devenue la cinquième zone du pays à abriter des rhinocéros, après les parcs nationaux de Chitwan, de Bardia, de Suklaphanta et de Parsa.

D'autres rhinocéros indiens sont revenus dans les sanctuaires de Laokhowa-Burhachapori dans l'État de l'Assam. En décembre 2023, trois (ou quatre) rhinocéros du parc national d'Orang se sont

'naturally'; and have since settled well into their new habitat, placing these two protected areas in Assam on the global map of rhino-bearing areas. The rhinos are closely monitored by the forest staff of the Laokhowa-Burhachapori WLS.

It is worth mentioning here that Laokhowa WLS was once the indigenous home of the GOH; but they were poached to local extinction in the 1980s by organized poachers who took advantage of the socio-political unrest that prevailed at the time. As of 2024, GOH rhinos are currently found in six protected areas in Assam in India, these are Kaziranga NP, Manas NP, Orang NP, Pobitora WLS, and Laokhowa-Burhachapori WLS. Rhinos are also found in Jaldapara NP and Gorumara NP in West Bengal, India and in Dudhwa NP in Uttar Pradesh. Some rhinos occasionally use the habitat in Katarniaghat WS in Uttar Pradesh.

Approximately eight more deaths of GOH rhinos have been reported in Jaldapara NP in North Bengal (India) in the past two years, which has been attributed to the prevalence of gastrointestinal parasite overload leading to their premature deaths. The high incidence of parasites indicates a subclinical disease that becomes pathogenic under stressful conditions, according to recent studies by the Institute of Science and Technology at Tribhuvan University with regards to the increase in rhino deaths in the areas of Nepal where rhinos occur.

As the chair of the AsRSG, I have advised senior officials in north Bengal to improve grassland management to ensure that all rhinos receive sufficient nutritious food, which helps develop natural immunity against parasites. A team of veterinarians is conducting further investigations into these deaths to understand the reasons for the increase in cases.

In terms of rhino poaching, Assam lost two rhinos in January 2024 in Kaziranga NP, and Nepal lost three rhinos between 16 July 2023 and 30 September 2024.

Current status of the Javan rhino

The last unofficial figures released by the Ujung Kulon NP authorities in 2023 for the critically endangered Javan rhino were 76. However, scientists and conservation bodies raised concerns

dispersés « naturellement » en direction du sud-est, vers le sanctuaire de Laokhowa-Burhachapori, et se sont depuis bien installés dans leur nouvel habitat. Ces deux périmètres protégés de l'Assam ont été placés sur la carte globale des zones habitées par les rhinocéros. Ces individus sont étroitement surveillés par le personnel des sanctuaires de Laokhowa-Burhachapori.

Il convient de mentionner que le sanctuaire de Laokhowa était autrefois le foyer originel des rhinocéros indiens. Ils y ont été chassés jusqu'à l'extinction dans les années 1980 par des braconniers organisés qui ont profité des opportunités créées par le climat sociopolitique troublé de l'époque. À ce jour, le rhinocéros indien est présent dans six zones protégées de l'État de l'Assam en Inde : les parcs nationaux de Kaziranga, de Manas et d'Orang, et les sanctuaires de Potibora et de Laokhowa-Burhachapor. D'autres individus se trouvent également dans les parcs nationaux de Jaldapara et de Gorumara dans l'ouest du Bengale en Inde, et de Dudhwa dans l'Uttar Pradesh. Dans la même région, certains rhinocéros utilisent de façon occasionnelle l'habitat du sanctuaire de Katarniaghat.

Environ huit morts de rhinocéros indiens ont été enregistrées dans le parc national de Jaldapara dans le nord du Bengale ces deux dernières années, qui ont été attribuées à la prévalence d'une surcharge de parasites gastro-intestinaux ayant entraîné un décès prématuré. Cette incidence élevée de parasites tend à indiquer l'existence d'une maladie subclinique qui devient pathogène dans des conditions de stress, selon de récentes études réalisées par l'Institut des sciences et des technologies de l'université de Tribhuvan (Népal), relative à l'augmentation de la mortalité chez les rhinocéros dans leurs habitats au Népal.

En tant que président du GSRAs, j'ai conseillé aux hauts responsables du nord Bengale d'améliorer la gestion des zones herbeuses afin de garantir que tous les rhinocéros puissent avoir accès à une nourriture nutritive en quantité suffisante, qui contribue à développer leur immunité naturelle contre les parasites. Une équipe de vétérinaires enquête actuellement sur ces décès dans l'optique de comprendre les raisons d'une augmentation des cas.

En termes de braconnage, l'État de l'Assam a perdu deux rhinocéros en janvier 2024 dans le parc national de Kaziranga et le Népal a fait état de trois individus abattus entre le 16 juillet 2023 et le 30 septembre 2024.

last year that the figures were inaccurate, as 18 of the rhinos counted had not been detected by camera traps in the three previous years. The main source of information for the monitoring of Javan rhinos is retrieved from camera traps, as it is very difficult to detect the rhinos living in dense rainforest. Their concerns were not unfounded, as tragically 26 of the estimated 76 rhinos counted in 2023 were killed between 2019 and 2023 by two groups of poachers.

The Javan rhino poaching case unfolded when police in Banten province, where UKNP is located, received a report dated 29 May 2023 about the disappearance of camera traps from the national park and fewer signs of Javan rhinos within the UKNP. Footage taken by other camera traps showed armed individuals inside the Park, ostensibly tracking rhinos.

The police eventually identified 13 residents of a nearby village, led by brothers Sunendi and Sahru, who were the respective leaders of two poaching gangs operating in the Park, and testimony from these gangs indicates that 26 rhinos were poached in the last five years. The loss of 26 Javan rhinos to poaching has resulted in a staggering 33% decrease in the total Javan rhino population. An in-depth investigation by the Indonesian police carried out during the first half of 2024 led to apprehension, conviction, and sentences handed down to the accused of 12 years imprisonment and a fine. The killings have shattered the male/female ratio as poachers targeted males that typically have a noticeable horn, reducing the number of breeding males. The news turns an issue of concern (low breeding and the degraded habitat of UKNP, including an invasive palm) into a disaster for the Javan rhino, and police and the army have increased security since the incidents. There are now only 46 individuals remaining in the wild.

Current status of the Sumatran rhino

Sumatran rhinos have faced challenges from habitat degradation and isolated population syndrome in southern Sumatra for the last three decades. However, in northern Sumatra, especially in Gunung Leuser area, the Sumatran rhino population appears to be stable according

État actuel du rhinocéros de Java

Les derniers chiffres, non officiels, communiqués en 2023 par les autorités du parc national d'Ujung Kulon (Indonésie) faisaient état de 76 individus pour le rhinocéros de Java, espèce en danger critique d'extinction. Cependant, en 2023, certains scientifiques et acteurs de la conservation ont exprimé des inquiétudes quant à l'exactitude de ces données, du fait que 18 des rhinocéros recensés n'avaient été détectés par aucun piège photographique au cours des trois années précédentes. La source d'informations principale pour le suivi des rhinocéros de Java provient des pièges photographiques, compte tenu des difficultés liées à la détection des rhinocéros vivant dans la densité de la forêt tropicale. Ces interrogations se sont avérées légitimes puisque 26 des 76 rhinocéros estimés en 2023 ont malheureusement été tués entre 2019 et 2023 par deux groupes de braconniers.

L'affaire a éclaté lorsque la police de Banten, localité où se trouve le parc national d'Ujung Kulon, a reçu un rapport daté du 29 mai 2023 mentionnant la disparition de pièges photographiques ainsi qu'une diminution des signes indiquant la présence de rhinocéros de Java dans l'enceinte du parc. Des images prises par d'autres dispositifs photographiques montrent des individus armés traquant ostensiblement les rhinocéros dans le parc.

La police est parvenue à identifier treize habitants d'un village voisin, menés par les frères Sunendi et Sahru, chefs de deux gangs de braconniers opérant dans le parc. Les témoignages des membres du groupe criminel ont indiqué que 26 rhinocéros avaient été abattus au cours des cinq années précédentes. La perte de 26 rhinocéros de Java du fait du braconnage a entraîné une chute considérable de l'ordre de 33 % dans la population de cette espèce. Une enquête fouillée, dirigée ces derniers mois par la police indonésienne, a permis d'appréhender et de condamner les accusés à douze ans d'emprisonnement et à des amendes. Ces massacres ont bouleversé le ratio mâles/femelles puisque les braconniers ont ciblé les mâles, qui présentent généralement une corne visible, réduisant ainsi le nombre de reproducteurs. Ces nouvelles font d'un sujet de préoccupations manifeste (faible taux de reproduction, habitat dégradé dans le parc national, notamment à cause d'une espèce invasive de palmier) un désastre pour le rhinocéros de Java, et la police et l'armée ont depuis renforcé la sécurité du site. Aujourd'hui, seuls 46 individus sont encore vivants à l'état sauvage.

to information received from AsRSG members based in Indonesia. Camera trap monitoring in Gunung Leuser NP has been able to locate Sumatran rhinos, including calves, indicating that the population in that landscape is finally breeding; however, the estimated population of 34-47 makes the Sumatran rhino the most endangered rhino.

To reverse the declining trend of critically endangered Javan and Sumatran rhinos in Indonesia, the creation of a national rhino task force under the leadership of the head of the government to guide recovery efforts of critically endangered Javan and Sumatran rhinos seems to be the need of the hour.

Forthcoming meetings and assessment training sessions planned for 2025

Three important events are upcoming in 2025, these are: 1) the AsRSG members meeting, which will take place in May 2025; 2) an IUCN Red List assessment training for members of the AsRSG; and 3) The IUCN Green Status of Species (GSS) protocol. This has been designed to assess the progress for the recovery of species and the impact of conservation efforts and will provide assessment training for members of the AsRSG beginning in 2025.

État actuel du rhinocéros de Sumatra

Les rhinocéros de Sumatra ont dû faire face à plusieurs défis ces trente dernières années, depuis la dégradation de leur habitat jusqu'au syndrome des populations isolées dans le sud de l'île. Néanmoins, dans la partie septentrionale (particulièrement dans la zone de Gunung Leuser), la population de rhinocéros de Sumatra semble stable selon les informations reçues de la part des membres du GSRAs basés en Indonésie. Le suivi effectué par pièges photographiques dans le parc national de Gunung Leuser a permis de localiser des individus, dont des petits, ce qui laisse penser que la population de cette zone parvient enfin à se reproduire. Cependant, les estimations indiquant un nombre de 24 à 47 rhinocéros en font la population la plus menacée.

Afin d'inverser la tendance à la baisse des populations de rhinocéros de Java et de Sumatra, la création d'une force opérationnelle nationale pour le rhinocéros, qui accompagne les actions de rétablissement des deux espèces en danger critique d'extinction sous l'égide du chef du gouvernement, semble être la nécessité actuelle.

Réunions et sessions de formation pour l'évaluation en prévision pour 2025

Trois événements d'importance sont prévus l'année prochaine : 1) la réunion des membres du GSRAs en mai, 2) une formation pour l'évaluation de la Liste rouge de l'UICN à destination de certains des membres du GSRAs et 3) une formation pour l'évaluation du Statut vert des espèces de l'UICN (« Green Status of Species - GSS »), protocole conçu pour évaluer les progrès réalisés dans le rétablissement des espèces et l'impact des actions de conservation, à laquelle assisteront les membres du GSRAs dès 2025.

RESEARCH

Tusk metrics and pair symmetry in savannah elephants

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Abstract

The right and left tusks and from both genders of five separately culled savannah elephant clans were measured, recording weight (n = 2453), overall length (n = 563), external length beyond the gingivae (n = 158), internal length within the alveolus (n = 158) and circumference at the lip (n = 158). The increase in tusk weights and lengths with age was reconfirmed as basically exponential in males and more linear in females up to their fifth decade. Between the right and left tusks, the five metrics were on average symmetrical (in the sense of being mirror images of one another), and predictive of both age and each other (i.e. from one the others can be deduced). Strikingly, however, pair length symmetry is less within alveoli, where growth takes place, than between their corresponding external parts, where tusks are essentially dead tissue. Such greater external symmetry can only occur if the shorter tusk grows faster to catch up with its partner or the longer tooth is reduced through wear towards parity with its partner, or both.

Résumé

Les défenses droite et gauche d'éléphants de savane (des deux sexes), abattus dans cinq clans différents, ont été mesurées selon des critères de poids (n = 2 453), de longueur totale (n = 563), de longueur externe après la gencive (n = 158), de longueur interne à l'intérieur de l'alvéole dentaire (n = 158) et de circonférence au niveau de la lèvre (n = 158). La croissance des défenses au fil des années, en poids et en dimensions, a été confirmée de nouveau comme étant essentiellement exponentielle chez les mâles et plus linéaire chez les femelles jusqu'à leurs 50 ans environ. Les cinq mesures sont en moyenne symétriques entre les défenses droites et gauches (en ce sens qu'elles sont des images miroirs l'une de l'autre), et s'avèrent prédictives de l'âge de l'individu et de comment serait constituée la deuxième défense (c'est-à-dire que l'on peut déduire l'une par rapport à l'autre). Il est toutefois frappant de constater que la symétrie des paires en longueur est moins importante à l'intérieur des alvéoles, où a lieu la croissance, qu'entre les parties externes correspondantes, où les défenses sont essentiellement constituées de tissus morts. Une telle symétrie externe ne peut se produire que si la défense la plus courte croît plus rapidement afin de rattraper sa semblable, ou si la plus longue des deux est réduite par l'usure, ou encore si les deux phénomènes coexistent.

Introduction

While using the term 'population' to infer genetic isolation, I use the term 'clan' to differentiate contiguous or separated groups of savannah elephants that are not necessarily genetically isolated (Parker 2023a). This paper statistically examines the tusk measurements from two populations: one in west-central Uganda and the other in the Nyika biome,

Table 1. The five populations sampled, showing regions, sampling areas, population designations (clan), sampling locations (coordinates), sample sizes, and date ranges when sampling occurred. NP = National Park

Region	Location	Clan	Coordinates	Sample Size	Dates
Murchison	Murchison Falls NP, Uganda	Murchison North	2°24'N, 31°42'E	1,197	Mar 1965–Jun 1967
		Murchison South	2°10'N, 31°50'E	798	Nov 1965–May 1967
Nyika	Tsavo NP, Kenya	Tsavo Koito	3°00'S, 38°42'E	298	Aug 1966
	Mkomazi NP, Tanzania	Mkomazi East	4°22'S, 38°35'E	299	Mar–Apr 1968
		Mkomazi Central	4°9'S, 38°14'E	295	Aug–Sept 1969

comprising coastal Kenya and north-easternmost Tanzania. Within them, five elephant clans were culled at different times and in separate places between 1965 and 1969, as described by Laws et al. (1975). Two were in the west-central part of Uganda's Murchison Falls National Park (Murchison), and three in the Nyika. The Murchison clans are referred to as Murchison North and Murchison South, located to the north and south of the Victoria Nile, respectively, and the Nyika clans as Tsavo Koito, Mkomazi East and Mkomazi Central (Table 1).

Materials and Methods

Field methods

The culling procedures and data collected are recorded in Laws et al. (1975). Elephants were aged using Laws' system (Laws 1966). Once the skulls were stripped of skin and flesh, the tusks were axed free, and the attached bone and tissue were removed. Where tusks were missing, the cause of absence was determined by dissecting the exposed skull.

All tusks were weighed to the nearest 0.25 kg on commercial scales (females: n = 1,343; males: n = 1,110). Measurements to the nearest 0.5 cm were taken from subsections of the culls as follows:

a. Total tusk length along the outer curves (n = 563)
b. Circumference at emergence from the gingiva (n =158)
c. External tusk length (n = 158)
d. Internal (i.e. within the alveolus) tusk length (n = 158) by subtracting (c) from (a).

All were identified as to gender and whether they were right or left[1].

Statistical analyses

The relationships between the dimensions of tusk pairs were examined for two-tusked elephants using one tusk per randomly selected elephant (i.e. rather than equating right against left or vice versa, comparison was randomly based). The relationships were effectively linearized, and the variances among y-values were homogenized for a range of x-values, by square-root transformation of circumference and cube-root transformation of weight. Linear regressions were used to test the independent values of total lengths and circumferences to predict weights, of circumferences to predict total lengths, and of internal lengths to predict external lengths.

Possible sources of variation in untransformed tusk weights while controlling for the effect of age were investigated using permutational ANOVAs. Only two-tusked elephants older than six years were included in the data analysis since below this age all tusks may not yet have erupted (Parker 2023a). The analysis was conducted with a random selection of either the left or right tusk, and exclusion of two individuals for which the selected tusk was broken and much smaller than the other. Possible explanatory variables considered were Gender and Age as fixed effects, and Region (Murchison and Nyika, Table 1) and Clan (nested in Region) as random effects, with all possible interactions included. Age was represented by five classes of approximately equal sample size, combining age year classes of 6.5–10.5, 11.5–16.5, 17.5–23.5, 24.5–30.5, and 31.5–60.5. Euclidean distance, Type III

[1]All the raw data from the five elephant clans cited in this paper are available at: http://ufdc.ufl.edu/AA00013409/0007

Table 2. Predictive relationships among tusk dimensions.

Relationship	r^2	p	n
Weight$^{1/3}$ = 0.0133 × length + 0.2287	0.939	<0.0001	553
Weight$^{1/3}$ = 0.6644 × circumference$^{1/2}$ – 1.5631	0.941	<0.0001	553
Total length = 45.5974 × circumference$^{1/2}$ – 114.2215	0.832	<0.0001	553
External length = 1.7842 × internal length – 24.8037	0.724	<0.0001	160

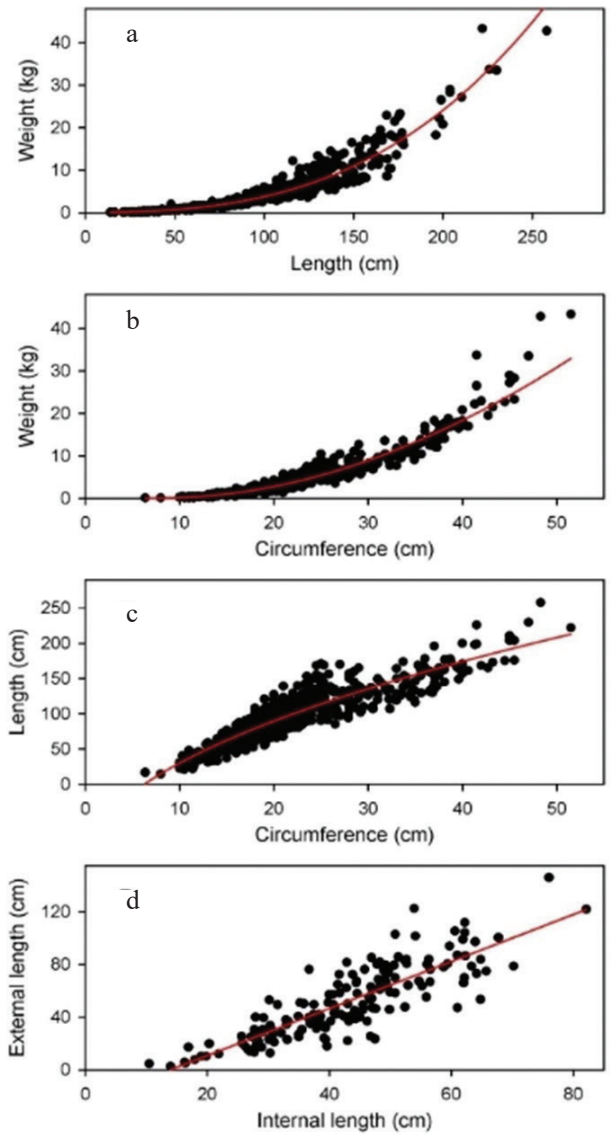

Figure 1. Relationships among the tusk dimensions of the savannah elephants' tusks. a) relates weight to length; b) weight to circumference; c) length to circumference and d) external length to internal (alveola) length.

(partial) sums of squares, fixed effects summing to zero for mixed terms, and 9,999 permutations of residuals under a reduced model were used.

The symmetry of three tusk measures (alveolar length, external length, circumference at lip) was investigated for two-tusked elephants as, for each measure: % dev = 100 × (right tusk– left tusk) / (left tusk + right tusk) where % dev is the percentage deviation from the mean, so that elephants with larger left tusks are represented by a negative percentage and those with larger right tusks by a positive percentage.

Effects on symmetry were investigated for each symmetry metric (as % dev) separately using permutational ANOVAs. Possible explanatory variables considered were Gender and Age as fixed effects and Clan as a random effect, with all possible interactions included. Except for weights, data were available for only three clans. Age was represented by five classes of approximately equal sample size, combining age year classes of 2.5–7.5, 8.5–14.5, 15.5–20.5, 21.5–27.5, and 28.5–57.5. Euclidean distance was used, Type III (partial) sums of squares, fixed effects summing to zero for mixed terms, and 9,999 permutations of residuals under a reduced model.

Table 3. Results of the permutational analysis of effects on tusk weight for elephants older than six years of age from five savannah elephant clans. Age was treated as categorical with five classes. Probabilities of significant terms at $p < 0.05$ are coloured red. df = degrees of freedom.

Terms	df	p
Age	4	**0.001**
Gender	1	0.16
Region	1	0.29
Region (Murchison or Nyika)	3	**0.001**
Age × Gender	4	**0.001**
Age × Clan (Region)	12	**0.001**
Age × Region	4	0.93
Gender × Clan (Region)	3	**0.002**
Gender × Region	1	0.66
Age × Gender × Clan (Region)	12	**0.001**
Age × Gender × Region	4	0.93
Residual	2,097	

Results

Tusk dimensions

Both length and circumference were strongly predictive of the weight of the tusk (Table 2; Fig. 1). Circumference also predicted total length, and internal length predicted external length, although less strongly and this applied to both sexes.

Tusk weight varied strongly with Age; it also varied with interactions between Age, Gender and Clan (nested in Region) (Table 3). Although Gender was not in itself a significant term in the model, interactions between Gender, Age and Clan (nested in Region) were highly significant, indicating that the gender effect on tusk weight is unevenly distributed. Neither the effect of Region nor any interactions including it were significant, but the effect of Clan (nested in Region), and interactions involving it, were all highly significant.

Overall, the weight of the female tusks showed a linear increase with age, although the small number of females older than 54 years may have had lighter tusks than predicted. The increase was exponential in males. The same patterns were identified for each clan examined separately with 70 to 91% of variance explained (Table 4; Fig. 2).

The effects of Age and Gender are highly significant, and differences between clans difficult to detect especially among females (Fig. 3). It is possible that the tusks of male elephants from Mkomazi Central are longer in comparison for age range than those from the other Tsavo ecosystem males, and that males from Murchison South have shorter tusks for age than those from Murchison North. It is also possible that the statistical effect of Clan (nested in Region) was exaggerated (especially through interactions) by poor representation of the oldest age class by males from the three Nyika clans.

Symmetry

As shown in Fig. 4, all four metrics for two-tusked elephants were on average quite strongly symmetrical, with the external length somewhat more symmetrical than the internal length, and circumference most strongly symmetrical but for a small number of outlying cases. For circumference, 89.5% of elephants were within 5% of the mean, whereas for external and internal tusk length the respective measures were 78.5% and 54.9%. For individuals with both metrics not prone to wear (internal length, circumference at

Table 4. Regressions of the relationship between tusk weight and age for each gender in elephants older than six years in five clans of savannah elephants. $p < 0.0001$ in all cases.

Gender	Clan	Relationship	r^2	n
M	Murchison North	Tusk weight$^{1/3}$ = 0.0581 × age + 0.7302	0.875	500
M	Murchison South	Tusk weight$^{1/3}$ = 0.0548 × age + 0.8068	0.886	377
M	Tsavo Koito	Tusk weight$^{1/3}$ = 0.0565 × age + 0.8414	0.909	108
M	Mkomazi East	Tusk weight$^{1/3}$ = 0.0569 × age + 0.8182	0.879	108
M	Mkomazi Central	Tusk weight$^{1/3}$ = 0.0615 × age + 0.7377	0.902	108
F	Murchison North	Tusk weight = 0.1498 × age – 0.2823	0.793	428
F	Murchison South	Tusk weight = 0.1625 × age – 0.289	0.733	266
F	Tsavo Koito	Tusk weight = 0.1684 × age + 0.0021	0.721	72
F	Mkomazi East	Tusk weight = 0.182 × age – 0.3473	0.698	97
F	Mkomazi Central	Tusk weight = 0.1746 × age – 0.4498	0.822	83

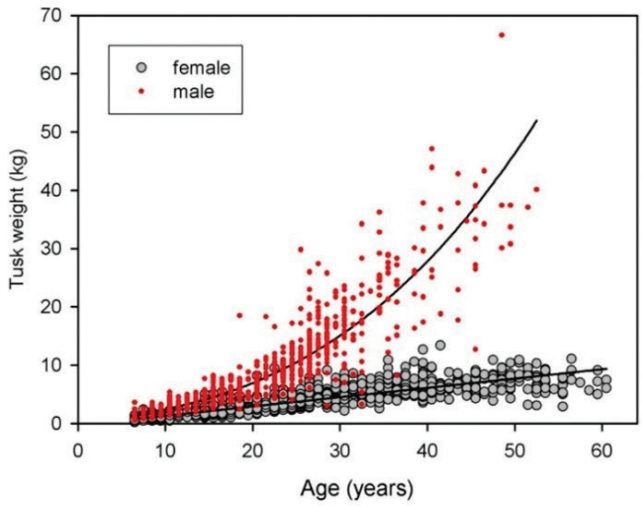

Figure 2. Relationship between tusk weight and age in five savannah elephant clans aged six years or older.
Females: tusk weight = 0.1594 × age – 0.2594; $r^2 = 0.7509$; $p < 0.0001$; n = 1,201
Males: tusk weight$^{1/3}$ = 0.0561 × age + 0.7864. $r^2 = 0.8775$; $p < 0.0001$; n = 946

lip), there was no relationship between them.

In all cases there were no significant effects of age or gender or their interaction on either the internal or external length symmetry scores ($p > 0.4$). For circumference, taking into account three clans, there were no significant effects of Age or Clan or of any of the interactions, but a weak effect of Gender ($p = 0.050$) that might imply that females are more left-biased than males. The difference, if real, is slight (mean symmetry scores of –0.68% and 0.26% for females and males, respectively).

There was no significant association between Tuskedness (left or right) and Gender (Fisher's Exact Test, $p = 0.24$). This was supported by recording serious transverse tusk breaks across the body of a tusk rather than minor breaks at and around the points. The two clans Murchison North and Murchison South provided the greatest volume of data, and in them transverse tusk breaks were recorded as occurring on 64 right-hand and 65 left-hand tusks, implying equal

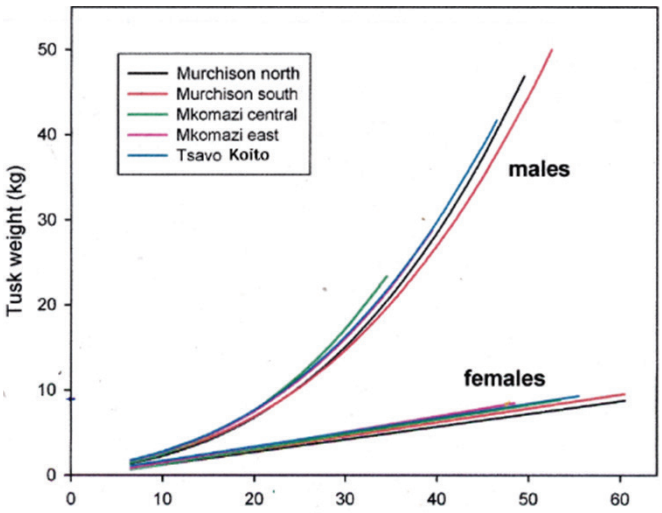

Figure 3. Modelled tusk weights with Age and Gender of savannah elephants aged six years or older from five clans. The model represents significant effects identified in the multivariate analysis (Table 3) and weight trends with Age for each Gender as demonstrated in Figure 2.

use, as shown in Table 5.

For individuals with both metrics not prone to wear (internal length, circumference), there was no relationship between the two (Fig. 5).

Discussion

The conclusion that male tusks are larger and heavier than female tusks at age and grow exponentially while female tusk growth is linear is not new. It was previously reported by Laws (1966); Laws and Parker (1968); Laws et al. (1975); Parker (1979) and Pilgram and Western (1986), all using the same data; and by Elder (1970). Whyte and Hall-Martin (2018) and Larramendi (2023) introduced lengths, circumferences, and in addition mass in describing tusk morphometrics. Here all these metrics—weight, total length, extruded and internal length, and tusk circumferences at lip—are analysed for symmetry between tusk pairs in East African savannah elephants.

From elephants viewed in the field as individuals, it may seem that shape variation infers low levels of symmetry between their two tusks. That perception is enhanced by knowledge that tusks may be broken and the belief that they are used preferentially and thus subject to differential wear. The data analysed here indicates otherwise, namely high levels of symmetry. The most obvious metric, external length, displayed a symmetry level of 78.5% between right and left. This highlights the caution necessary when using data from individuals as measures of population parameters. Fig. 6 visually illustrates tusk pair symmetry that is not readily apparent in the field in six families, bearing out the findings revealed by the metric analysis.

However, in both sexes, internally within the alveolus, symmetry is 23.6% less than what is visible externally. The fact that the pairs are less similar internally than externally seems counterintuitive, since outside the head, tusks are separated from the growth sources, and as ‘dead tissue’ can only be subject to reduction that is counterbalanced by extrusion from within the alveolus. Two possible causes may produce the greater tusk similarity outside the head. One would be differential growth between the tusks of a pair, in which the initially shorter one grows faster, catching up with its longer partner. The other, that elephants use the longer of their tusk pair preferentially, decreasing its length towards parity with the shorter. This levelling between external tusk lengths is the subject of a companion paper.

This study does not support the idea that elephants preferentially use one tusk more than the other as claimed by Whyte and Hall-Martin (2018) and others,

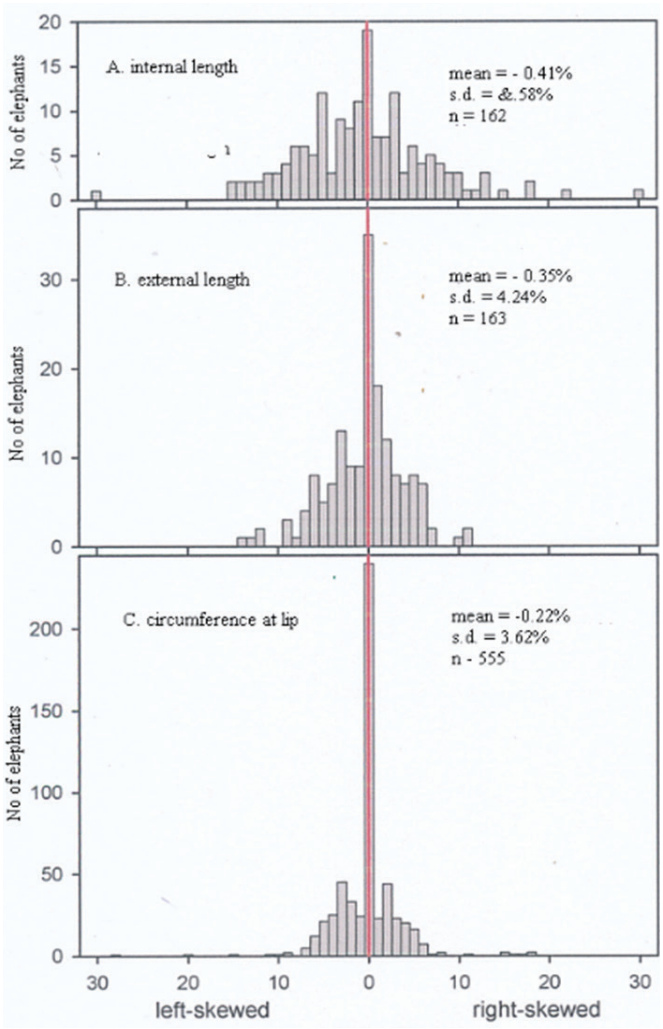

Figure 4. Percentage deviations from symmetry between pair of tusks of three tusk metrics in two-tusked savannah elephants. The red line indicates perfect symmetry. The numbers for data skewed left or right are shown as % deviation from the mean (% dev; see Materials and Methods).

Table 5. Broken tusks excluding tip loss, as occurred between right and left tusks.

Clan	Sample size	Right breaks	Left breaks
Murchison North	937	20	18
Murchison South	648	44	47
Combined	1,585	64	65

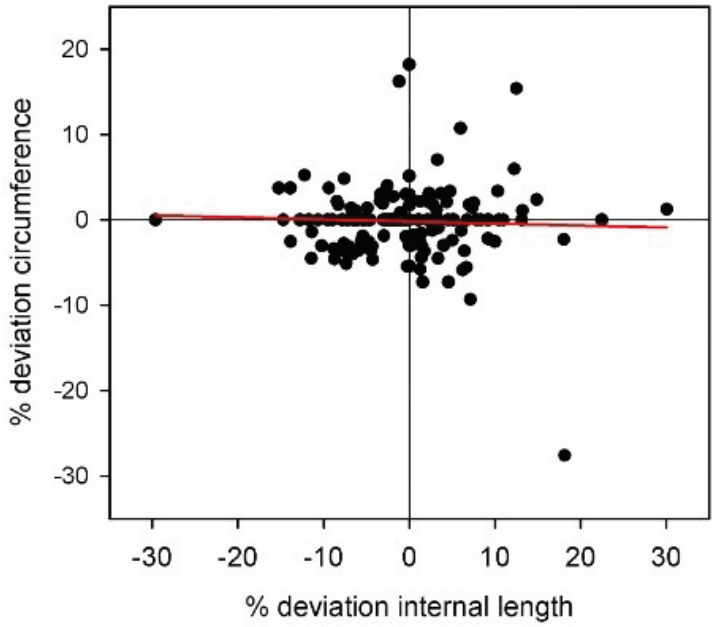

Figure 5. Relationship (r = –0.043, p = 0.59) between two measures of tusk symmetry not prone to wear (lip circumference and internal tusk length) for 161 two-tusked savannah elephants.

in the manner of human handedness. This will be examined further in the companion paper.

As an aside, given the finding by Steenkamp et al. (2007) that elephant tusk breakage in southern Africa was greater in dry seasons than when wet, it was reasonable to expect that tusk breakage in the semi-arid Nyika (rainfall <500 mm p.a.) would be greater than in humid Murchison (rainfall >1,000 mm p.a.). This finding is contradicted by the data here. In similar vein, elephants chiselling bark off *Terminalia glaucescens* (Planch. Ex Benth 1849) in Murchison North, where this tree was abundant, were stressing their tusks in a manner not occurring at the same time in Murchison South where the trees had been largely eliminated. The expectation that bark-chiselling would be reflected in different tusk lengths and breakage between the two clans was also not met. Furthermore, whatever the habitat differences between Murchison and Nyika may be, mean clan tusk weights at age (predictive of both lengths and circumferences (Figs. 1 and 3) were very close, suggesting that such environmental differences as may exist do not determine these metrics.

Acknowledgements

Over the 58 years since collecting the data reported herein, I have discussed them with more people—Wata, professional and recreational hunters and biologists—than I can recall. To all, I am very grateful as, *in sensu stricto*, such merit as the paper may have is as a collaborative product. In particular, however, I am indebted to Don Franklin for his statistical analyses, my editor and reviewers for their patience, and, once again, my wife for grammatical correction and proofreading.

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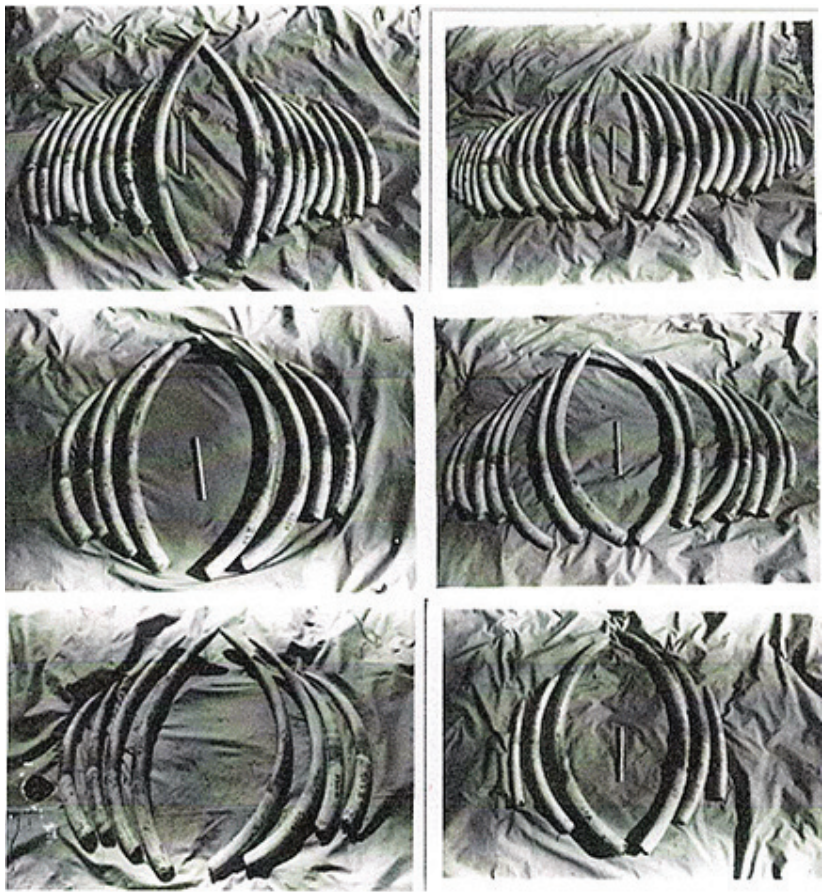

Figure 6. Pair symmetry of tusks in six family units. The oldest pair in the centre with age descending outward to youngest as the edge. Right tusks are on the left and left tusks on the right.

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Further observations on savannah elephant tusks

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Abstract

The paper analyses weights of 2,425 tusk pairs, and lengths of 398 pairs obtained between 1965 and 1969 from two East African savannah elephant populations, one in Uganda, the other in eastern Kenya and north-eastern Tanzania. They are presented as averages in five-year age cohorts. Separately, length, weight and gender showed no significant differences between the use of the right and left tusks. If neural lateralization exists in elephants, it is concealed by the dynamics of tusk growth and wear, which are described. The fact that average asymptotes at age are only 31% (female) and 38% (male) of the theoretical asymptotes is explained by weathering and wear. Contrary to expectations that single tusks, having to do the work of two, would be shorter than the pair average, they are not, but stay within pair length parameters. Evidence is presented that declining tusk growth occurs in both sexes with advanced age. The longer-tusk pairs have a tight curvilinear relationship to average shoulder height, rising evenly from 24% (females) and 26% (males) under 6.5 years to 58% and 76% respectively in the oldest age classes. That is, they relate to an elephant's height.

Résumé

Dans cet article, nous analysons le poids de 2 425 paires de défenses et la longueur de 398 paires obtenues entre 1965 et 1969 sur deux populations d'éléphants de savane d'Afrique : l'une en Ouganda, la deuxième dans l'est du Kenya et le nord-est de la Tanzanie. Les données sont présentées sous forme de moyennes par cohortes d'âges de cinq ans. Pris séparément, la longueur et le poids des défenses ainsi que le sexe de l'animal ne montrent pas de différences significatives entre l'utilisation des défenses droite et gauche. Si la latéralisation cérébrale existe chez les éléphants, elle est cachée par les dynamiques de croissance et d'usure des défenses, qui sont décrites. Le fait que les asymptotes moyennes à l'âge ne représentent que 31 % (chez les femelles) et 38 % (chez les mâles) des asymptotes théoriques s'explique par l'altération et l'usure. Contrairement à ce que l'on pourrait penser, une défense unique, devant effectuer le travail pour deux, n'est pas plus courte que la moyenne des paires, mais reste dans les paramètres de longueur de la paire. Il est prouvé que la baisse de croissance des défenses se produit chez les deux sexes à partir d'un certain âge. Les paires de défenses les plus longues ont une relation curvilinéaire étroite avec la hauteur moyenne des épaules, passant uniformément de 24 % (femelles) et 26 % (mâles) en dessous de 6,5 ans à, respectivement, 58 % et 76 % dans les classes d'âge les plus élevées. En somme, leur longueur est relative à la hauteur de l'animal.

Introduction

Given the elephant's size and longevity, much previous research has, perforce, had only small samples and individual cases to deal with. Here I had the advantage of large samples. Larramendi (2023) comprehensively summarizes knowledge of proboscidean tusks, extinct and extant. The field has been researched with a focus on taxonomy, particularly by Osborn (1936, 1942). What follows extends and/or qualifies previous records of savannah elephant tusk morphology by Elder (1970) and Raubenheimer et al. (1989).

In elephants, all three components of mammalian teeth – cementum, enamel and dentine – are present.

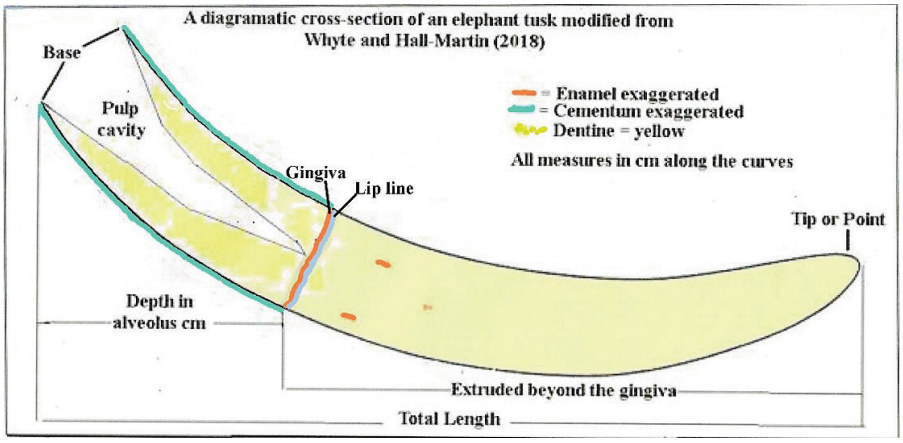


Figure 1. Characteristic features of a tusk (adapted from Whyte and Hall-Martin 2018).

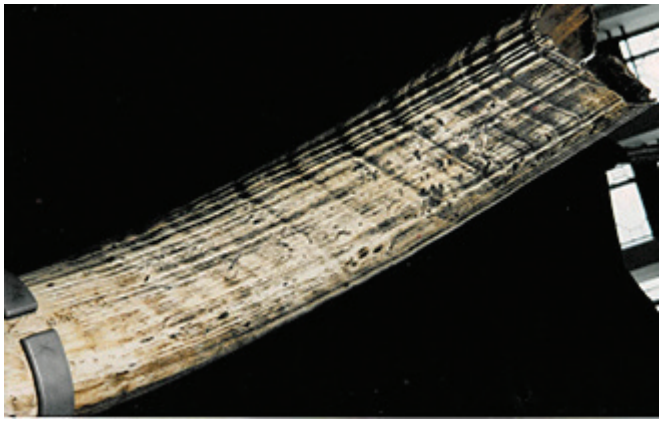


Figure 2. Growth rings are obvious in the alveolar sections of all tusks. They occur like tree rings throughout their entire dentine body but are only visible in lateral and longitudinal cross-sections.

Cementum plays its internal role as a thin sheath that via the periodontal ligament bonds the tusk to the surrounding alveolar bone. Enamel occurs variably within proboscidean taxa as a very thin lateral layer as the tusk emerges from the alveolus but is only known as a cap in juvenile tusk tips in extant elephants (Larramendi 2023). In the savannah elephant tusk, the enamel is only sustained as a cap over the erupting tusk bud, which is usually abraded away when less than 30 cm of the tusk is beyond the lip fold (pers. obs. 1960s; Whyte pers. comm. 2018). Thereafter, if present at all, it is very thinly and unevenly distributed along the external elephant tusk shaft beyond the gingiva, tending to persist in longitudinal grooves deep enough to protect it from wear (pers. obs. 1960s), but seemingly serving no structural role. As an aside, Nasoon (2020) records similar enamel caps on emergent walrus (*Odobenus rosmarus*) tusks, and Berkovitz (2016) noted them on narwhal (*Monodon monoceros*) tusks that are also composed of dentine. In both species, and as observed on East African elephant tusks by myself and by Whyte in tusks from the Kruger National Park, these enamel caps are soon lost and may provide the emergent tusks some protection while they are still too small to withstand unprotected use.

In the tusk of the savannah elephant, dentine (ivory) has replaced the functional role of enamel. However, unlike enamel, which is hard, inflexible and brittle, dentine is relatively soft, slightly flexible (Kingdon 1979), and easily worn down. Ivory

flexibility is obvious when reduced to a flat blade like a bendable paper knife, but this is limited by the circular cross-section of the entire tusk. As observed by Raubenheimer et al. (1989), and noted in Larramendi (2023), what tusks lose through abrasion is exceeded by the constant growth recorded by Laws (1966), which allows size to increase throughout life.

Parker (2024) describes symmetry in tusk pairs in the metrics of weight, length and circumference related to the ages of elephants. Here, that study is extended, to address the difference between measured asymptotes of tusk weight and length (females: 160 cm; males: 250 cm) (Parker 1979) and Laws' (1970) theoretical asymptotes (female: 510 cm; males: 660 cm) calculated from dental growth rings (vide Laws 1952), such as those shown in Fig. 2.

This paper examines evidence of whether savannah elephants are neurally predisposed to use their tusks in the sense that people are right-handed/left-handed or ambidextrous. It tests the hypothesis that single tusks are shorter than those in pairs due to doing the work of two. It discusses observations on tusk growth and how dentine is lost through abrasion and breakage. Finally, it explains the paradox of how tusk sizes so closely correlate with age (Laws 1966), while being subject to many random, stochastic influences (breakage and accidents) in long lives, that might reasonably be expected to disrupt close correlation.

Materials and methods

This paper is based on hard data acquired from five clans culled from two savannah elephant populations: one in west-central Uganda, the other in the Nyika biome, comprising Kenya's and north-easternmost Tanzania's coastal hinterland, as described in Laws et al. (1975) and Parker and McCullagh (2021) (Table 1). However, it is also informed by personal experience accumulated between 1956 and 2000, first as a game warden, and then while documenting the ivory trade and handling many thousands of tusks in 11 African countries, Britain, Belgium, Germany, India and Hong Kong (Parker 1979).

For this study and given both the small differences between them (Parker 2024) and to minimise the possible flaws in the Laws (1966) aging system (Parker 2023), the five-clan data have been combined and pooled into five-year age cohorts. Where useful, however, the two Uganda clans are referred to as Murchison North and Murchison South, located to the north and south of the Victoria Nile, respectively, and the three in the Nyika biome as Tsavo Koito, Mkomazi East and Mkomazi Central.

In some culls, age was ascribed without decimal points. In others, ages were recorded variably: some neonates were recorded as 0, while ages of others, particularly calves but also few older animals, were estimated to one decimal point. Here, across all clans, ages were standardized into year classes 0.5, 1.5, 2.5 .... where 0.5 = 0–0.9, 1.5 = 1.0–1.9, etc.

The study does not include data on milk tusks (tushes) or pre-emergent permanent tusks before they show through the gingivae as they were not collected. Tusk pair data recorded from all elephants included whether right or left, lengths (to 0.5 cm), weights (to 0.25 kg), sex, age, and shoulder height (cm). Elephants less than 6 years of age, whose tusk pairs may not have fully erupted and usually show few signs of abrasion by use, were examined separately for evidence of a congenital difference between the right and left.

Table 1. The five study populations, showing regions, sampling areas, population designations (clan), sampling locations (coordinates), sample sizes, and date ranges when sampling took place. NP = National Park

Region	Sampling area	Clan	Coordinates	Sample size	Dates
Murchison	Murchison Falls NP, Uganda	Murchison North	2°24'N, 31°42'E	1,197	Mar 1965–Jun 1967
		Murchison South	2°10'N, 31°50'E	798	Nov 1965–May 1967
Nyika	Tsavo NP, Kenya	Tsavo Koito	3°00'S, 38°42'E	298	Aug 1966
	Mkomazi NP, Tanzania	Mkomazi East	4°22'S, 38°35'E	299	Mar–Apr 1968
		Mkomazi Central	4°9'S, 38°14'E	295	Aug–Sept 1969

Results

Paired tusk length data were obtained from 189 females and 177 males, all over 6.5 years of age. A paired *t*-test for the null hypothesis (Quinn and Keough 2002) found no significant difference between right and left tusks (females: p = 0.87; males: p = 0.84) (Table 2; Fig. 3 a and b).

Overall differences expressed as proportions of the average pair's longer tusk did not exceed 3.1% in females and 1.0% in males; in both cases, these maxima were in the oldest class. This closeness notwithstanding, as would be expected from cumulative, stochastic wear and breakage over time, the proportion of equal-length pairs was greatest in the youngest cohort (females: 52.2%; males 38.7%), becoming slightly less equal with increasing age to midlife. The ratio rose again with increasing age (Fig. 4), the most likely reason being an artefact from inadequate older elephant data.

Paired tusk weight data were available from 1,304 females and 1,021 males, all over the age of 6.5 years. A paired *t*-test for the null hypothesis (Quinn and Keough 2002) found no significant difference in weight between right and left tusks (females: p = 0.83; males p = 0.504) (Table 3; Fig. 5).

The information in Table 3 above is represented

Table 2. Tusk pair lengths (cm) from 212 female and 186 male elephants between the ages of 6.5 and 55.5 years, as averages of five-year cohorts.

Age cohort	No. in cohort	Right tusk		Left tusk	
		Mean	SD	Mean	SD
Females					
0–5.5	23	39.0	2.54	39.1	2.57
6.5–10.5	31	60.6	2.66	61.4	3.50
11.5–15.5	31	77.7	2.79	77.1	2.00
16.5–20.5	21	91.3	3.53	90.3	3.22
21.5–25.5	35	103.2	3.29	104	3.27
26.5–30.5	19	113.1	3.30	111	3.01
31.5–35.5	8	122.8	3.20	123.4	3.81
36.5–40.5	10	126.6	2.95	127.9	2.48
41.5–45.5	5	127.1	1.89	124.1	2.98
46.5–50.5	20	140.7	3.54	137.1	3.34
51.5–55.5	6	151.8	2.52	154	4.12
56.5–60.5	3	143.0	3.26	138.8	3.81
Totals	**212**				
Males					
0–5.5	31	43.4	2.90	43.5	2.87
6.5–10.5	52	74.6	3.45	75.0	3.42
11.5–15.5	31	103.3	3.00	103.1	3.10
16.5–20.5	28	122.6	3.17	122.4	3.31
21.5–25.5	12	137.9	3.35	136.9	3.53
26.5–30.5	18	155.8	3,55	154.3	3.72
31.5–35.5	5	181.8	0.26	183.6	1.16
36.5–40.5	1	230.0	15.2	228.0	15.10
41.5–45.5	6	186.6	4.92	176.9	4.28
46.5–50.5	2	224.0	0.81	248.0	0.81
Totals	**186**				

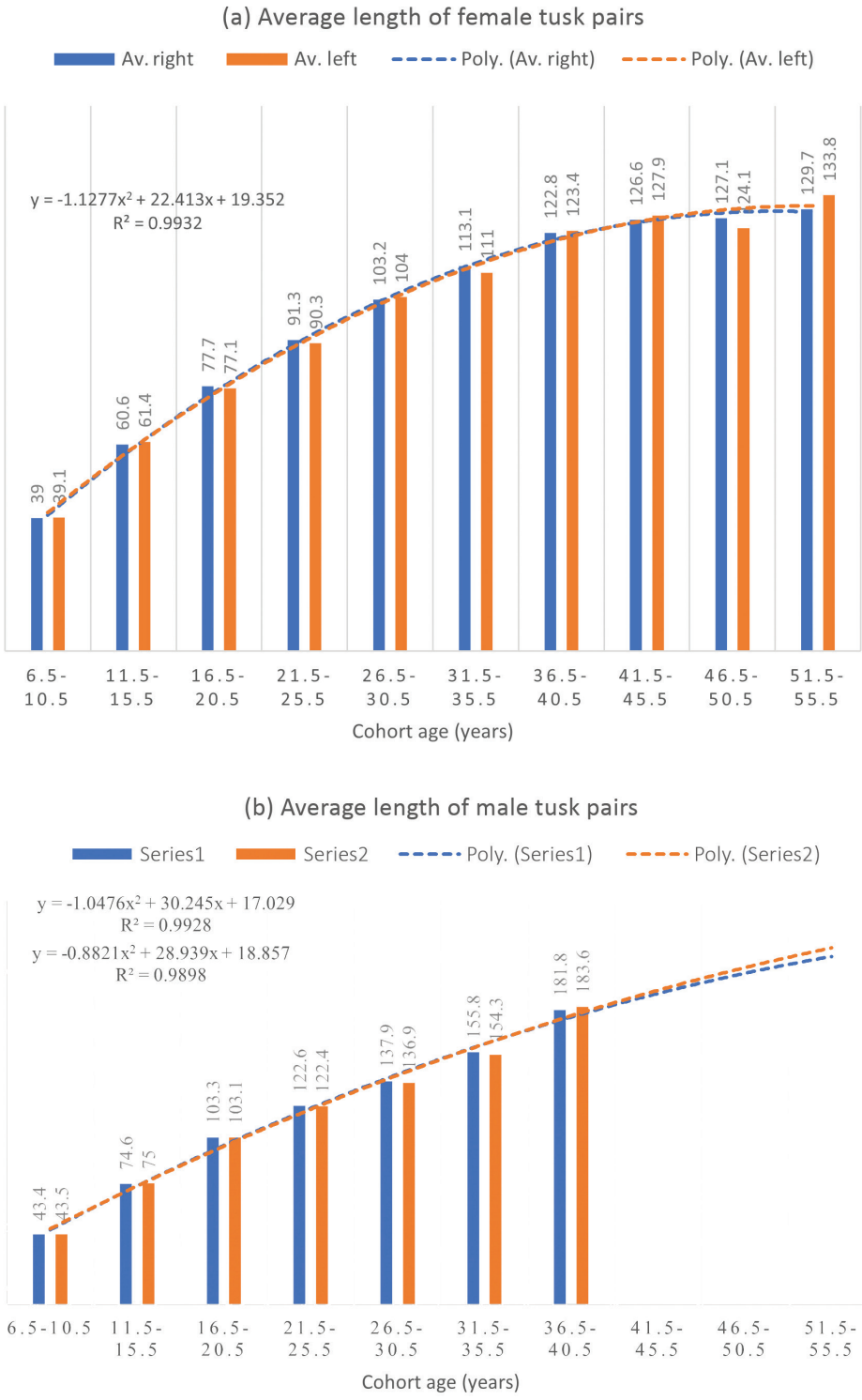


Figure 3. Average left and right tusk lengths for (a) female (n = 189) and (b) male (n = 177) elephants. Cohort ages are averages, i.e. 8.5 = 6.5–10.5, 13.5 = 11.5–15.5, etc. Bar labels indicate mean values for each age cohort. Dashed lines show curvilinear fits based on second-order polynomial regressions.

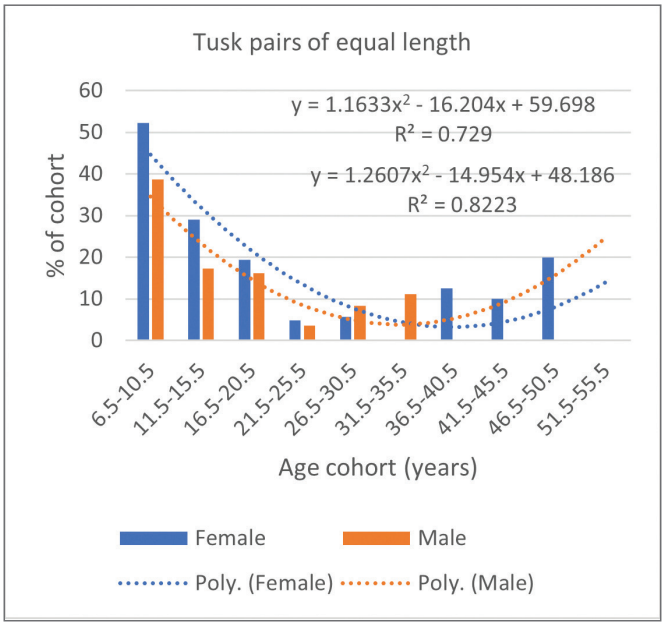


Figure 4. Proportion of tusk pairs of equal lengths in female (n = 189) and male (n = 177) elephants. Cohort ages are averages, i.e. 8.5 = 6.5–10.5, 13.5 = 11.5–15.5, etc. Dashed lines show curvilinear fits based on second-order polynomial regressions.

graphically in Fig. 5 a and b, below.

Proportions of pairs of tusks of equal weight in each age cohort follow similar trajectories to those for length pairs, being greatest early in life, declining to midlife, and then levelling out (Fig. 6).

Bearing in mind that tusk lengths and weights are predictive of one another (Parker 2024), the results for the larger weight sample makes the upswing in the proportion of equal length tusks in later life (Fig. 4) all the more likely to be an artifact of too few data.

When presented as averages in five-year cohorts, neither in length nor weight do tusk pairs display any bias to either right or left, confirming that finding in Parker (2024). To address the possibility that tusk metrics are nevertheless influenced congenitally, the lengths were examined of 69 tusk pairs of elephants under 5.5 years old, before tusks can be much worn in use and when most still have enamel caps. Table 4 presents average lengths (cm) from 69 tusk pairs (31 female and 38 male).

The data in Table 4 suggests some level of inequality. With 31 females, mean right and left tusk lengths were the same (38) cm (paired *t*-test =1.00). In 38 males, the mean tusks of the right and left tusks were 41.4 and 41.6 cm, respectively (paired t = P 0.28). However, pairs of exactly equal length were 39.1% of the sample, while the remaining 60.9% were very slightly unequal. Statistically, therefore, though there was no significant length difference between right and left tusks, within each sample, more emergent tusks than not are congenitally slightly different. While not statistically significant, given the measurements made, this leaves the question of congenital influence on tusk metrics open. Suffice it to say, as far as this study goes, there is no evidence of lateralization in emergent tusks, but with 60% unequal, not all tusk pairs start as mirror images of one another and some length differences may be congenital.

The relationship of lengths to weights, in samples of 561 tusk pairs (272 females, 289 males) is given in Table 5. The longer tusk was also heavier in 80.0% of females and 80.6% of males. The right tusk was longer, but the shorter left tusk heavier in 5.6% of females and 4.5% of males. The left tusk was longer, but the shorter right tusk heavier in 4.8% of females and 6.6% of males. The right and left tusks were equal in both length and weight in 9.6% of females and 8.3% of males.

Differing gender tusk shapes (*in alveolum* before any wear can have influenced them) are illustrated in

Table 3. Comparison of average weights (kg) of the summed cohort between the right and left tusks in samples of 1,304 female and 1,021 male tusk pairs, presented in five-year cohorts from 6.5 to 55.5 years.

Age cohort	No. in cohort	Right tusk		Left tusk	
		Mean	SD	Mean	SD
Females					
0–5.5	122	0.39	0.44	0.39	0.44
6.5–10.5	219	1.00	0.53	1.00	0.53
11.5–15.5	165	1.78	0.57	1.79	0.64
16.5–20.5	184	2.51	0.68	2.50	0.66
21.5–25.5	190	3.32	0.77	3.32	0.77
26.5–30.5	174	4.61	0.92	4.62	0.93
31.5–35.5	102	5.54	0.94	5.67	0.99
36.5–40.5	94	6.34	1.08	6.35	1.08
41.5–45.5	50	6.73	1.08	6.42	1.01
46.5–50.5	53	7.55	1.06	7.49	1.06
51.5–55.5	39	6.96	1.19	6.87	1.13
56.5–60.5	12	6.97	1.11	6.97	1.04
Totals	**1,404**	**3.35**	**0.75**	**3.35**	**0.75**
Males					
0–5.5	160	0.59	0.52	0.60	0.52
6.5–10.5	263	2.03	0.79	2.06	0.75
11.5–15.5	188	4.02	0.90	4.01	0.90
16.5–20.5	152	9.57	1.35	9.47	1.34
21.5–25.5	19	14.25	1.69	14.20	1.72
26.5–30.5	47	18.67	2.35	19.00	1.61
31.5–35.5	25	25.91	2.49	26.00	2.38
36.5–40.5	17	30.74	2.65	29.41	2.57
41.5–45.5	8	39.61	2.53	38.16	2.57
46.5–50.5	2	39.30	2.72	38.6	2.90
Totals	**1,021**	**39.3**	**1.14**	**38.6**	**1.12**

Table 6 and Figure 7 where, as an index of taper (cone shape), the difference between the tusk base and lip diameters is given as a percentage of the former and related to the elephant's age. From these data, it is apparent that males' tusks retain a conical form until around the mid-20s, after which the slope decreases and in old age has reversed. Female tusks are more cylindrical until the mid-30s, after which, as with males, the base diameter decreases. In both sexes, this pattern suggests slower growth in late age.

The difference in typical tusk shape between the sexes (females cylindrical, male conical) shown in Fig. 7 is illustrated visually in Fig. 8.

That female and immature elephants associate as family units under the leadership of a matriarch was noted by Laws et al. (1975) and described in detail by Moss and Poole (1983). Their findings are further supported by photographs of the tusks of two such families shown in Figure 9. Those on the left were registered by Game Management Uganda as herds GMU 30 and those on the right as GMU 32. In each, the oldest female's (assumed matriarch's) right and left tusks are at the centre opposite one another and

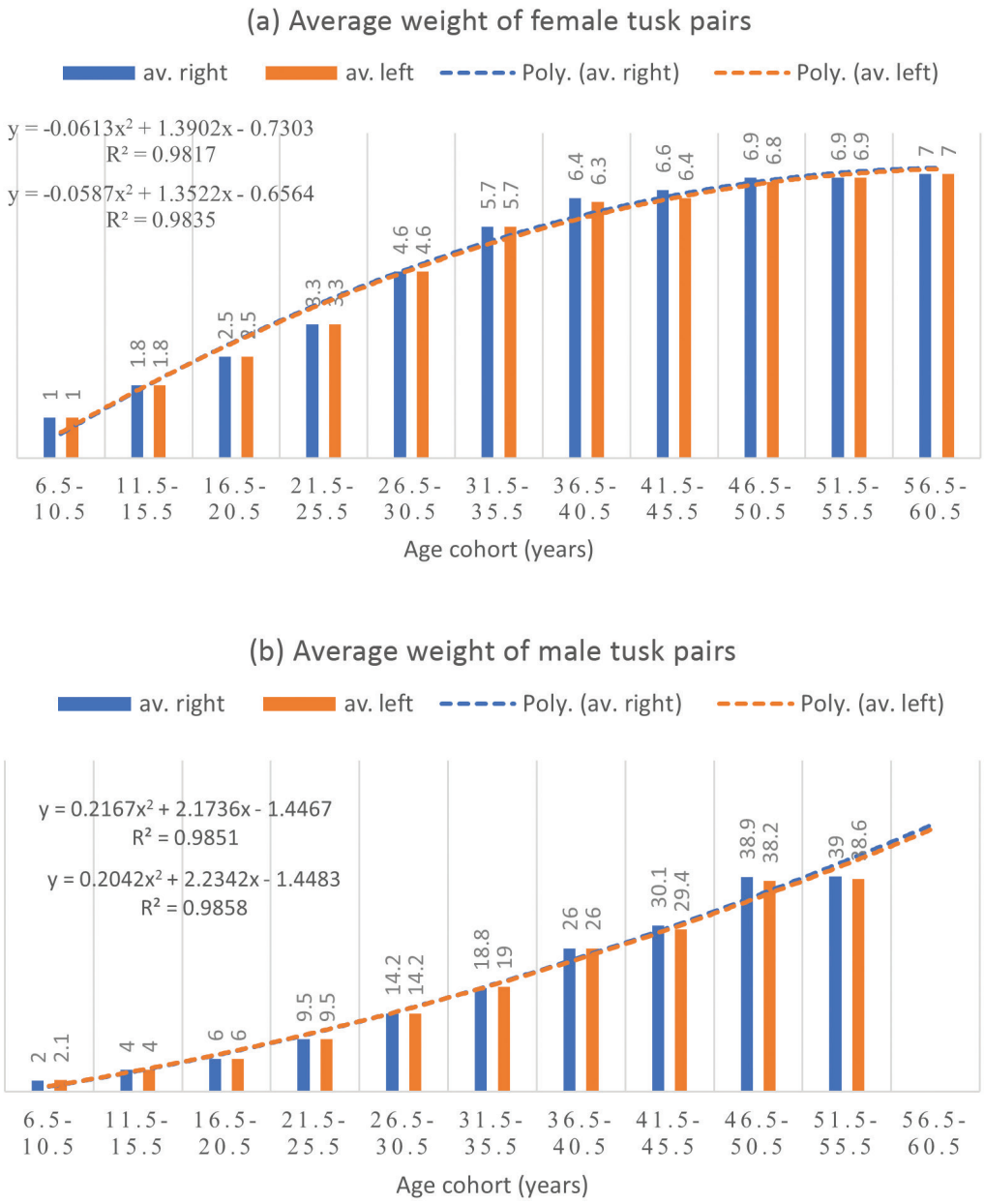


Figure 5. Average left and right tusk weights for (a) female (n = 189) and (b) male (n = 177) elephants. Cohort ages are averages, i.e. 8.5 = 6.5–10.5, 13.5 = 11.5–15.5, etc. Bar labels indicate mean values for each age cohort. Dashed lines show curvilinear fits based on second-order polynomial regressions.

the rest of the herd's tusks are laid in descending age order outwards with the youngest pair at the outer edges. Both herds reflect their individual matriarch's distinctly different and presumably inherited tusk curvature in one plane.

Table 7 and Fig. 10 use the close genetic links within elephant families to estimate tusk growth and wear from use over an individual lifespan. They present data from 1966 on the six females of different ages of herd GMU 32, showing for each animal the measured tusk length and potential tusk length based on Laws' (1970) estimate of annual female tusk

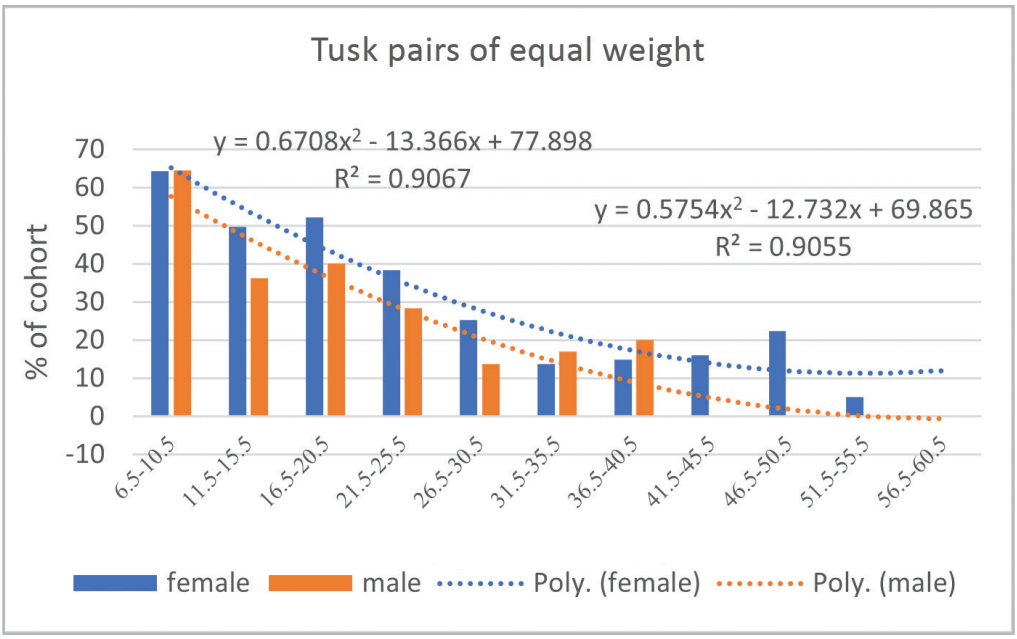


Figure 6. Proportion of tusk pairs of equal weights in female (n = 189) and male (n = 177) elephants. Cohort ages are averages, i.e. 8.5 = 6.5–10.5, 13.5 = 11.5–15.5, etc. Dashed lines show curvilinear fits based on second-order polynomial regressions.

Table 4. Comparison of the lengths of tusks (cm) in 69 pairs of tusks (31 female and 38 male) from elephants aged 5.5 years or less.

Sex	No.	Unequal (%)	Equal (%)
Female	31	58.1	41.9
Male	38	63.3	36.8
Combined	**69**	**60.9**	**39.1**

Table 5. Lengths of tusk to their weights for females (n =272) and males (n = 289) as a percentage of each sample.

Sex	Longer tusk heavier	Right tusk longer, left heavier	Left tusk longer, right heavier	Pairs with equal length and weight	Totals
F	80.0	5.6	4.8	9.6	100.0
M	80.6	4.5	6.6	8.3	100.0

length growth of 8.5 cm. The potential lengths of the tusks are greater than the actual lengths, and the differences are presumed indices of loss. Regressions fitted for the measured tusks at age were $y = 25.171x + 4.7333$, $R^2 = 0.9401$, and for potential length were $y = 6.0714^3 - 58.1354x^2 + 227.51x - 161.67$, $R^2 = 0.9963$. Matching data for males are not shown, as there were too few male tusks available for statistical analysis.

The expectation that a single tusk would have twice the work of those in pairs and suffer twice the wear would be shorter was tested. In a sample of 304 female elephants, 11 were single-tusked, distributed between the ages of 4 and 49 years. Samples of 10 same-age two-tusked animals for each of them were not available so their lengths were contrasted with the average tusk lengths of the 10 closest age pairs to each case. The data are given in Table 8 and Figure 11. Linear regressions with equations and coefficients of determination (nearest age pairs $R^2 = 0.945$, single tusks $R^2 = 0.771$) indicate that single tusks fall within the same scatter as tusks in pairs and are not shorter despite doing the work of two. In a sample of 274 male tusk lengths, only three were unilaterally tuskless. These were too few for worthwhile statistical analysis, but two were respectively 13% and 8.6% longer and one was 6.3% shorter than the average of their 10 closest pairs, providing no ground for assuming that a greater workload produces a shorter tusk.

Table 6. Gender differences in tusk shape, showing tusk weights, diameters (mm) of the tusk base and at the lip, the difference (mm) and difference as a percentage of the base diameter. Negative values in bold red type indicate the base diameter was less than the lip diameter. ID numbers were assigned by Game Management Uganda (GMU).

ID	Age (year)s	Tusk weight (kg)	Diameter (mm)		Difference (base–lip)	
			Base	Lip	mm	%
Females						
1585	8	1.1	20	21	**-1**	**-5.0**
1487	9	1.1	42	45	**-3**	**-7.0**
1557	10	0.9	22	23	**-1**	**-4.5**
1507	17	1.8	32	32	0	0
1589	22	3.2	26	26	0	0
1587	23	3.6	28	28	0	0
1595	25	5.0	28	28	0	0
1502	26	2.7	26	27	**-1**	**-3.8**
1572	39	5.2	25	27	**-2**	**-8.0**
1554	47	10.4	32	33	**-1**	**-3.1**
1513	52	8.2	36	39	**-3**	**-8.3**
1515	52	6.3	30	32	**-2**	**-6.7**
1501	53	7.0	35	35	0	0
1561	53	10.4	30	30	0	0
1514	55	6.5	34	38	**-4**	**-11.8**
1484	59	9.1	30	35	**-5**	**-16.7**
Males						
1556	5	0.9	32	28	4	12.5
1557	5	0.9	31	27	4	12.9
1572	6	1.6	33	30	3	9.1
1569	9	1.8	31	28	3	9.7
1555	10	2.7	41	37	4	9.8
1593	11	3.6	37	34	3	8.1
1440	14	5.7	44	39	5	11.4
1562	15	5.0	46	42	4	8.7
1410	17	4.1	47	40	7	14.9
1468	17	48	30	27	3	10.0
1429	21	9.7	35	30	5	14.3
1500	21	6.6	41	38	3	7.3
1416	24	7.7	50	45	5	10.0
1445	24	9.1	55	49	6	10.9
1432	26	8.6	45	44	1	2.2
1434	31	19.3	37	33	4	10.8
1407	36	24.5	40	40	0	0
1443	38	32.4	45	44	1	2.2
1466	40	43.9	36	35	1	2.8
1444	45	28.3	45	46	**-1**	**-2.2**
1546	49	66.6	30	31	**-1**	**-3.3**
1546	49	62.1	40	40	0	0

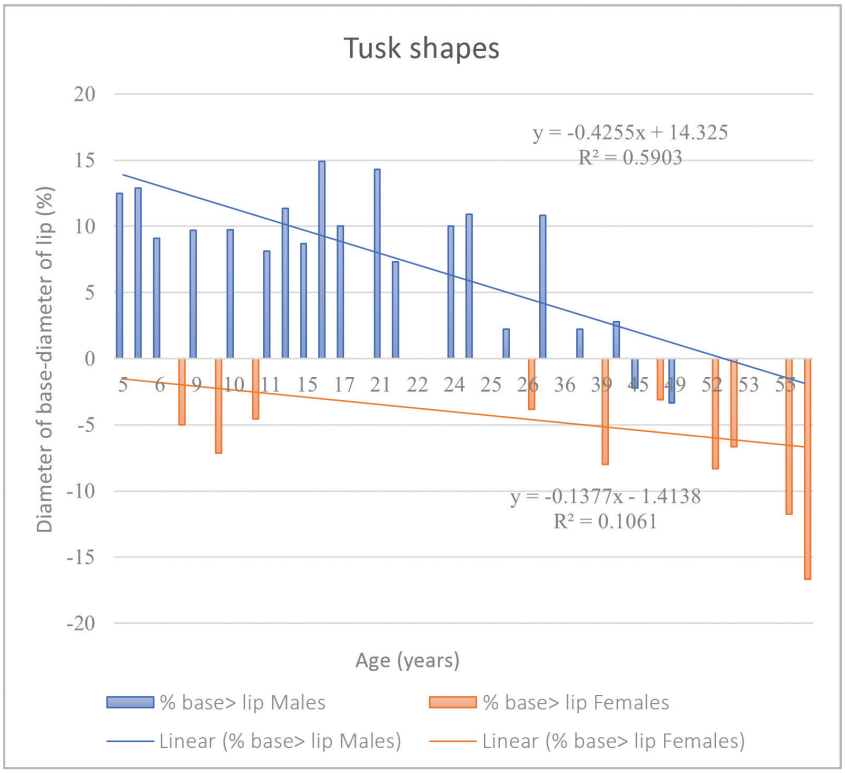


Figure 7. Tusk shape for females (n = 16) and males (n = 22) shown as the difference between diameter at the tusk base and at the lip. Positive values indicate a tapered shape where the tusk base diameter is greater than the diameter at the lip. Solid lines show linear regressions of tusk shape related to age.

Figure 8. The alveolar sections of (left) a cylindrical female tusk and (right) a tapered male tusk.

That closeness of length and weight between tusk pairs, the close relationship between tusk size and age, and the finding that single tusks were not shorter than tusks in pairs indicated that tusk length variations were responses to another driver. As body size is known to be correlated to age (Laws et al. 1975), possibly size was that driver. As shoulder heights of culled elephants were available, the relationship between this variable and the longer tusk of a pair was examined. Table 9 and Fig. 12 present the average of the longer tusks and the average of all shoulder heights at age in each five-year cohort for 289 females and 269 males.

From the youngest age class (<0–5.5) to the oldest class (56.5–60.5), the shoulder heights and tusk lengths of females have curves rising towards a maximum (Fig. 12A), which closely fit polynomial regressions (coefficients of determination, R^2 = to approximately 0.99; Quinn and Keough 2002). The ratio of tusk length to shoulder height curve is nearly linear (R^2 = 0.99). For males, shoulder heights and tusk lengths have similar curves to those of females, and fit well with polynomial regressions (Fig. 12B), but were more variable (R^2 varied from 0.95 to 0.98). The ratio of tusk length to shoulder height for males was also nearly linear (R^2 = 0.89). Using these data for females in the twelve age classes, it was found that the average length of the longer tusk length (y) can be accurately predicted from the average shoulder height

Figure 9. Examples of two herds from the same clan (Murchison South): (left) herd GMU 30 whose tusks are heavily curved, and (right) herd GMU 32 whose tusks are relatively straight.

Table 7. Measured and potential lengths of tusk of six females of herd GMU 32, showing their age in 1966, their year of birth, years between births, the matriarch's age at the time of the other elephants' births, the measured length of the longest tusk of each individual (cm), its potential length at the same age using Laws' (1970) formula, the difference between actual and potential lengths, showing estimated loss through wear, in centimetres and as a percentage of the measured length. ID numbers were assigned by Game Management Uganda (GMU).

ID	Age (years) in 1966	Year of birth	Years between births	Matriarch (235)'s age at birth	Longest measured tusk (cm)	Potential length (cm)	Loss through wear (cm)	Loss through wear (%)
235	50	1916			155	425	270	174
239	32	1934	18	18	127	272	145	114
231	26	1940	6	24	104	221	117	113
229	18	1948	8	32	81	153	72	89
228	13	1953	5	27	76	110.5	34.5	45
233	2	1964	3	48	14	(Emergent)	0	0

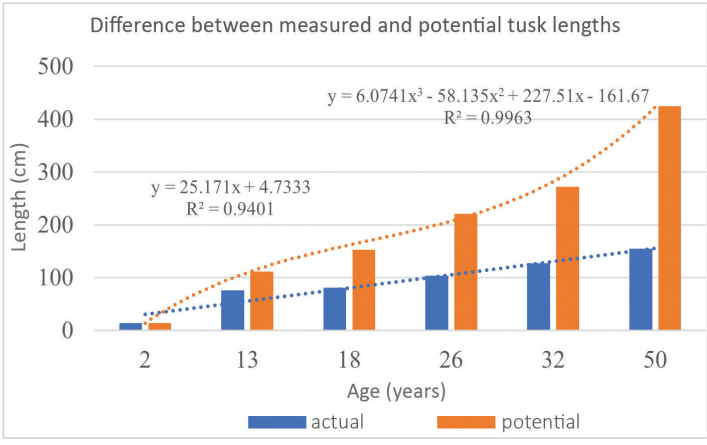


Figure 10. Actual and potential lengths of tusks for females of different ages in herd GMU 32; as an indication of tusk loss through wear. Potential lengths are estimated based on average growth of 8.5 cm a year as given in Laws (1970). Dotted lines show fits based linear (measured length) and third order polynomial (potential length) regressions.

Table 8. The tusk lengths in cm of eleven single-tusked female elephants compared to the average tusk lengths of the ten pairs closest to them in age.

Age (year class)	Tusk length (cm)	
	Paired tusks	Single tusk
4.5	42.4	42.0
7.5	54.4	44.5
8.5	63.7	51.0
13.5	81.6	81.5
18.5	86.0	51.0
18.5	88.2	94.0
20.5	84.8	107.0
22.5	98.9	67.5
30.5	120.7	128.5
43.5	127.2	174.0
49.5	147.3	132.0

(x) by the exponential growth equation $y = y_0 + ab^x$, which is best fit as $y = 22.14 + 0.7096 \times 1.0204^x$ ($r^2 = 0.99$, $p < 0.001$) (Quinn and Keough 2002). For male data in 10 age classes (with no data for the oldest two cohorts), the longest average length of the tusk was also accurately predicted from average shoulder height by the exponential growth curve, $y = -180.8 + 125.1 \times 1.0036^x$ ($r^2 = 0.92$, $p < 0.001$). Thus, the average size of female and male elephants, as measured by average shoulder height, provides a template for the average longest tusk length.

Discussion

Lateralization

In elephants <5.5 years old (69 pairs), when their enamel caps may prevent dentine erosion, some 60.9% of erupting tusk pairs were unequal in length. Sheldrick, cited in Laws (1966), reports that appearances of the first and second tusk through the gingivae in a tame female elephant calf were separated by seven months. Though the data sample is small, it indicates that, from the start, tusk pairs are not necessarily mirror images of one another. However, average tusk pair lengths and weights of elephants over 6.5 years of age assembled in five-year cohorts showed no significant statistical length or weight differences between the right and left tusks in either gender. Nevertheless, pairs of exactly equal length and weight are greatest early in life and decrease slightly with age, which is not unexpected over ~60 years of life, wear and use. Presumably, the 'congenital' differences noted in elephants < 5.5 years old are too small to be detected in the measurements taken or are evened out by use, for which there is much evidence (see below).

Versace and Vallortigara (2015) report that preferentially using either right or left sides occurs across the animal realm in both vertebrates and invertebrates including humans. Long-standing lore among hunters and traders is that elephants use one tusk preferentially in the manner of handedness in humans. The findings presented here contradict that perception. They also, for example, contradict the observations of Hall-Martin, who used the term 'servant tusks' for the lighter in a pair (Bosman and Hall-Martin 1986; Raubenhmeimer et al. 1989; Bielert et al. 2017). With tusk weights as their only measure in examining lateralization, Bielert et al. (2017) found that 94.29% of right tusks were lighter than left tusks and, without considering other possible causes, attributed this to preferential use. Their data were 683 "sportsmen's" trophy tusk pair weights that originated in 16 different African countries between 1955 and 2010 and included both elephant species, i.e. *Loxodonta cyclotis* and *L. africana*. Their mean weights of right and left tusks, respectively, were 30.24 and 30.65 kg. This difference of only 0.41 kg or 1.3% of the heavier weight challenges their assessment of significant difference. They noted, but did not explore, that the heavier of a tusk pair was sometimes the shorter. They did not test the possibility that the identification of a tusk as 'right' and 'left' may have been determined by the myth of 'handedness' itself—a possibility, given how deeply set it was in hunters' lore.

Whyte and Hall-Martin (2018) detected no such lateralization in weights of tusks of 271 females or 200 males when analysed separately, but when the sexes were combined there was a slight bias for 'right-tuskedness'. They sought no support from such lengthy data as they had; nor did they consider the possibility that ratios between right and left might alternate through an elephant's life or be affected by any other dynamic. Their combined total of 471 was only 20.5% of the 2,305 sampled here, where both length and weight presented in five-year cohorts showed no such bias, suggesting their sample in animals living >50 years was too small.

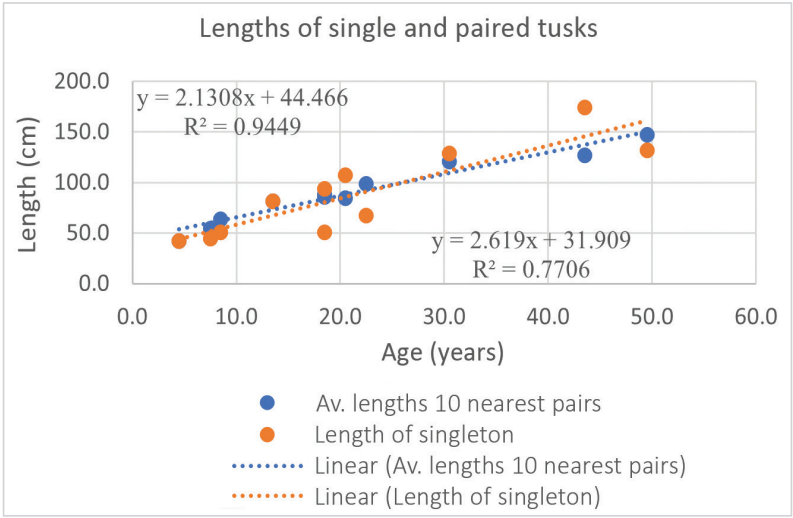


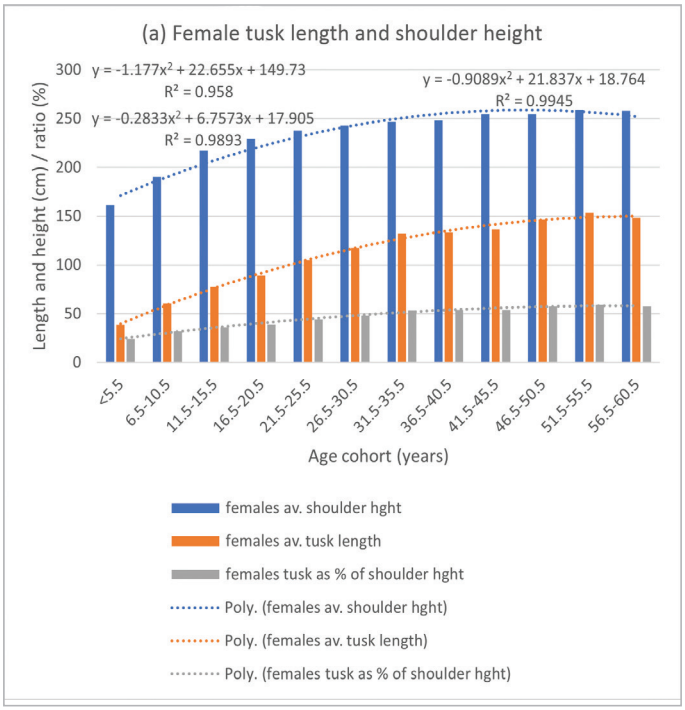
Figure 11. The length of tusks of single-tusked females in herd GMU 32, compared to the average lengths of pairs of tusks of 10 females closest in age to them. Dotted lines show linear regression equations.

Table 9. The shoulder heights and lengths of the longer tusk in 294 female tusk pairs and 269 male pairs, and tusk length as a percentage of shoulder height, presented as averages in five-year cohorts.

Age class (years)	Females			Males		
	Shoulder height (cm)	Tusk length (cm)	Tusk length as % of shoulder height	Shoulder height (cm)	Tusk length (cm)	Tusk length as % of shoulder height
<5.5	161.1	38.3	**23.8**	166.8	43.6	**26.1**
6.5–10.5	190.3	60.4	**31.7**	197.2	76.9	**39.0**
11.5–15.5	216.9	77.6	**35.8**	219.0	96.9	**44.2**
16.5–20.5	229.4	89.2	**38.9**	254.0	122.8	**48.3**
21.5–25.5	237.7	104.9	**44.1**	270.0	141.6	**52.4**
26.5–30.5	243.1	117.1	**48.2**	287.5	155.4	**54.1**
31.5–35.5	246.6	132.0	**53.5**	307.3	183.6	**59.7**
36.5–40.5	248.4	133.3	**53.7**	304.0	230.0	**75.7**
41.5–45.5	254.3	136.7	**53.8**	300.8	203.7	**67.7**
46.5–50.5	254.3	146.6	**57.6**	323.5	198.0	**61.2**
51.5–55.5	258.7	153.2	**59.2**			
56.5–60.5	258.0	148.3	**57.5**			

Summarizing the data of both genders, in ~80% of pairs of tusks the longer tusk is heavier, in 5–6% of pairs the heavier tusk will be the shorter and in 8–9% both length and weight will be equal. However, these differences are equally distributed between right and left. Data on neither length nor weight of average tusk pairs assembled in five-year cohorts support the idea that elephant tusk pairs reflect neurally lateralized use, similar to human right- or left-handedness.

However, this does not mean the phenomenon is absent in elephants: only that if it occurs, the dynamics of tusk growth and wear (discussed below) conceal it. It might be better looked for in how they use their



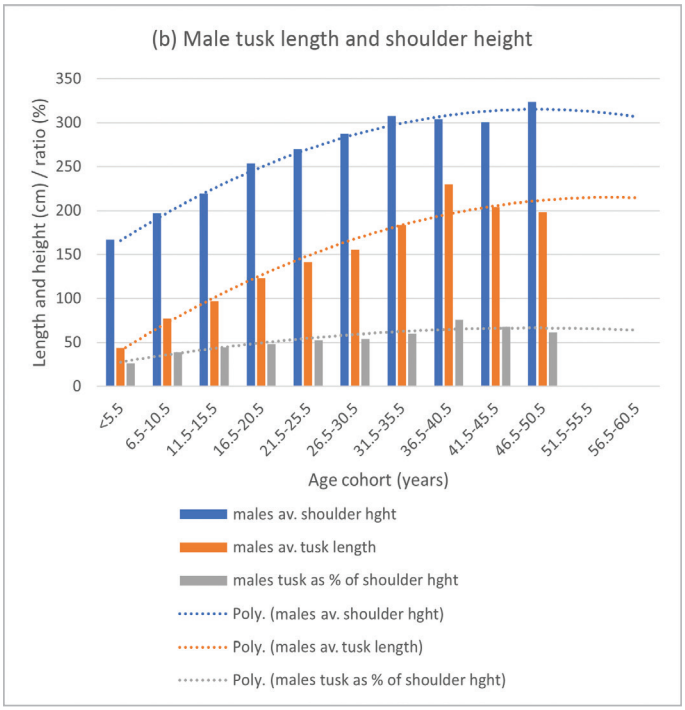


Figure 12. Average shoulder heights and longest tusk lengths, and tusk length as a percentage of shoulder height for (a) female (n = 294) and (b) male (n = 269) elephants. Cohort ages are averages, i.e. 8.5 = 6.5–10.5, 13.5 = 11.5–15.5, etc. Dashed lines show curvilinear fits based on second-order polynomial regressions.

feet which, despite lacking primate-like digits, are used for scuff-digging, forwards, backwards and sideways, both forcefully or gently, or using 360° of the rims of both front and rear feet with surprising sensitivity to gently explore an object (pers. obs. 1960s). Further, suggestion of a bias towards the right has been observed in how elephants use their trunks (Lefeuvre et al. 2021).

Tusk shapes

While length and weight at age differentiate male from female elephant tusks, their shapes also separate the genders. Long-known to traders and hunters, this experience-based albeit subjective knowledge is illustrated in Figures 5 and 6. The data presented here extends and confirms Elder's (1970) observations. Measurements of tusk base and lip diameters within the alveoli before they have been exposed to external influences confirmed that the female tusk is more or less cylindrical until aged in the mid-20s, after which its base circumference starts gradually shrinking. In males, the initially strongly tapered alveolar shape is retained until around the mid-20s. From this age on, the taper decreases until after the 40s, when the base:lip ratio gradually becomes negative. Photographic data support Whyte and Hall-Martin's (2018) observation that female tusk growth declines in late age, which is cautiously suggested in Parker (2024). The photographic evidence indicating that a similar decline also takes place in male tusks contradicts both Laws' (1966) and Whyte and Hall-Martin's (2018) assertions that there is no fall-off with age in male tusk growth. However, caution is advisable in accepting findings from so small a data set. This apparent declining tusk growth in late life requires confirmation based on more comprehensive evidence.

Elder (1970) reports changes in tusk pulp volumes with age. Parker (1979) records a decline of pulp volume from 820 ml around the end of the female's fourth decade down to 300 ml in the late fifth decade, with pulp being replaced by dentine. Whyte and Hall-Martin (2018) found a similar regression from a maximum pulp volume of 785 ml coinciding with age 41 years, when the average weight of tusks was also at its maximum. While not giving pulp volume minima after 41 years, they also report its replacement with dentine. This contraction of tooth pulp volume and substitution by internal dentine is not apparent from external shape and weight. Presumably, pulp reduction is accompanied by diminished activity of dentine-producing odontoblasts, explaining Whyte and Hall-Martin's (2018) findings of a decline (but not cessation) of female tusk growth after age 41. Comparable data from male tusks were not available (vis-à-vis we do not have comparable data on pulp regression from males). If the replacement of pulp volume by internally deposited dentine exceeds the rate at which tusks are extruded, this might explain the findings of both Laws (1970) and Whyte and Hall-Martin (2018) that exponential male growth, when measured by weight, was uninterrupted. If pulp volume and length had been their measures of tusk growth, they would have found otherwise. The fact that there is a reduction in male pulp with age is hinted at by East African professional trophy hunters who could accurately judge the lengths and girths of the tusks, but with the caveat that weight "depended on the size of the nerve [pulp]". Personally, having looked into the pulp cavities of many hundreds of big tusks, I can confirm that there is much variation in volume. This subjective recall would also be consistent with some degree of pulp decline. The evidence of tusk pulp volume regressing in both genders is persuasive but still needs definitive confirmation.

Tusk growth

The finding that the weights of single tusks are not less than those of tusk pairs of similar ages, despite single tusks having to do the work of two, implies that the tusk sizes are determined by factors other than normal wear and usage. This determining factor appears to be the size of the animal (considered below).

The photographs showing the two-dimensional shape of tusks of herds GMU 30 and GMU 32 (Fig. 9) are missing any spiral dimension, either supporting or contradicting Laws' (1970) assertion that tusks grow in logarithmic or helical spirals. This feature of proboscidean tusks is mentioned by Larramendi (2023) with reference to Evans et al. (2021). Nevertheless, the photos suggest a genetically transmitted curvature common to herd members in accordance with Moss and Poole's (1983) finding that members of such units are closely related, many being the matriarch's direct descendants. This was the basis for the assumption made in this study that since GMU 32 females are the matriarch GMU 235's daughters or grand-daughters their tusks represent images of what her tusks would have been like at their respective ages. While conscious

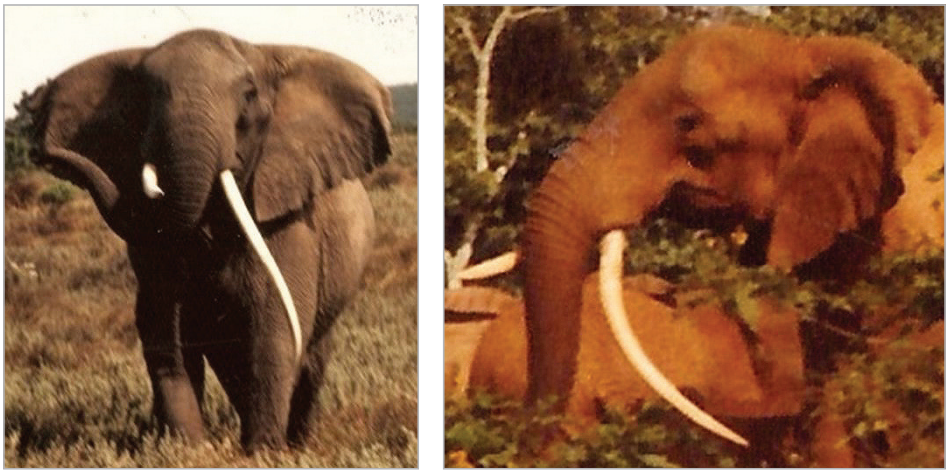


Figure 13. Two views of the same elephant illustrate a tusk oriented so that it could not be used as a tool and thus not subject to wear, as was its partner. The only loss of length would have been through weathering. (© AMD Seth-Smith).

of having only one example where much larger samples would have been desirable, the results presented here give an insight into the discrepancy between Laws' (1970) putative average asymptote for female tusk length of 510 cm and Parker's (1979) measured average maxima of at 60 years of only 160 cm. It is evidence that at all ages after losing the enamel cap, tusk dentine is being eroded and at 50 years female elephants may have grown and lost much more ivory than is present in the tusks they carry.

Empirical supporting evidence comes from Figure 13, showing a female whose left tusk was either congenitally or traumatically rotated in its alveolus so that it curved backward continuing to grow but could not be used normally. Freed from use (but not weathering), it had grown towards its potential length. The backward curving tusk's partner appears typical and from the finding that single tusks are not shorter than paired tusks, the disparity between the two gives some idea of what the shorter tusk may have lost through use and wear. The fact that such cases are rare may be because the tusks would be obstructions and likely to be accidentally broken or shed. Figure 14 depicts a similar case recorded by Joyce Poole in the Mara area of Kenya.

Tusk wear

The reason why tusks never reach their theoretical asymptotes is explained by wear. Devoid of contact with the blood supply or any means of replenishment from the tooth pulp, for all practical purposes, tusk outside the skull is dead tissue and can only lose matter. Replacement and augmentation by growth and

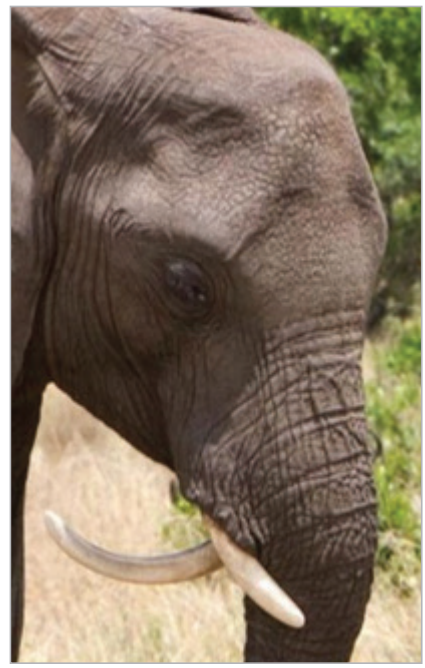


Figure 14. A similar case to Fig. 13 is the above photo of a juvenile elephant, with a tusk rotated in the alveolus, either congenitally or traumatically, so that its curvature prevented normal use.
(© Joyce Poole).

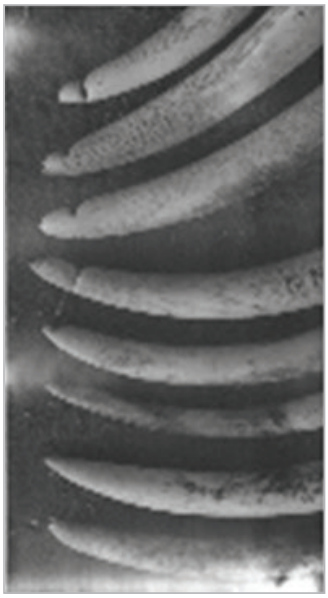


Figure 15. Tusks (from Murchison Falls NP) showing 'shakes' (see text) and the notching that results in tusk tips breaking off. The tips of the second and fourth tusks from the top show evidence of recent breakages.

further extrusion originates within its alveolus (Raubenheimer et al. 1990). Dentine's relative softness renders tusks subject to loss from decomposition, abrasion, chipping, notching and transverse fractures. Chipping occurs when small bits of ivory break off tips, for example when digging into hard substrates. The degree to which elephants are prepared to do this was illustrated by three males who were seen digging pieces out of a concrete floor that were then ingested (Hinga Muigai, pers. comm. 1994).

Ivory decomposition is most obvious postmortem (pers. obs. 1960s). Exposed to the elements, its smooth, glossy surfaces progressively become rough, powdery, chalky and eventually crumble to a powder. Depending on multiple environmental factors including tusk size, this decomposition may be rapid and destroy a small tusk in less than a year, or in larger specimens slow and take several decades (Parker and Graham 2020). Yet, it will have commenced while the animal is still alive, with the effects of constant abrasion in use and rubbing with the trunk seen in the smooth surfaces of the tusks of living animals.

Weathering, due to the combined effects of insolation, temperature, humidity, etc., of a tusk's exposed surface is part of the foregoing process. Because of dentine's poor thermal conductivity (Jakubinek et al. 2006), these influences do not penetrate deeply into the dentine matrix. In addition, since dentine is slightly flexible, compression and expansion stresses during use will also be greatest around the circumference of the tusks, i.e. at the surface. Combined, these stresses produce fine longitudinal, hairline cracks that penetrate tusks radially and were called 'shakes' or 'streamers' by ivory craftsmen (Fig. 15).

On the living animal and in freshly extracted ivory these cracks are seldom more than 1 mm deep, progressively becoming more abundant toward tusk tips, presumably the result of longer exposure and the tusk becoming thinner toward the tip and thus more vulnerable to flexure. By allowing extraneous matter, such as plant saps and soil, to penetrate the surface and acquire and lose moisture, 'shakes' are not only produced by but also contribute to decomposition. Until post-mortem, they do not extend into a tusk's protected alveolar sections where growth occurs, and where tissues are alive and have a blood supply. After death and on leaving a dead elephant's skull, shakes deepen radially inward toward the tusk core, extend in length, appear in the alveolar section, and eventually develop into multiple longitudinal splits.

Notching (Fig. 15), mentioned by Capstick (1977) and Raubenheimer et al. (1989), produces tip-snapping. Notches are usually apparent within the 15 cm of a tusk's tip. Feeding elephants use their tusks as fulcra, over which they drag and break vegetation, which is caught up in nicks or faults in the tusks' circumferences or depressions produced when an ivory 'bean'[1] drops out, creating grooves or notches that, as they grow, progressively snag more material. Their development accelerates until, when stressed, the tip breaks off, leaving only a small rough breakage area that is quickly smoothed back to a point. If Laws' (1970) estimates of the annual growth of female and male tusks are of the right order (respectively 8.5 and 11 cm), then a notch loss could remove a year

[1]Ivory 'beans' or 'pearls' are independent dentine bodies usually developing near the apex of the tooth pulp, usually small (~1 cm) in diameter but occasionally much larger, that become embedded in the tusk matrix, carried forward by the tusk's outgrowth and, when the retaining dentine around them wears away, drop out leaving a hollow.

(a) August 1998

(b) October 2011

(c) October 2011

(d) Later October 2011

Figure 16. Photos of elephant f0096 in Maasai Mara, Kenya, showing tusk changes over a period of more the 13 years, from a transverse break in the right tusk coupled with evidence of notching.
(a) In 1998 a transverse right tusk break coupled with a developing left tusk notch.
(b) By 2011, thirteen years later the right tusk in a) with a developed notch, now longer than the left tusk.
(c) The left tusk in b) enlarged to show a developing notch that is less than the left tusk notch in a), and clearly younger.
(d) The same tusk as in b) and c) but later in the same month showing how much the notch in c) has grown.

of growth in both genders. Although notching was only entered on culling field data sheets as an occasional note, it was recorded from 17 females and 11 males, with 48% and 52% of all notches found on right and left tusks respectively, again supporting evidence of even use. However, the incidence of notching was much higher than occasionally recorded on the culling data sheets. In a photographic sample of 235 tusk tips across a range of tusk sizes, 86% showed ends characteristic of chipping or notching having occurred (Parker unpublished data). Figure 15 supports this, showing eight tusk tips with notches and/or evidence of chipping. If tusk pairs grow at around the same rate and there are no statistically significant length and weight differences between average right and left tusks, both sides must be equally vulnerable to chipping and notching. Since this is unlikely to happen in both tusks at the same time, it follows that over time the longer tusk will alternate between right and left. The results will only be apparent from repeated observations of the same animals over long periods. Nevertheless, an unavoidable conclusion is that substantial dentine loss is not occasional but a constant feature of the average savannah elephant tusk.

Transverse fractures occur when a stressed tusk snaps across its longitudinal axis anywhere between the tip and the lip, excluding notching. However, while occurring in only 8% of a sample of 1,525 tusk pairs (Parker 2024) and contributing to dentine loss, they are most likely unpredictable stochastic accidents, and there is no evidence that most or all elephants other than fighting males will experience them, though that has to be proved.

Fig. 16 images from Elephant f0096 from the Mara

in Kenya observed by Joyce Poole: Panel (a) August 1998, illustrates a transverse right tusk break and a left tusk notch. Panel (b) from 2011 shows a recovered right tusk length with a notch already starting to form, while the left tusk point suggests some loss between (a) and (b), with a new notch already developing, as shown close up in Panels (c) and (d). These repeated breakages make it impossible to measure relative growth rates between right and left.

Fig. 17 shows the tusks of an Amboseli male elephant named Tolstoy whose life was followed from birth in 1971 to his death from natural causes in 2022 aged 51. In Panel (a) he was 35 years old and both tusks were near parity in length. In Panel (b) four years later, aged 39, his right tusk had lost more than 40% of its length through a transverse break, presumed from fighting. Panel (c) shows how over the next three years not only had the broken tusk recovered considerable length, but its ragged break had worn back to a blunt rounded point. In Panel (d) the left tusk was now shorter than the right tusk, having had a substantial portion sawn off by the Kenya Wildlife Service, apparently for cosmetic reasons. For this study, it was the equivalent of a natural transverse break. Panel (e), a photograph taken a year before he died, shows that over the preceding seven years not only had right and left tusks grown considerably longer, but they were once again close to parity.

Figs. 16 and 17 are individual cases that illustrate savannah elephant tusk dynamics and their complexities. Both reflect broken tusks catching up and regaining parity in length with their partner tusk, whose length is set by the bearer's shoulder height. With the broken tusk not being used, its circumference at the break will be carried forward without wear until once again long enough to come into use. During this recovery in length the lack of wear would result in circumference inequality between pairs, and account for a shorter tusk sometimes being the heavier of a pair as reported by Bielert et al. (2017) and as shown in Table 5.

Tusk length and body size

This population perspective of parity between tusks of a pair and their correlation with the elephant's shoulder height is facilitated by extravagant continual tusk growth (though not necessarily at constant rates) throughout life. Its evolutionary value seems to lie in the physics of providing a tool that fits the size of the user, in turn determined by behaviour. It explains why elephants in Kenya, north-eastern Tanzania, and much of Uganda have tusks that are so similar and match their heights. Climate, geology and habitat undoubtedly influence rates of growth (Laws et al. 1975; McCullagh 1969) and wear, but these influences are concealed by the latitude provided in the huge disparity between potential and actual lengths. The evidence presented here explains the difference between Laws' (1970) and Parker's (1979) length asymptotes.

These findings should be extrapolated cautiously beyond East Africa, particularly as Elder (1970) was moved to write his paper on subjective but consistent hunters' reports that elephants in Botswana were different to those in East Africa. Parker (1979) subjectively recognized four continental tusk types: Sahelian, Cyclotiform, South-western and East African. Bosman and Hall-Martin (1986) noted that elephants from different parts of Africa varied in body size, tusk form and length and ear shape. Raubenheimer et al. (1989) also asserted that the size and qualities of tusks from different parts of Africa varied, but only documented dissimilarity between Namibian (Parker's South-western type) and the Kruger NP ivory (Parker's East African type).

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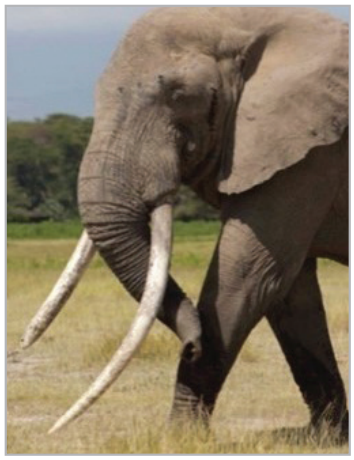
Data availability

All the raw data from the five elephant clans cited in this paper are available at:
http://ufdc.ufl.edu/AA00013409/0007

(a)

(b)



(c)

(d)

(e)

Figure 17. Photos of the Amboseli male elephant 'Tolstoy' at five points in his life to illustrate tusk recovery in length after major transverse breaks.
(a, b, c and d) © Joyce Poole/Amboseli Trust for Elephants; (e) © Federico Veronesi)

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African elephant reintegration from captivity to wild living: quantifying the detailed behavioural changes

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Abstract

There is increasing evidence of compromised welfare for captive African savannah elephants managed in confined spaces. With the trend for zoos and captive facilities to close due to public pressure, reflecting ethical concerns, and their limited capacity to manage 'difficult' behaviours, elephants will continue to require rehabilitation into free-ranging areas or living in the wild. During reintegration from captivity into a free-roaming system, management methods need to be carefully considered to ensure the individual's welfare. Elephants have a sophisticated social life and exhibit complex body language, employing a multitude of behavioural signals and gestures to demonstrate their needs or feelings. These detailed signals could be valuable when assessing the welfare status of elephants as any large deviation in behaviour could indicate changes in elephant wellbeing. In this study, a group of African elephants (*Loxodonta africana*) were monitored as they transitioned from captivity to a free-roaming system. To track the impact of reintegration on elephant welfare, we recorded frequencies of behaviours categorized as Ambivalent, Assessing, Frustrated, and Social, and of specific behaviours within each category, across four phases of reintegration into the wild (Stables, Boma, Release and Free). Significant differences in rates between reintegration phases were observed for several categories of behaviour and specific behaviours. Decreased frequencies of Frustrated behaviours and an increase in social behaviours when the elephants were Free were potentially indicative of improved welfare in wild settings. We conclude that monitoring of behaviours is important when assessing elephant welfare and to establish the success of reintegration operations.

Résumé

De plus en plus d'éléments tendent à montrer que le bien-être des éléphants vivant en captivité dans des espaces confinés est compromis. La tendance étant à la fermeture de ces installations — du fait de la pression du public qui manifeste des préoccupations éthiques et en raison des capacités limitées dont elles disposent pour gérer les comportements « difficiles » — les éléphants qui y résident continueront de devoir être réintroduits dans des zones de liberté ou en pleine nature. Les méthodes de gestion de la conservation doivent être soigneusement étudiées afin d'assurer le bien-être des animaux durant le processus de remise en liberté. Les éléphants ont une vie sociale sophistiquée et ils emploient un langage corporel complexe, fait d'une multitude de signaux comportementaux et de gestes leur permettant d'exprimer leurs besoins ou leurs ressentis. Ces signaux élaborés peuvent s'avérer précieux dans l'évaluation de leur niveau de bien-être, tout écart important de comportement indiquant potentiellement des variations dans leur équilibre. Dans cette étude, un groupe d'éléphants d'Afrique (*Loxodonta africana*) a été placé sous surveillance lors de sa remise en liberté après captivité. Afin d'évaluer l'impact de la réintégration sur le bien-être des éléphants, nous avons enregistré des fréquences de comportements, répertoriées dans les catégories suivantes : « ambivalent », « en

recherche de repères », « nerveux » et « sociable », ainsi que les comportements spécifiques au sein de chaque catégorie, sur quatre étapes de réintroduction dans la vie sauvage : « en étable », « en boma » (abri temporaire), « remis en liberté », « libre ». Des différences significatives de taux ont été relevées entre les différentes phases de réintégration pour plusieurs catégories de comportements et de comportements spécifiques. Une baisse de fréquence des comportements « nerveux » ainsi qu'une hausse des comportements « sociables », relevées lorsque les éléphants se retrouvaient « libres », indiquent potentiellement une amélioration du bien-être de ces animaux dans un contexte sauvage. Nous en tirons les conclusions selon lesquelles la surveillance des comportements est importante lors de l'évaluation du bien-être des éléphants, et une observation minutieuse des comportements devrait être mise en place pour des opérations de réintégration réussies.

Introduction

Elephant reintegration is an increasingly relevant concern among animal welfare and conservation organizations, tourists, and tour operators (Doyle 2017; Bansiddhi et al. 2018). Elephant reintegration (or rewilding) refers to the process of facilitating a transition from captive to free roaming, defined as occupancy of an area that is large enough to allow for natural home range size, foraging possibilities, and social interactions with other elephants within a representative age and sex structure (Baker and Winkler 2020). During reintegration from captivity into a free-roaming system, conservation management methods need to be carefully considered to ensure the animals' welfare. Elephants, have a sophisticated social life and exhibit complex body language, employing a multitude of behavioural signals and gestures to demonstrate their needs or feelings. These detailed signals could be valuable when assessing the welfare status of elephants as any large deviation in behaviour could indicate changes in elephant wellbeing.

Although some scientists have questioned the ability of captive elephants to adapt to unfamiliar environments (Doyle 2017; Bansiddhi et al. 2018), numerous successful elephant reintegration operations have been reported in recent years (see for example Evans et al. 2013a, 2013b). This is encouraging since there is increasing evidence of compromised welfare of African elephants managed in captivity (Pretorius et al. 2023). With the trend for these facilities to close due to public pressure in response to ethical concerns and their limited capacity to manage 'difficult' behaviours, elephants will continue to require rehabilitation and reintegration into the wild (Rees 2021). However, fenced reserves that receive captive elephants are not always equipped to facilitate complete reintegration into free-roaming areas due to lack of space and adequate vegetation to allow the elephants to sustain themselves. To address this problem, some partially reintegrated elephants are subsequently translocated to another, larger reserve, sometimes in another province, where they can be fully integrated into a wilder system. The success of reintegration, especially when individuals are translocated to a novel environment (Goldenberg et al. 2022), depends on the behavioural flexibility of the species (Roos et al. 2024). Learning ability and behavioural plasticity are positively associated with animal brain size (Sol and Lefebvre 2000). Elephants have large brains and are recognized as being intelligent, self-aware, and socially complex (Mellor 2019). The combination of these qualities suggests that elephants exhibit unusual potential for successful release and rehabilitation into a novel and natural system.

Inevitably, elephants in both captive (Morgan and Tromborg 2007) and wild environments (Szott et al. 2019; Garai et al. 2022) will experience stressors, though the cause and duration (acute or chronic) will differ (Stead 2000). In more natural settings, elephants regularly face a variety of natural stressors associated with finding fodder and water, avoiding predators, disease, injury, and interacting with other elephants (Stead 2000). In captive settings, stressors are related to restricted freedom of choice and lack of opportunity for avoidance of, or flight from discomforts in their environment (Morgan and Tromborg 2007). The consequences of such chronic stress are manifested as increased abnormal behaviour (Carlstead and Brown 2005), increased vigilance behaviours (Carlstead et al. 1993), reduced behavioural complexity (Rutherford et al. 2004) and increased aggression (Bartolomucci et al. 2004).

Various methods have been developed to evaluate animal welfare (Jordan 2005; Boissy et al. 2007). One

such method assesses whether or not the basic welfare needs of an animal are being met according to the 'Five Domains Model' (i.e. nutrition, environment, health, behaviour, and mental state) (Mellor 2017). This approach acts as an effective baseline but is open to interpretation. Dawkins (2008) reports behavioural and physiological abnormalities in apparently healthy animals and suggests that these factors should also be included in welfare assessments. Stressors can lead to repetitive self-directed behaviours (SDBs; Manning et al. 2022) or stereotypic behaviours. These can be considered a form of displacement activity, with no apparent function, and as such are valuable indicators of discomfort (Whitehouse et al. 2022). They are linked to stress and anxiety in primates such as chimpanzees and baboons and have been reported across a range of other species including rats and domestic chickens (Troisi 1999). SDBs and are a potential but still infrequently utilised behavioural marker in elephants, and could include behaviours such as 'brushing face', 'touching face', and 'touching mouth', which are considered useful welfare indicators (Mason and Veasey 2010; Manning et al. 2022). For example, Manning et al. (2023) report decreased frequencies of self-directed touching in captive elephants when tourism numbers declined during the Covid-19 pandemic (Manning et al. 2023). Studies of several successful elephant reintegration operations evaluate the health of elephants (dung, body condition), general behaviour (activity budget), ability to form social bonds, movement patterns, breeding success, and their interaction with surrounding human communities (Evans et al. 2013a, 2013b; Perera et al. 2018). However, despite the recognition of the importance of behaviour, few studies of such conservation management interventions monitor the frequencies of different behaviours (Veasey 2006).

Elephants naturally display a wide range of behaviours in different contexts, under both stressed and unstressed conditions (Poole and Granli 2011). Specific behaviours can act as an indication of an elephant's likely response to stimuli (Poole and Granli 2011). Similar to Garai et al. (2022), we looked at a range of behaviours, grouped into four categories: Social (affection and reassurance), Ambivalent, Frustrated, and Assessing. In a natural system, elephants exhibit social behaviour in the form of play, advertisement or attraction, reassurance, protection, and affection (Poole 2011). Social behaviours considered in this study, included only those that involve interactions with another elephant to demonstrate affection or provide reassurance. Ambivalent behaviours express uncertainty and indecision (Poole and Granli 2011). Frustrated behaviours are associated with displeasure and may occur when key stimuli are absent or in response to physical (tethering) or social barriers (Broom 1985). Assessing behaviours involve paying attention to the environment by smelling, observing, and listening (Poole and Granli 2011). However, behavioural expression is not uniform across individuals (Yasui et al. 2013) and varies by age, sex (Garai et al. 2022, Poole and Granli 2011), personality (Poole 2011) and past experience (Morgan and Tromborg 2007).

The objective of this study was to determine how the transition from captive to wilder living altered the expression of specific behaviours of a group of African elephants. Behaviours that fell within the four behavioural categories (Ambivalent, Assessing, Frustrated, and Social) were assessed to determine changes in their frequencies. We hypothesized that the frequency and array of specific behaviours and behavioural categories would differ across the four phases of transition to wild living, namely Stables, Boma (an enclosure of a specified size), Release, and Free, and that age and sex may further alter elephants' behavioural responses. More specifically, we predicted that reintegration into a wilder environment would lead to a decrease in behaviours associated with Frustration and Ambivalence due to less direct human intervention, less restriction, and more freedom of choice. Furthermore, we predicted an increase in behaviours associated with Assessment as elephants were exposed to environmental stimuli and began to rely on their own senses without human intervention. Additionally, we hypothesized an increase in Social (affective and reassuring) behaviour as interaction forms a crucial part of the daily lives of free-ranging elephants. We propose that such changes would be indicative of improved welfare.

Methodology

Study site

The study was carried out in the Shambala Private Game Reserve (SPGR) located in the Waterberg

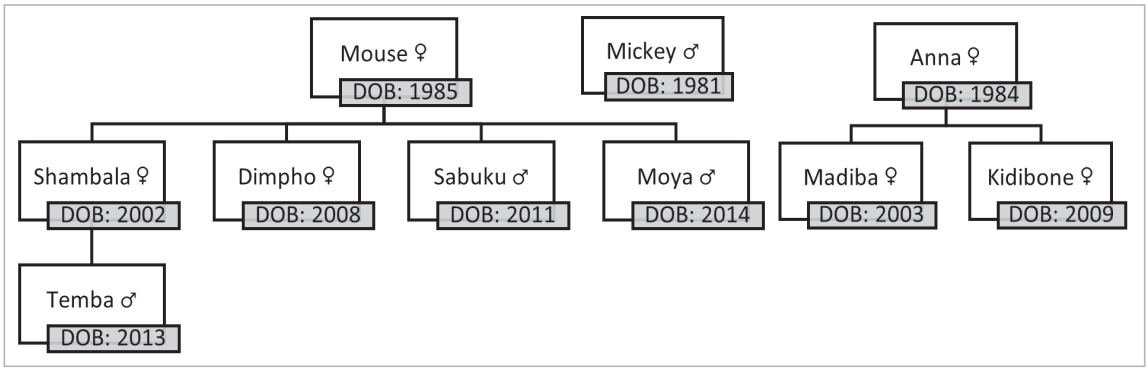

Figure 1. Family tree of study animals on SPGR, showing the date of birth (DOB) and the sex of the elephants.
Anna, Mickey and Mouse came from Sondalani in Zimbabwe and were previously used for riding safaris, Dimpho was previously used for riding safaris within SPGR, but no longer is. Madiba, Moya, Sabuka and Temba were housed in a captive facility at SPGR and now have access to the entire 10,000 ha free release section of SPGR.

Mountain region (Limpopo Province) of South Africa. This 10,000ha fenced reserve falls within the central bushveld bioregion of the savannah biome (Rutherford et al. 2006) and covers most of the elevated plateau west of the slope from the Magaliesberg in the south to the Southpansberg in the north.

The reserve hosts a variety of herbivores such as steenbok (*Raphicerus campestris*), impala (*Aepyceros melampus*), blue wildebeest (*Connochaetes taurinus*), zebra (*Equus quagga*), giraffe (*Giraffa camelopardalis*) and white rhinoceros (*Ceratotherium simum*). The predator species present include spotted hyena (*Crocuta crocuta*), lion (*Panthera leo*) and leopard (*Panthera pardus*).

Study animals

SPGR currently hosts 14 elephants, ten of which were previously kept in captivity (Fig. 1). In 2002, SPGR acquired three of these study elephants (one male, Micky, and two females, Mouse and Anna) from a captive elephant facility in Zimbabwe. These elephants were originally captured as calves following culling operations that took place in Gonarezhou National Park (NP), Zimbabwe, in the 1980s. Once at SPGR, these elephants and later some of their offspring (Shambala and Madiba) were used to conduct Elephant Back Safaris, once a day, for 12 years (2004–2016). The rest of the offspring, though not ridden, were held in the same captive conditions. Elephant Back Safaris operated for approximately one hour each morning, and then the elephant handlers guided the elephants out into the reserve to forage for the remaining daylight hours before returning them to their stables at night. The stables consisted of secure holding enclosures designed to separate the elephants from each other and were locked at night. The calves (Temba and Moya) were not separated from their mothers (respectively, Shambala and Mouse) at night. In 2019, two additional calves were born at SPGR (one to Mouse, and the other to Shambala) and in 2022 two subadult bulls were translocated to SPGR. These four individuals were not part of this study as they were not subjected to the reintegration process.

Captivity does not provide a sufficient environment for the social- and space requirements of an elephant. To ensure this group of elephants was afforded this opportunity, a reintegration programme was designed and managed by Brett Mitchell, an elephant expert in the reintegration of captive elephants. He was assisted by experienced elephant handlers who had worked with the elephants for many years. The reintegration programme was designed to ensure the elephants attained full autonomy by reintegrating them into a larger natural system, thereby improving their well-being. The duration of each reintegration phase varied and was adapted to the elephants' requirements, based on the herd's behaviour and speed of adaptation to the new conditions. As each phase was entered, the duration was determined by the elephants' behaviour and adaption to that phase. As soon as the transition was deemed successful, the next phase was started. Table 1 summarises the duration and the description of each of the phases of reintegration.

Table 1. Breakdown of the duration and description of different phases of reintegration of SPGR elephants from captive to wilder living.

Phase	Date	Description
Stables	5–16 Mar 2016	The elephants were not ridden; however, they were managed by the handlers during the day and secured in individual stables at night. Some elephants were tethered during certain times of the day (usually when the handlers were cleaning the stables areas).
Boma	17 Mar–20 May 2016	At night, the elephants roamed freely in an electric fenced 1.7 ha (4.2 acres) open-air boma. During the day, they were allowed to roam freely from the boma on the reserve up to a distance of 5 km (under the supervision of the handlers). The elephants were returned to the boma and closed in at night.
Release	21 May–28 Jun 2016	In the penultimate stage, the boma gate was left open permanently and the elephants were allowed to roam freely on the reserve without any handler supervision. The elephants had complete autonomy within the 10,000 ha fenced reserve. Management interventions were carried out during this phase: Collar checks and removal of a collar that was on Mouse, and, where necessary, redirection by the handlers of unwanted behaviours towards infrastructure and vehicles, to prevent any human–elephant conflict.
Free	22 Jun–10 Jul 2019 28 Jan–15 Feb 2020	The elephants were roaming free for more than three years on the 10,000-hectare fenced reserve. Management interventions were carried out during this phase: Quarterly GnRH (Gonadotropin Releasing Hormone) darting of the adult bull (Micky), and, where necessary, redirection by the handlers of unwanted behaviours towards infrastructure and vehicles, to prevent any human–elephant conflict.

Data collection

Behavioural data were collected over the entire reintegration process (Table 1). However, the duration of observation periods within each phase differed. Specifically, during the Boma, Release, and Free phase, observation periods were adapted in response difficulties associated with restricted access to the elephants. Observations in the first three phases took place continually between 5 March and 28 June 2016. Observations in the Free phase consisted of two data collection periods (22/06/2019–10/07/2019 and 28/01/2020–15/02/2020), when the elephants had been roaming freely on the 10,000 ha reserve for more than three years.

During each phase of the study, multiple video recordings (focal samples of approximately 10 minutes), were taken of each elephant and processed upon completion of all fieldwork (Table 2). Panasonic and Canon cameras were used to film the elephants during the course of this study. When filming the elephants during the Stables and Boma phases, the researcher maintained a distance of 20 m from the elephant that was being filmed. To ensure the safety of the researcher, an elephant handler was always present. Due to the arrangement of the Stable and Boma systems it was not possible to film the elephants from greater distances. During the Release and Free phases, the elephants were filmed from a game viewing vehicle which they were accustomed to. The vehicle was parked at least 30 m from the elephants to minimize disturbance. Filming during all phases was initiated only when the elephants seemed settled and were not directing attention to the vehicle or the researcher. We aimed to collect an even spread of all individuals during each phase of reintegration; however, due to restrictions imposed by the reserve's road network and topography, this was not always possible during the Release and Free phases. To account for pseudoreplication, we did not process more than one focal sample of each elephant from the same day. The focal samples processed were randomly selected, and

Table 2. The date of birth, sex, age and number of focal samples analysed for each elephant during each phase of the reintegration process. The average gap (number of days) between focal samples is also shown. A = adult; S = subadult; J = juvenile.

Name	Date of birth	Sex	Age	Stables		Boma		Release		Free	
				No.	Gap	No.	Gap	No.	Gap	No.	Gap
Anna	1984	F	A	5	1	5	2	5	9	7	3
Dimpho	2008	F	S	5	2	5	2	5	12	3	5
Kidibone	2009	F	J	6	2	4	3	4	8	4	7
Madiba	2003	F	S	5	2	6	3	4	3	4	4
Mickey	1981	M	A	4	1	6	4	5	8	7	5
Mouse	1984	F	A	5	2	5	3	5	8	4	2
Moya	2014	M	J	5	2	3	1	3	9	5	5
Sabuka	2011	M	J	5	2	5	3	5	8	6	5
Shambala	2002	F	S	5	2	4	3	4	10	2	5
Temba	2013	M	J	6	2	3	1	2	11	2	*
Total number of focal samples				**51**		**46**		**42**		**44**	

*One focal sample was taken in 2019 and one in 2020.

we only processed the samples if the elephants were fully visible. The focal samples within each phase were collected throughout the entire period allocated for the study of each of the reintegration phases. At the beginning of each focal sample, the elephant under observation was identified, with each elephant identification linked to date of birth, sex (male or female), and age (juvenile: 2–7 years, subadult: 8–20 years, or adult: >20 years) (Fig. 1).

Behavioural data processing

Prior to the study, an ethogram was compiled based on collected literature and consulted to record specific behavioural frequencies during each focal sample. Specific behaviours were contextualized prior to the study to form various behavioural categories (Table 3). The focal processing phase involved noting the number of occurrences of all specific behaviours exhibited by the observed elephant, continuously, throughout each sample. For analysis, data on the number of occurrences were transformed to show frequency of occurrence (number per minute). All focal recordings were retrospectively coded by a single researcher with considerable experience of observing elephant behaviour between October 2020 and October 2021. This approach eliminated discrepancies between multiple observers in the coding of the behaviour data and minimized any change in interpretation over time.

For the purposes of this study, selected specific behaviours were chosen for further analysis (Table 3). However, when the behavioural categories were analyzed, all behaviours that fell into the category were considered.

Statistical analysis

We used generalised linear mixed models (GLMMs) to identify relative changes in behavioural frequencies between the four stages of reintegration. The reintegration phase, plus the age and sex of individual elephants, were included as fixed effects in the model. We included the elephant identification as a random intercept since we expected that individual variation might influence behavioural responses to the reintegration process. GLMMs were run for each of the four behavioural categories (Ambivalent, Assessing, Frustrated, and Social) and a subset of the most frequently recorded specific behaviours. All behavioural data were found to violate the assumption of normality (Shapiro-Wilk, $\alpha = 0.05$) and therefore ideally a gamma distribution would have been used for continuous, positive, non-normal distributed data. However, given the limited sample size, a gamma distribution could not converge, and so a Gaussian distribution, which remains robust to non-normal data,

Table 3. Description of the behavioural categories into which the chosen specific behaviours were categorized (Garai et al. 2022; Elephant Voices 2021, 2023). (The authors recognize that elephants in captive facilities form a close bond with their handlers, and this was factored into the rehabilitation programme on an individual-by-individual basis. For instance, the handlers themselves became monitors during the Release and Free phases, however, this was not part of the study design, nor scientifically measured. We understand that each elephant's needs are unique, again this was factored into the reintegration programme).

Behavioural categories	Selected detailed behaviours	Description
Ambivalent: Behaviours that seem inappropriate or irrelevant, often caused by a direct stimulus.	Front foot swing	Lift the front foot slightly and swing back and forth.
	Touch mouth with trunk	Elephant touches its mouth with its own trunk tip.
	Trunk in own mouth	Elephant places the tip of its trunk in its own mouth.
	Trunk twist and twirl	The trunk is folded onto itself, resulting in a twisted trunk that unwinds in a fast action.
	Hanging trunk rotate left and right	Trunk hangs straight while the tip is flicked to the left and right.
	Brushing face	Tip of trunk brushes over face (this is a fast action).
	Touching face	Touch any part of the face, including the ears with the tip of the trunk. Not a fast action.
	Swing trunk through the legs or to the foot	Trunk kept straight while being swung through front feet or touches one of the front feet.
Assessing: Gestures displayed by elephants to gain sensory information about their surroundings.	Smelling down	Trunk held in a relaxed position while the tip of the trunk is curled under and points in the direction of an object of interest.
	Lift trunk to smell	Lifts and holds the trunk up in an S-shape.
	Sudden pause to listen	Sudden, short pause during any activity to listen.
Frustrated: A range of reactions to unpleasant stimuli	Head shake	An abrupt shaking of the head.
	Throwing item	Throwing an object into the air or in the direction of the cause of frustration.
	Trunk swing/ swish	The trunk is swished/swung forward in a fast action.
Social: Behaviours displayed when elephants interact with one another. The behaviour was only noted if the focal elephant was the instigator of the behaviour.	Trunk	Touching another elephant's head, trunk, or body with its trunk.
	Trunk to mouth	Trunk to another elephant's mouth.
	Trunk on back/ head	Trunk on another elephant's back/reach over the head.
	Rub with head/ body	Rubbing against another elephant with its head/body.
	Tusk to body	The elephant gently nudges the other elephant with its tusk.
	Trunk to genitals	The elephant holds its trunk towards the genital area of the other elephant.
	Tusk to head	The elephant gently nudges the other elephant with its tusk.
	Push with head	The elephant pushes the other elephant with its head.
	Push with body	The elephant pushes the other elephant with its body.

was used throughout. Tukey's honest significant test ($\alpha = 0.05$) was used to identify significant differences between the release phases, age, and sex levels while calculating multiple comparisons. All analyses were carried out in R version 4.1.2 using the packages glmmTMB (1.1.7) and multcomp (1.4-18). None of the outliers that were identified and represented in the Fig. 2 were removed from the dataset or excluded from the statistical analysis, as these data points represent the natural variability in elephant behaviour.

Results

We observed significantly higher frequencies of Frustrated behaviour during the Stables phase compared to the Boma ($p < 0.001$) and Release phases ($p = 0.019$) (Fig. 2c; Table 4; Table A1). During the Free and Stables phases, the elephants showed significantly higher frequencies of Social behaviour compared to the Boma and Release phases (Free vs. Boma: $p = 0.006$; Stables vs. Boma: $p = 0.017$; Free vs. Release: $p = 0.007$; Stables vs. Release: $p = 0.019$) (Fig. 2d; Table 4; Table A1).

Subadult elephants showed a significantly higher frequency of Frustrated behaviour than adults ($p = 0.037$). No significant differences were reported between males and females when the frequencies of Ambivalent, Assessing, Frustrated, and Social behaviours were compared.

There were significant differences among the frequencies of specific behaviours in all four behavioural categories. Within the Ambivalent category, the 'Swing trunk through the legs or to the foot' was significantly more frequent during the Stables compared to the Release phase ($p = 0.031$) (Fig. 3A). The 'Touching face' behaviour was more common during the Free compared to the Release phase ($p = 0.005$) (Fig. 3A). Within the Assessing behavioural category, the frequency of 'Sudden pause to listen' occurred at significantly higher rates during the Free compared to the Stables phase ($p = 0.023$) (Fig. 3B). Within the Frustrated behavioural category, the elephants also showed significantly higher rates of 'Head shake' in the Free than during the Boma phase ($p = 0.017$) (Fig. 3C). 'Trunk swing/swish' occurred at significantly higher rates during the Stables compared to the Boma phase ($p = 0.032$) (Fig. 3C). Furthermore, 'Throwing item' only occurred during the Stables phase, and never while in the Boma ($p = 0.024$), Release ($p = 0.026$), or Free ($p = 0.029$) phases (Fig. 3C). Within the Social behavioural category, the elephants showed significantly higher frequencies of 'Trunk to another elephant's mouth' during the Stables phase compared to the Boma ($p = 0.011$), Release ($p = 0.001$), and Free ($p = 0.033$) phases (Fig. 3D). Significantly higher frequencies of 'Push with head' were observed during the Free compared to the Boma ($p = 0.01$) and Release ($p = 0.029$) phases (Fig. 3D) (Table 5; Table A2).

Table 4. Significant differences in frequencies of behavioural categories among phases of the reintegration operation.

Behavioural category	Significant differences in frequency	p-value
Frustrated	Stables > Boma	<0.001
	Stables > Release	0.019
Social	Free > Boma	0.006
	Stables > Boma	0.017
	Free > Release	0.007
	Stables > Release	0.019

Discussion

Elephants communicate via a rich and complex array of behaviours (Poole and Granli 2011). Studying the occurrence and patterns of usage of specific behaviours in different contexts can improve our understanding of what these different gestures signal or express about the internal emotions or feelings of individuals. Such knowledge increases our awareness of their wellbeing (Mason and Veasey 2010), allowing us to intervene when necessary.

This study assessed whether the different phases (Stables, Boma, Release, and Free) of reintegration (transition from captive to wild living) affected the expression of specific behaviours that fall within four behavioural categories (Ambivalent, Assessing, Frustrated, and Social). We hypothesized that changes in behavioural frequencies and the array thereof would occur during the transition from a captive to a free-roaming environment, as well as between different age and sex groups. Specifically, it was hypothesized that the frequencies of Frustrated and Ambivalent behaviours would decrease and Assessing and Social

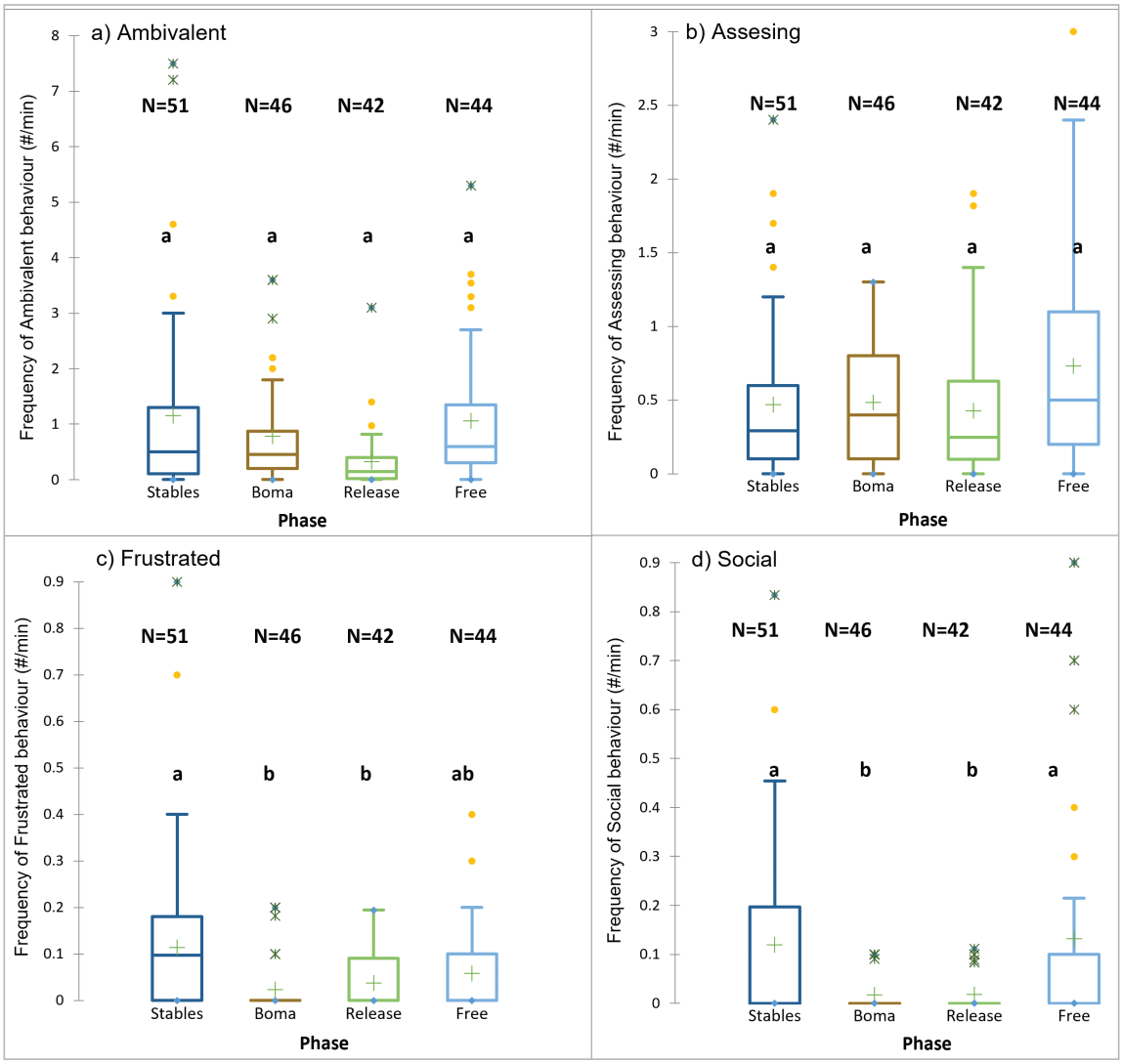

Figure 2. The frequency (no./min) of behaviours in a) Ambivalent, b) Assessing, c) Frustrated, and d) Social behavioural categories expressed by the 10 elephants during the different phases of the reintegration process. N = number of focal samples. The crosses represent means, whereas the central horizontal bars show medians. The first and third quartiles are the lower and upper limits of the box, respectively. The length of the whiskers indicates 1.5 times the interquartile range. The points above the upper limits of the whiskers are outliers. The yellow circles represent outliers >1.5 interquartile ranges from the median, and the dark green stars represent outliers >3 interquartile ranges from the median. Minimum values were zero in all cases and maximum values corresponded to the uppermost outlier. The hashtag symbol (#) indicates no significant difference between different integration phases. Asterisks indicate significant differences as follows: *p < 0.05; **p < 0.01; ***p < 0.001.

behaviours would increase in a wilder environment (Free phase). Our investigation showed significant differences among the phases of reintegration and ages for some behavioural categories and detailed behaviours.

The elephants, particularly juveniles, exhibited significantly higher rates of Frustrated behaviours during the confinement of the Stables phase compared to Boma and Release phases, suggesting that they were stressed by the captive environment. The increased levels of Frustrated behaviours during the Stables phase could be attributed to restricted movement and choice of social companions, as well as the lack of ability to escape pressure (Wiepkema and Koolhaas 1993; Morgan and Tromborg 2007). During the Stables phase, some elephants exhibited

Table 5. Significant differences in frequencies of specific behaviours among phases of the reintegration operation.

Behavioural category	Specific behaviour	Significant differences in frequency	p-values
Ambivalent	Swing trunk through the legs or to the foot	Stables > Release	0.031
	Touching face	Free > Release	0.005
Assessing	Sudden pause to listen	Free > Stables	0.023
Frustrated	Head shake	Free > Boma	0.017
	Trunk swing/swish	Stables > Boma	0.032
	Throwing item	Only occurred in the Stables phase	≈0.03
Social	Trunk to another elephant's mouth	Stables > Boma	0.011
		Stables > Release	0.001
		Stables > Free	0.033
	Push with head	Free > Boma	0.01
		Free > Release	0.029

Ambivalent behaviours up to eight times per minute. These frequencies were high compared to other phases and are higher than those reported for wild elephants (2–6 times per 10 minutes) (Garai et al. 2022). Furthermore, the higher frequency of Frustrated behaviour shown by juveniles and subadults suggests that older elephants may possess more developed skills in regulating their emotions, or be better acclimatized to captivity after living for many years in confinement.

An important factor to consider is the source of uncertainty and stress during each phase. When confined to their stables, the needs to search for food and water and to avoid predators were eliminated. This suggests that uncertainty was most likely related to the elephants' inability to escape other stressors (Morgan and Tromborg 2007), such as boredom, physical confinement that prevented elephants from interacting with or moving away from other group members, and restricted access to food and water.

Interestingly, elephants showed similar frequencies of Assessing behaviour during the Stables, Boma, and Release phases. A large, but insignificant, increase was observed during the Free phase, within which some elephants exhibited Assessing behaviours up to three times per minute. This increase could be attributed to increased exposure to natural stimuli and aligns with what is expected for wild elephants (Garai et al. 2022). When observations were made during the Free phase, the elephants had been roaming independently for more than three years, so it is probable that they had begun to recognize the need for assessing their environment as they were no longer guided and protected by the handlers. In line with this, we also expected the frequency of Assessing behaviours to increase during the Release phase, but this was not the case. This could be because, initially after release, elephants spent more time in familiar areas and only began to roam more widely across the reserve in the Free phase.

Social behaviours were significantly more frequent and diverse in the Stables and Free phases compared to the Boma and Release phases. The lower frequencies observed during the Boma and Release phases could be attributed to the novelty of the environment, elephants' increased drive to investigate, and the freedom to explore away from the rest of the group. The Boma phase was the beginning of their life as a herd in the wild. However, the presence of their handlers may have altered the behaviour of the elephants, and they might have found familiarity or reassurance by being near the handlers. Another explanation could be that, during the Stables phase, the elephants were kept adjacent to each other in small enclosures, thus increasing the opportunity for social interactions.

The results showed differences between the array and frequencies of specific behaviours expressed by the elephants during the different phases of reintegration. This was expected as the elephants were exposed to different levels of freedom and environmental stimuli during the four phases. One Ambivalent behaviour that stood out was 'Swing trunk though legs or to foot', with some elephants exhibiting this behaviour up to 5–6 times per minute during the Stables phase, suggesting that repeated self-directed behaviours (SDBs) can represent a form of stereotypic behaviour

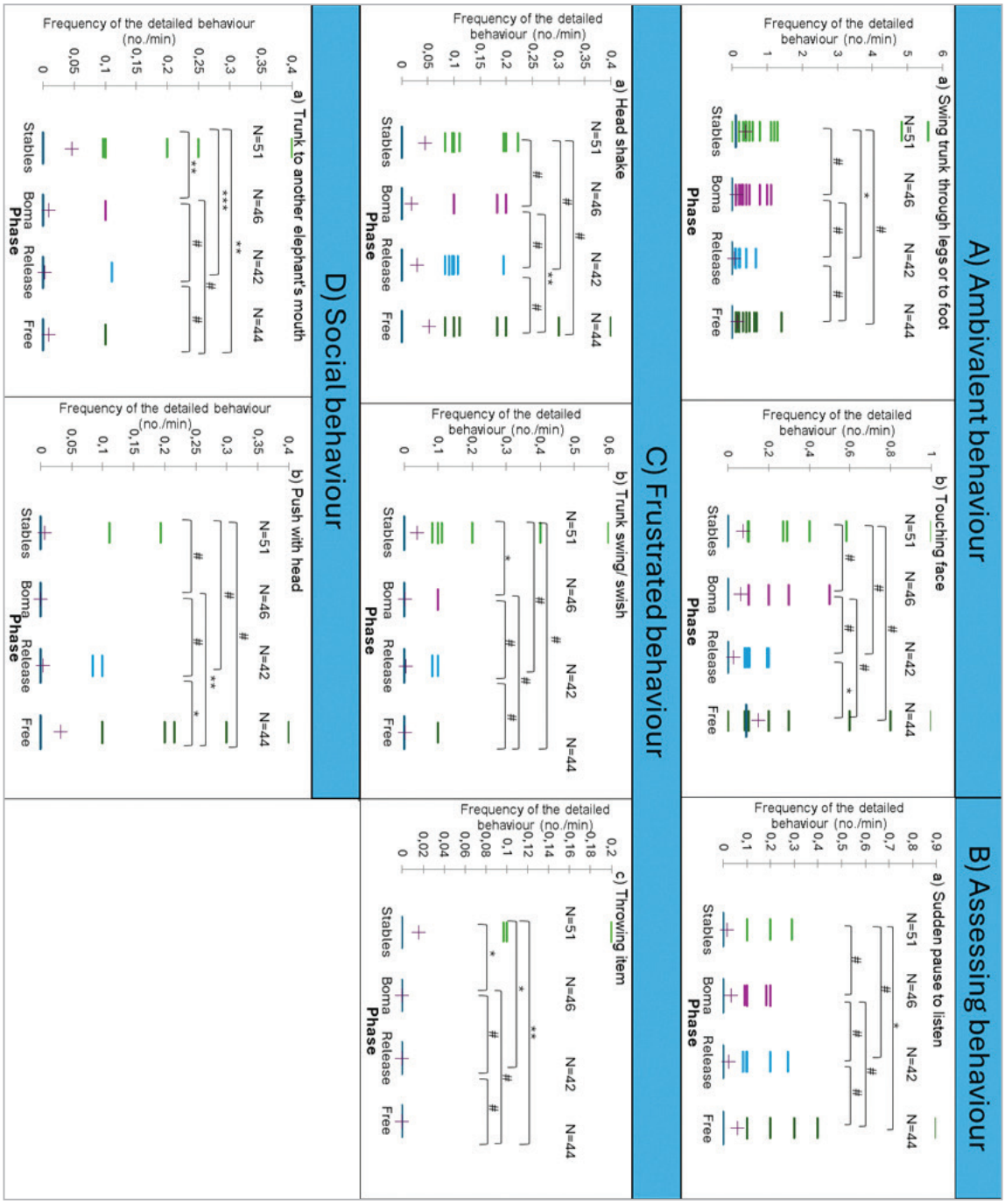

Figure 3. Strip plot showing the means (cross) and medians (blue line) of the most frequently recorded detailed behaviours within the categories A) Ambivalent, B) Assessing, C) Frustrated, and D) Social during the four reintegration phases. N = number of focal samples. The hashtag symbol (#) indicates no significant difference between different integration phases. Asterisks indicate significant differences as follows: *p < 0.05; **p < 0.01; ***p < 0.001.

(Elzanowski and Sergiel 2006) with no obvious goal or function (Mason 1991).

The array of Frustrated behaviours also differed across the four phases. 'Throwing item' was only observed in the Stables phase. This behaviour can be interpreted as an escalation of the 'Trunk swish/swing' behaviour and may have been common in the Stables phase due to physical restrictions (tethering) experienced. 'Throwing item' can also act as a warning signal and can become dangerous in certain situations (Poole and Granli 2011). The significant increase in 'Sudden pause to listen' (freezing) during the Free compared to the Stables phase was encouraging, possibly indicating an increased engagement with the environment and an increasing occurrence of auditory or seismic communication among individuals (Langbauer et al. 1989). It was also to be expected that the increased access to novel areas and environmental stimuli would result in heightened levels of awareness. During the Stables phase, the adults were sometimes constrained (tethered) and interactions between adults and other group members included reassurance behaviours in the form of 'Trunk to another elephant's mouth' and 'Trunk to body' of conspecifics. This was not seen at such elevated levels in the Boma, Release, or Free phases, when individuals exhibited more physically affectionate social interaction behaviours like 'Push with the head' and 'Rub with head' (social rubbing).

In this study we observed higher levels of stress and uncertainty during the Stables phase in the form of increased reassurance behaviour amongst stablemates, as well as high frequencies of self-directed touching in the form of 'Swing trunk to leg or foot' behaviour. The behaviours indicating uncertainty were mostly observed when the elephants could not escape circumstances such as being tethered or confined to the Stables without the freedom to express natural movement. We would expect significantly greater disparities between captive and free phases when elephants are initially held in more restrictive captive environments. In cases where reintegration is not a feasible option, the next most appropriate system is a genuine sanctuary. Such a captive setting represents a considerable improvement on a stable system that separates bonded individuals and is designed to ensure that the elephants experience the highest standards of welfare and complete freedom to make decisions within their (restricted) environment. This can be achieved by the creation of either single or multiple areas that are large enough to allow bonded individuals or mother and offspring to have the freedom to choose where to sleep or with whom to associate. This would reduce stress-related behaviours during captivity.

Conclusions

The results of the study suggest that the frequency and array of specific behaviours and behavioural categories differed between different phases of reintegration, although not all differences were significant. The results showed decreased frequencies of Frustrated behaviours and an increase in Social behaviours when the elephants were Free, possibly indicative of improved welfare in wild settings.

Although additional research including longer observation periods, more reintegrated individuals, larger behavioural sample size, and direct comparisons with wild elephants on the same reserve would be required to draw more concrete conclusions, the preliminary results presented here suggest that reintegration is a vital management tool to improve the welfare of captive elephants.

It would also be important to determine the timing of different phases of the reintegration process to accommodate elephants from different captivity systems. For example, elephants subjected to very restricted forms of captivity or those being reintegrated into reserves in faraway locations may require longer periods of adjustment between phases.

We acknowledge that the captive system to which these study elephants were subjected may be viewed as a more conducive to their welfare and freedom of movement compared to more restrictive captive management systems. Nevertheless, our research underscores that even these relatively improved circumstances do not allow expression of the natural behaviours observed in fully wild elephants.

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Impact of severe drought on the age structure of a population of African savannah elephants

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Abstract

Hundreds of elephants died during a severe drought in Gonarezhou National Park (Gonarezhou) in south-east Zimbabwe during 1992. The following year, entire female herds comprising 670 female and juvenile elephants were captured and translocated elsewhere. Sex-specific von Bertalanffy growth functions for shoulder height against age for elephants culled in Gonarezhou a decade earlier allowed 667 elephants captured during 1993 to be aged based on shoulder height. The captured elephants provided a representative sample of the age and sex structure of the population one year after the drought. Immediately after the drought, the age structure was determined by deducting one year from each elephant's age at capture and compared with that of elephant herds culled in Gonarezhou during 1972–1987. Adult females formed a high proportion (45%) of the individuals in female herds immediately after the 1992 drought, implying that there was high mortality of non-adults during the drought. There were relatively few surviving individuals in the 0–4-year age class, suggesting that mortality was greatest amongst the youngest individuals. When non-adults of all ages were considered, there were fewer males than females amongst the drought survivors, suggesting that the males experienced greater mortality than the females. Significant mortality of weaned elephant calves during droughts is uncommon and the high mortality of non-adults in Gonarezhou during 1992 highlights the particular severity of the drought.

Résumé

Des centaines d'éléphants sont morts lors d'une grave sécheresse qui a touché en 1992 le parc national de Gonarezhou, au sud-est du Zimbabwe. L'année suivante, des hardes entières comprenant 670 femelles et juvéniles ont été capturées et transférées en d'autres lieux. La fonction de croissance de von Bertalanffy spécifique au sexe (permettant de calculer l'âge des éléphants selon la hauteur de leurs épaules) a rendu possible de déterminer l'âge de 667 de ces individus capturés, par rapport aux données de hauteur d'épaules obtenues sur des éléphants abattus une décennie plus tôt à Gonarezhou. Les individus transférés ont fourni un échantillon représentatif de la répartition des âges et des sexes dans la population un an après l'épisode de sécheresse. La détermination des âges directement après la sécheresse a été effectuée en déduisant une année à l'âge de chaque éléphant lors de sa capture, et en le comparant à celui des hardes abattues à Gonarezhou entre 1972 et 1987. Les femelles adultes représentaient une large proportion des individus (45 %) dans les hardes de femelles immédiatement après la sécheresse de 1992, laissant entendre un taux élevé de mortalité chez les juvéniles pendant cet épisode. Relativement peu de survivants ont été comptés dans la classe d'âge de 0 à 5 ans, ce qui indique une plus grande mortalité des individus les plus jeunes. L'étude des juvéniles de tous âges a révélé qu'un nombre inférieur de mâles se trouvaient parmi les survivants de la sécheresse, ce qui tend à signifier que les mâles ont subi une plus grande mortalité que les femelles. Lors d'une sécheresse, il n'est pas rare de voir mourir une partie importante des éléphanteaux sevrés, et le taux élevé de mortalité chez les juvéniles de Gonarezhou en 1993 témoigne de la sévérité de la sécheresse de 1992.

Introduction

The frequency, duration and intensity of droughts have increased in southern Africa since the late nineteenth century (Chiang et al. 2021) and vulnerability to drought is predicted to increase across Africa (Ahmadalipour et al. 2019). Drought-induced mortality can have major impacts on the numbers of African savannah elephant *Loxodonta africana*, with juveniles and older adults often disproportionately affected (Corfield 1973; Dunham 1988; Dudley et al. 2001; Lee et al. 2022). Commonly, elephants that die during droughts are in poor condition and die close to water, implying that these animals die from dehydration, rather than starvation, or conditions associated with malnutrition.

Drought-related mortality can impact the age-sex structure of a population, with periods of high juvenile mortality causing a pronounced depression in the age profile (Lee et al. 2022). Even during relatively dry years, but not necessarily drought, elephant calf mortality may be elevated. Environmental factors also influence elephant conception rates. A further consequence of these impacts on mortality and conception may be the appearance of population pulses, with brief, exceptional rates of population increase if females become synchronized in their conceptions and births (Lee et al. 2011).

During 1992, there was a severe drought in south-eastern Zimbabwe and hundreds of elephants died in Gonarezhou National Park (henceforth Gonarezhou) (Leggett 1994). A year after the drought Wildlife Management Services (WMS) captured entire female herds in the park and these animals were translocated elsewhere (Coetsee 1996). Female herds are elephant herds that contain adult females and immatures, both females and males. These herds may be accompanied by adult males, which are assumed to be temporary visitors. The relatedness of the adult females and immatures in a female herd is unknown, but it is assumed that the herd is a family unit sensu Moss et al. (2011). The capture of numerous elephants in entire female herds during 1993 provided a representative sample of the population of females and immature males, from which the immediate post-drought sex and age structure of the female herds could be estimated. This study uses these estimates to demonstrate the severe impact of the 1992 drought on the population structure, as the first step in a study of the long-term consequences of the drought on the dynamics of the Gonarezhou elephant population.

Methodology

Study area

Gonarezhou NP lies <600 m above sea level and covers ~5,000 km^2 in the south-east lowveld of Zimbabwe, along the border with Mozambique. The region experiences a hot wet season during November–March, a cool dry season during April–July, and a hot dry season during August–October. Mean maximum temperatures exceed 30°C during all months except June and July. The area is noted for low, but very variable, annual rainfall, which declines slightly towards the south. Based on Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) records (Funk et al. 2015), annual rainfall over the entire park averages 486 mm (July–June rainfall year, n = 42 years; coefficient of variation 29%). The 1992 drought followed a year when annual rainfall was 157 mm (32% of the mean) (Fig. 1). The period between the 1983 and 1986 elephant culls (see below) included two successive years of low rainfall during 1982/83 and 1983/84, when rainfall was 60% and 79% of the long-term mean, respectively. Dry season precipitation in the form of drizzle (*guti*) is common and averaged 21 mm during June–September (1981–2023), but with a significant decline since 1980.

The CHIRPS records do not fully capture the impact of the 1992 drought. During March 1992, a lowveld resident (T. Balance, quoted by Tayler 1992) wrote: "Zimbabwe has experienced the worst drought in living memory. In the south-east lowveld, the season's rainfall, which should have started in November, has ranged from 20 mm to 100 mm. This, in conjunction with high temperatures and endless cloudless days, has meant that there has been no summer growth. In addition, there is very limited browse, and in some areas, the trees have not flushed at all. There is therefore a total lack of food." The rain gauge on Malilangwe Wildlife Reserve, which adjoins the northern boundary of Gonarezhou, recorded 72 mm during the 1991/92 rainfall year, which contrasts with the annual mean of 563 mm (n = 73 years; coefficient of variation 34%) (B. Clegg pers. comm. 23 May 2024).

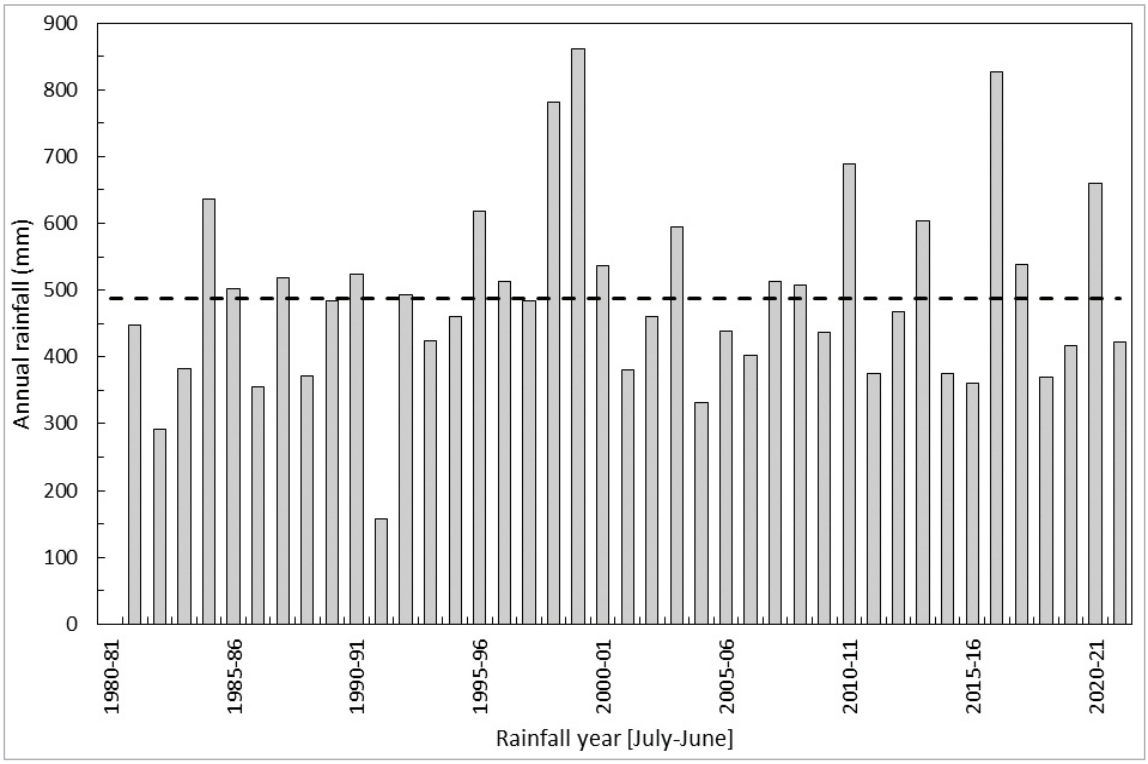


Figure 1. Temporal trend in annual rainfall (July–June) over Gonarezhou NP since 1981. The dashed line indicates the mean annual rainfall. Source: Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) daily rainfall data downloaded from https://climateserv.servirglobal.net/

The Save, Runde and Mwenezi Rivers dominate Gonarezhou. The Runde and Save Rivers are perennial and dry-season flow in the Mwenezi River is controlled by the release of water from the Manyuchi Dam, ~130 km to the northwest. Other rivers flow only seasonally. The vegetation has been significantly impacted by elephants, drought and fire (Cunliffe et al. 2012; O'Connor et al. 2024). The major vegetation types are *Colophospermum mopane* shrubland or woodland on heavier soils; *Guibourtia conjugata* dominated woodland on sands; mixed woodland on granophyre; and riverine woodland (Farrell 1968; Cunliffe et al. 2012). As well as elephants, the Park supports hippopotami, buffalos, zebras and a range of antelope species and large predators (Dunham 2012; Groom et al. 2014).

During the 1970s, >2500 elephants were culled in Gonarezhou in response to concerns about the impact of elephants on the vegetation and another >4,000 were culled in total during 1983, 1986 and 1987 in response to continuing concerns (Booth 1989). Aerial sample surveys during the 1980s gave population estimates as shown in Table 1.

During culls, entire breeding female herds were sampled and so it is likely that these herds were representative of the population as a whole, excluding adult males, and therefore also that their removal had no significant effect on the age-sex structure of the remaining breeding population.

Culls were usually conducted during the middle of the dry season, before the onset of any drought-related mortality, as this normally occurs during the late dry season. Thus, for example, the age structure of the elephant population culled in 1983 cull might have been impacted by rainfall during the 1981/82 climate year (and/or preceding years), but was unlikely to have been affected by rainfall during the 1982/83 climate year, which ended shortly before the cull.

A year before the 1992 drought, the number of elephants in Gonarezhou and the corresponding 95% confidence interval (CI) were estimated using a transect sample survey as 6,306 ± 39% (Jones 1991). A sample survey a year after the drought used a

non-stratified design and produced an even less precise population estimate, namely 5,223 ± 55% (Bowler 1995).

During 1992, the fences bordering sections of the park boundary were not electrified and hence were ineffective at preventing the movement of elephants in or out of the park. However, there is no evidence that significant numbers of elephants moved in or out of the park as a consequence of the drought. An unrecorded number of elephants were culled by management staff during 1992; Tayler (1992) gives the number as ~350. A further 257 elephants were captured and removed from the park during late 1992 (Dobb 1993; Mockrin 2000). Of these, based on age estimates from shoulder heights (see Table 2, Fig 2 below), nine were aged 1.5–3.5 years, 194 were aged 3.5–7.5 years, 54 were described as 'adults' (taller than 185 cm and thus >7.5 years old). Many of these animals were expected to die as a consequence of the drought if they were not removed from Gonarezhou (Dobb 1993). The sex ratio of the animals captured is not known, as detailed records of the individuals captured during 1992 were seized from Wildlife Management Services, which undertook the captures, by the Department of National Parks and Wild Life Management. These were never returned and now appear effectively lost (Mockrin 2000).

Leggett (1994) searched near the Park's major rivers 12–18 months after the drought and collected jawbones and skulls from 251 drought victims, but, as he acknowledged, other jawbones may have disappeared during the interval between the drought and the collections. He determined the estimated age at death from 216 of the jawbones.

Table 1. Estimated elephant population and confidence intervals in Gonarezhou, 1980–1989. Sources: Coulson (1980, 1981); Sharp (1982, 1983, 1984, 1986, 1987); Gibson (1989)

Year	Estimated number of elephants	95% Confidence interval (%)
1980	4,704	30
1981	6,103	35
1982	7,315	34
1983	3,986	25
1984	3,937	36
1986	4,450	44
1987	3,802	42
1989	5,286	27

Age and sex composition of elephant female herds before and after 1992 drought

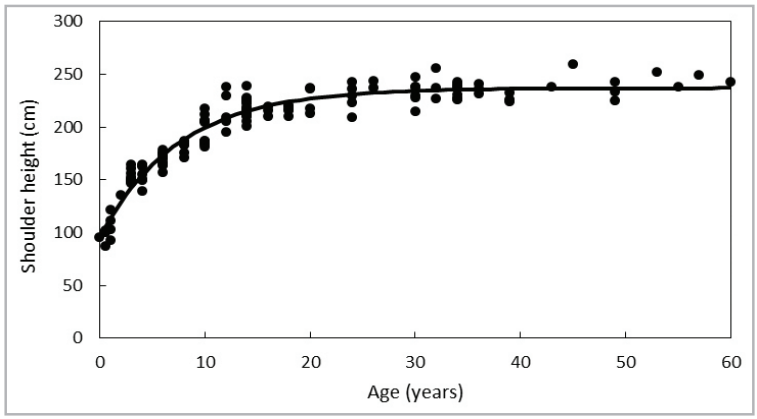
During August–October 1993, WMS captured 670 elephants in Gonarezhou (Coetsee 1996). Complete female herds of elephants were captured and translocated elsewhere. Sex and shoulder height were recorded for 667 of these elephants. Shoulder height was recorded whilst an elephant was immobilized, lying on its side.

Elephants were culled in Gonarezhou in 1983 (G.P. Sharp, unpublished data in the files of Gonarezhou NP). Data from that cull were used to determine, for each sex, a von Bertalanffy growth function for shoulder height against age for females aged up to 60 years and males aged up to 24 years. After this cull, the jawbone of each animal was examined and the individual was allocated to an age class based on molar eruption and wear (Laws 1966). For the current study, an actual age was allocated to each culled animal following Jachmann (1988). The Laws (1966) technique provides a robust mechanism for age determination and Jachmann's revision corrects for some deviations at younger ages (Lee et al. 2012), and the revision was used during this study because it included a high proportion of animals in these younger ages. The von Bertalanffy growth functions were fitted by minimizing the sum of the squared deviations for the data points, using the *Solver* tool in MS Excel. The equations for these sex-specific growth functions were used to estimate the age of each non-adult elephant captured during 1993 from its recorded shoulder height. The age of each captured elephant immediately after the 1992 drought was estimated by deducting one year from its age when caught during 1993.

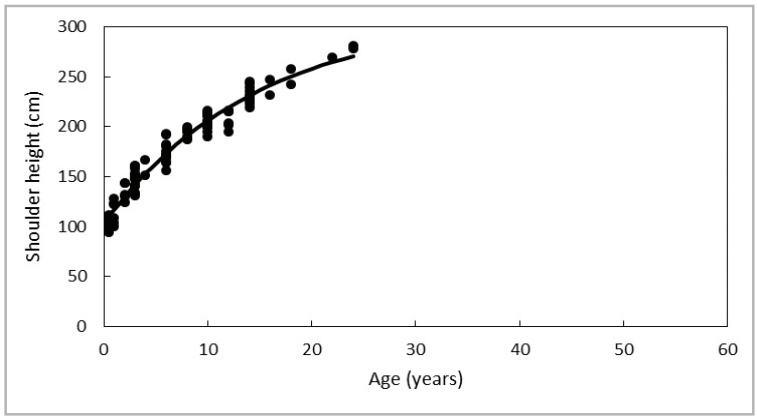
The age and sex composition of Gonarezhou elephant female herds immediately after the 1992 drought was compared with the compositions determined from the culls in Gonarezhou during 1972 (Sherry 1975), 1983, 1986 and 1987. Age determinations from 1972 were based on the criteria of Laws (1966) incorporating Jachmann's (1988) adjustments. For the 1983–87 culls, the age of each elephant was estimated from its shoulder height using the sex-specific von Bertalanffy

Table 2. The parameters of the von Bertalanffy growth functions relating shoulder height to age for elephants in Gonarezhou, using data from the 1983 cull. Following Hanks (1972), the von Bertalanffy growth function can be written as $h_t = H_\infty (1 - e^{-K[t - t_0]})$, where h_t is shoulder height (cm) at age t, K is the growth coefficient, t_0 is the theoretical age when height is zero, and H_∞ is the asymptotic shoulder height. The asymptotic shoulder height calculated for females is similar to the figure calculated for females culled in Gonarezhou during 1971–72 (241 cm; Sherry 1978).

Growth parameter	Asymptotic shoulder height (cm) (H_∞)	Growth coefficient (K)	Theoretical age when height is zero (t_0)	Sample size
Shoulder height females (0.5–60 years)	237	0.133	–3.877	125
Shoulder height males (0.5–24 years)	311	0.068	–5.916	91



(a) Females



(b) Males

Figure 2. Growth of shoulder height against estimated age for: (a) female elephants aged 0.5–60 years and (b) males aged 0.5–24 years, based on data from elephants culled in Gonarezhou during 1983. Age estimated from the lower molars using the Jachmann (1988) revision of the Laws (1966) criteria. The bold lines are the von Bertalanffy growth functions (See Table 2).

growth functions. During 1983–87, some young elephants within cull herds were captured for live sale. Only females were captured during 1983 and the age of each was estimated from its shoulder height. For 1986 and 1987, the number of captured elephants is known, but the shoulder height and sex of each was not recorded (although it is likely that, as during 1983, most were female aged 1–3 years). The dataset for the 1987 cull is incomplete and animals were included in this analysis only when the available data are for complete herds.

Results

Growth of Gonarezhou elephants

The von Bertalanffy growth function for the shoulder height of culled elephants in Gonarezhou (Table 2, Fig. 2) implied that the shoulder height of a female elephant averaged 218 cm at 15 years. Most females were mature by this age (Sherry 1975) and so females captured during 1993 that had a shoulder height ≥218 cm are defined as adults, with an estimated age of ≥15 years. Male elephants grew faster than females and the shoulder height of a male averaged 236 cm at 15 years and 271 cm at 24 years.

Age and sex composition of elephant female herds immediately after the 1992 drought

i. Proportion of immature elephants in female herds

Based on the age and sex structure of the elephants captured during 1993 (Table 3), it was estimated that a year earlier, immediately after the 1992 drought, there were, on average, 1.23 immature elephants aged 0–14 years in the female herds for each adult female. This compared with 2.00–2.96 immatures per adult female during the earlier years (Table 4). The ratio differed significantly between years, based on a chi-square test of the numbers of immatures and adult females during each year ($\chi2 = 57$, df = 4, n = 2,546, $p < 0.001$) and the 1992 ratio was also significantly different from the smallest of the earlier ratios, that for 1987 ($\chi2 = 5.7$, df = 1, n = 725, $p = 0.02$). The ratios also differed among years before the 1992 drought, based on a chi-square test of numbers during the years 1972, 1983, 1986 and 1987 ($\chi2 = 8.9$, df = 3, n = 1,947, $p = 0.03$).

ii. Ages of immature elephants

After the 1992 drought, there were 0.22 juveniles aged 0–4 years per adult female, compared with 0.75–1.49 per adult female during earlier years (Fig. 3). The ratio differed significantly between years ($\chi2 = 127$, df = 4, n = 1,457, $p < 0.001$) and the 1992 ratio was significantly different from the smallest of the earlier ratios, that for 1986 ($\chi2 = 58$, df = 1, n = 949, $p < 0.001$).

After the 1992 drought, there were 0.30 females in the 5–9 year age class per adult female, compared with 0.41–0.45 per adult female during earlier years (Fig. 3), but the ratio did not differ significantly between years ($\chi2 = 5$, df = 4, n = 1,166, $p = 0.29$). For males in this age-class, the ratio differed significantly between all years ($\chi2 = 17.5$, df = 4, n = 1,159, $p < 0.002$), but did not differ significantly between 1972, 1983, 1986 and 1987 ($\chi2 = 3.5$, df = 3, n = 825, $p = 0.32$).

For immature elephants in the 10–14 year age-class, the number per adult female did not differ between years for females ($\chi2 = 6$, df = 4, n = 1,078, $p = 0.2$), males ($\chi2 = 5$, df = 4, n = 1,066, $p = 0.29$), or both sexes combined ($\chi2 = 5$, df = 4, n = 1,299, $p = 0.27$).

iii. Sex ratio of non-adults

Immediately after the 1992 drought, the numbers of females and males aged <2 years (aged 1–3 years at the time of the captures a year after the drought) were identical (Table 3). But in each year class (except one) covering the ages 3–13 years, the number of females exceeded the number of males. Considering all elephants aged 3–13 years, the ratio of females to males (150:111) was significantly different from 1:1 (binomial test, $p < 0.02$).

The ratio of females to males aged 3–13 years in 1972 (131:111) and 1983 (54:61) did not differ significantly from 1:1 (1972: $p = 0.27$; 1983: $p = 0.6$). For 1986 and 1987, the sex ratio of immatures could not be determined, because the sex of captured animals is not known.

Table 3. Shoulder heights and numbers of elephants in female herds captured in Gonarezhou during August–October 1993 (Coetsee 1996). The age of each elephant was estimated from sex-specific, von Bertalanffy growth functions derived from data for elephants culled in Gonarezhou during 1983. The individuals in the 0–0.99 year age class were born during the year after the 1992 drought. The age of all other individuals at the end of the drought was estimated by subtracting 1 year from their age at capture.

Females			Males		
Age class (years)	**Shoulder height (cm)**	**Number in class**	**Age class (years)**	**Shoulder height (cm)**	**Number in class**
0–0.99	<114	23	0–0.99	<117	30
1–1.99	114–129	6	1–1.99	117–130	6
2–2.99	130–142	3	2–2.99	131–142	3
3–3.99	143–154	13	3–3.99	143–153	2
4–4.99	155–164	7	4–4.99	154–163	6
5–5.99	165–173	8	5–5.99	164–173	5
6–6.99	174–181	22	6–6.99	174–182	10
7–7.99	182–188	15	7–7.99	183–191	21
8–8.99	189–194	17	8–8.99	192–199	10
9–9.99	195–200	9	9–9.99	200–206	8
10–10.99	201–204	18	10–10.99	207–213	16
11–11.99	205–208	13	11–11.99	214–219	11
12–12.99	209–212	11	12–12.99	220–225	9
13–13.99	213–214	17	13–13.99	226–231	13
14–14.99	215–217	7	14–14.99	232–236	7
15–15.99	218–219	19	15–15.99	237–241	12
≥16	≥220	269	16–16.99	242–246	6
			≥17	≥247	15
Total		**477**			**190**

*Elsewhere in this paper, the ages of elephants are described simply by the number of full years; for example, animals described as 4 years old are in the 4–4.99 year age class.

Table 4. The numbers of females and immature males in entire female herds of elephants in Gonarezhou. Adult females are estimated to be 15 years of age or older and immatures 0–14 years of age. Data for 1972–1987 is from culls and data for 1992 from the 1993 captures. The sex and height of young elephants captured during the 1986 and 1987 culls was not recorded. The table gives the minimum and maximum possible numbers, but it is likely that most, if not all, were female.

Year	Immature female			Immature male			Adult female	Total
	0 to 4 yr	5 to 9 yr	10 to 14 yr	0 to 4 yr	5 to 9 yr	10 to 14 yr		
1972	97	52	45	86	49	28	123	480
1983	35	24	22	35	30	20	56	222
1986	(79–166)	145	89	(100–187)	159	105	355	1119
1987	(16–24)	19	10	(10–18)	11	10	42	126
1992	37	81	67	22	65	58	269	599

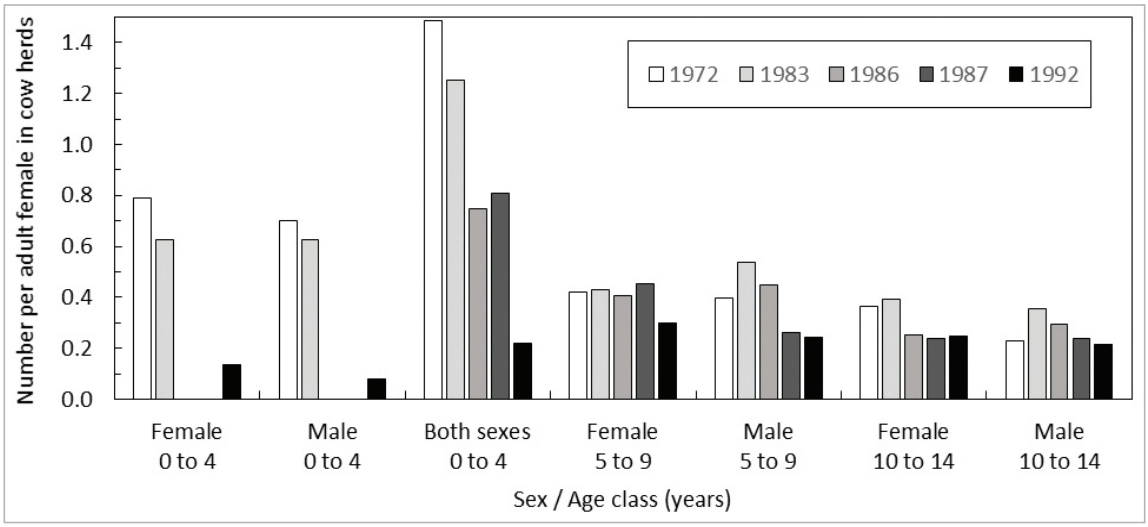


Figure 3. Ratio of the numbers of immature elephants, by sex and age class, to the number of adult females in female herds in Gonarezhou immediately after the 1992 drought and during culls in earlier years. The sex of some young elephants captured during the 1986 and 1987 culls was not recorded, but it is likely that most, if not all, were female.

Discussion

The small number of calves aged 0–4 years per adult female immediately after the 1992 Gonarezhou drought compared to earlier years (Fig. 3) suggests that there was major drought-related mortality amongst juvenile elephants in this age class. Determining if the impact of this mortality varied between males and females aged 0–4 years is complicated by the incomplete sex records for the 1986 and 1987 culls. Numbers of females and males aged 5–9 years per adult female were smaller during 1992 than during earlier years, but the difference between years was not statistically significant for females. The difference between years for males was significant only when 1992 was included in the comparison. This implies that there were significantly fewer males aged 5–9 years per adult female in 1992 than during earlier years, which was likely a consequence of greater mortality amongst these males than amongst similarly aged females during the 1992 drought. The female bias amongst the 1992 drought survivors aged 3–13 years (Table 3) also suggests that there was greater drought-related mortality amongst non-adult males than amongst non-adult females. The number of elephants in the 10–14 year age class per adult female did not vary significantly between years for males or females (Fig. 3). This suggests that mortality amongst animals in this age class during the 1992 drought was similar for males and females, and that the drought-related mortality experienced by elephants in this age class was similar to that experienced by adult females.

These observations are consistent with those of Leggett (1994) who recovered jawbones of drought victims up to ~50 years. A high proportion (49%, n = 216) were from elephants aged <12 years. That non-adults suffered greater mortality during the Gonarezhou drought and that, amongst younger non-adults, males probably suffered greater mortality than females, is also consistent with the pattern of drought mortality observed amongst elephants elsewhere (Foley et al. 2008; Lee et al. 2022).

In common with the Gonarezhou results, studies elsewhere find high drought mortality among immature elephants. In Amboseli, Kenya, extreme, prolonged droughts during the 1970s and 1980s resulted in exceptionally high calf mortality of between 40 and 60% during the first two years of life, while average non-drought calf mortality was ~12% (Lee et al. 2011, 2022). In Tarangire, Tanzania, drought mortality during 1993 among animals aged <8 years was 20%, with the majority of these deaths occurring amongst dependent calves (Foley et al. 2008). Elephants aged <8 years were also highly vulnerable to drought in Mana Pools, Zimbabwe, during 1983 and Hwange, Zimbabwe, during 2019 (Dunham 1988; Ndlovu et al. 2023) and in Tsavo NP, Kenya during 1970 and 1971,

when high juvenile mortality occurred amongst youngsters in the 2–4 and 5–10-year age classes (Corfield 1973).

When males aged 15 years or older within breeding herds were ignored, the percentage of adult females in Gonarezhou herds varied from 25% during 1972 and 1983, to 32–33% during 1986 and 1987, and 45% in 1992. These differences may reflect high non-adult mortality during droughts, with the first increase in the proportion of adult females coinciding with low rainfall during 1982/83 and 1983/84, and the second increase overlapping the 1992 drought. However, the relatively high proportion of adult females in herds during 1986 and 1987 could also reflect a low birth rate two years after the droughts (two years being the gestation period), or a combination of high juvenile mortality during droughts and a low birth rate two years afterwards. Although the 1993 captures provide good data on the age and sex structure of the female herds after the 1992 drought, there is no information available about the structure immediately before it. Hence, any attempt to use the post-drought age structure to quantify the impact of the drought on the Gonarezhou elephant population would be speculative and is avoided here.

The demographic consequences of the high mortality amongst the non-adults and its impact on the age and sex structure of the female herds will be examined in a forthcoming paper. This will demonstrate how the high rate of increase in the number of elephants in female herds observed after the drought (7.3% per annum during 1995–2009; Dunham 2012) is consistent with the high proportion of mature females in the female herds immediately following the drought. It will also argue that the absence of any observed increase in the number of males in bull groups over that same period is consistent with the low recruitment of males from female herds to bull groups for ~15 years after the drought, until the cohort of males born during 1993, the year after the drought, left their natal female herds.

Acknowledgements

All the data used during this study were collected by other people. The foundations of the study are the records of the elephants captured during 1993 by the late Clem Coetsee and I am grateful to Em Coetsee for making her husband's data available to me. The study also draws on unpublished data collected by Gary Sharp and his colleagues during the 1980s. Hugo and Elsabe van der Westhuizen of the Frankfurt Zoological Society have helped me over many years. I thank them for their patience.

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Nutritional profiles of some preferred food grasses of the greater one-horned rhinoceros before and after grassland burning in Manas National Park, Assam, India

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Abstract

The nutritional variations of food plants play a significant role in the health and population dynamics of wildlife. The body conditions of vulnerable greater one-horned (GOH) rhinoceros (*Rhinoceros unicornis*) in Manas National Park (MNP), Assam, India deteriorate noticeably during the late monsoon to winter, and improve after routine grassland burning, when rhinos feed on the newly emerged leaves and young shoots of grasses. To investigate this, we analysed the nutritional parameters of the leaves of five grass species preferred by rhinos, including three tall grasses (*Saccharum spontaneum*, *S.narenga* and *Imperata cylindrica*) and two short grasses (*Cynodon dactylon* and *Axonopus compressus*), before and after grassland burning. Leaf samples were collected in triplicate from five different sites in MNP before (September) and after (March) grassland burning. Biochemical analyses showed the highest crude protein content in *S. narenga* before and after grassland burning. *S. spontaneum* and *S. narenga* had the highest and second highest fat contents, respectively, after grassland burning. Crude fibre content in *S. narenga* increased significantly ($p < 0.05$) after grassland burning, but not in the other two tall grasses. The total ash content and the acid-insoluble ash content increased significantly ($p < 0.05$) in post-burning samples of all five grasses. The short grasses *A. compressus* and *C. dactylon* showed the highest calcium and phosphorus contents, respectively, after grassland burning, highlighting their significance in the diets of GOH rhinos along with tall grasses with higher proximate nutrient contents, and their contribution to the improved health status of rhinos after grassland burning. This study will be helpful for improved management of rhino health and their habitats, essential to maintaining the progress made in MNP since the 2008 to 2022 GOH rhino reintroductions under the Rhino Vision 2020 initiative.

Additional Keywords: Mega-herbivores, proximate analysis, macronutrient, minerals, grassland management

Résumé

Les variations nutritionnelles des plantes alimentaires jouent un rôle significatif dans la santé et les dynamiques de population des animaux sauvages. Le rhinocéros indien (*Rhinoceros unicornis*), espèce vulnérable présente dans le parc national de Manas (Assam, Inde), voit son état de santé se dégrader sensiblement entre la fin de la mousson et l'hiver. Après les brûlages systématiques des prairies, qui permettent aux rhinocéros de se nourrir des nouvelles pousses d'herbes et des jeunes feuilles tendres, leur condition s'améliore nettement. Afin d'étudier cette situation, nous avons examiné, avant et après brûlage, les paramètres nutritionnels sur les feuilles de cinq espèces d'herbes ayant les faveurs des rhinocéros : trois espèces d'herbes hautes (*Saccharum spontaneum*, *S. narenga* et *Imperata cylindrica*) et trois espèces d'herbes basses (*Cynodon dactylon* et *Axonopus compressus*). Les échantillons ont été collectés en trois exemplaires sur cinq sites différents dans le parc national de Manas, en septembre (avant brûlage) et en mars (après brûlage). Les analyses biochimiques ont montré que, de tous les échantillons, *S. narenga* contenait le plus de protéines brutes avant et après brûlage. *S. spontaneum* et *S. narenga* avaient respectivement les deux teneurs les plus élevées en matières grasses, après brûlage. Le taux de fibres brutes contenu dans *S. narenga* avait nettement augmenté ($p < 0.05$) après brûlage, contrairement aux deux autres espèces d'herbes hautes. La teneur totale en cendres et la teneur en cendres insolubles dans l'acide se sont significativement accrues ($p < 0.05$) dans tous les échantillons après brûlage. Les herbes basses *A. compressus* et *C. dactylon* ont montré, respectivement, les taux les plus élevés en calcium et en phosphore après brûlage. Ces éléments illustrent par là même leur importance dans le régime alimentaire des rhinocéros indiens — de même que celle des herbes hautes ayant des teneurs immédiates en nutriments plus élevées — ainsi que leur contribution à l'amélioration de l'état de santé des rhinocéros après le brûlage des zones herbeuses. Cette étude représentera un outil intéressant pour une meilleure gestion sanitaire des rhinocéros et de leur habitat, composante essentielle à la continuité des progrès effectués dans le parc national de Manas depuis qu'a été initié en 2008 le programme Vision 2020, pour la réintroduction du rhinocéros indien.

Mot-clés supplémentaires: Méga-herbivores, analyse immédiate, macronutriments, minéraux, gestions des prairies

Introduction

The nutritional profiles of food plants have a significant effect on locomotion, activity patterns, demography, and population dynamics of wild animals, especially mega-herbivores (Hazarika and Saikia 2012). Specialist mega-herbivores are affected by habitat modification to a greater extent than generalist mega-herbivores, as they are not able to switch to foods that are more readily available during periodic shortages of their preferred food when they cannot meet their nutritional targets (Felton et al. 2009). The greater one-horned (GOH) rhinoceros (*Rhinoceros unicornis Linnaeus*, 1758) is an iconic but globally threatened megaherbivore. GOH rhinos are browsers and grazers, eating a very wide range of plant species (Devi 2022). They once existed across the northern Indian sub-continent including parts of Nepal, Bangladesh, and Bhutan, but their distribution is now fragmented and restricted to a few protected areas in India and Nepal (Thapa et al. 2013; Rookmaaker et al. 2016; Ellis and Talukdar 2019). Following the successful implementation of conservation strategies, the GOH rhino population is recovering, and recent estimates show that there are more than 3,500 individuals in the wild (Ellis and Talukdar 2019; Pant et al. 2020). In Manas National Park (MNP), Assam, India, the species was extirpated during a period of civil unrest in the late 1990s and early 2000s (Barman et al. 2014; Dutta et al. 2017). The rhino population has now been re-established in MNP following a successful reintroduction programme initiated by Rhino Vision 2020 (IRV2020) in 2008.The MNP is well known for its rare and endemic wildlife. However, wildlife habitats are being degraded by the invasion of alien plant species (Das et al. 2019; Nath et al. 2019), causing food-related problems in populations of many wildlife species, especially mega-herbivores which require large amounts of food per day. Given the requirement for grassland habitats by GOH rhinos and

the significance of the nutrient content of their diet for their health and reproduction, it is essential to understand the nutrient dynamics of their preferred food grasses (Hazarika and Saikia 2012).

Since GOH rhinos prefer riverine grassland and savannah grassland for food and shelter, controlling the invasion of grassland by pioneer trees and invasive weed species is an important strategy for the maintenance of rhino habitat (Sinha et al. 2022). GOH rhinos show a seasonal preference for alluvial plain grasslands but also feed in adjacent swamps and forests (Laurie 1978; Jnawali 1995; Devi et al. 2022). Their diet consists mainly of grasses but also includes some fruits, leaves, shrubs, and tree branches, as well as cultivated crops (Hazarika et al. 2012). GOH rhinos avoid eating sharp-edged, woody, hard, and thorny plant parts. During dry seasons GOH rhinos exhibit preferential rather than non-selective grazing. Preferential grazing involves searching for species of choice like *C. dactylon* and *Andropogon sp.*, and tender shoots of *S. spontaneum*, *Mikania micrantha*, etc. (Fig. 1), whereas non-selective feeding involves eating whatever is within the reach including *Arundo donax*, *Phragmites karka*, etc. (Sinha and Ghosh 2000). GOH rhinos are equipped with hypsodont dentition, and they consume mainly grass all year around. At MNP, grasses constitute 87%, and aquatic and woodland species only 13% of the total annual diet of rhinos (Dutta et al. 2016). However, during the monsoon season and receding monsoon, preferred tall-grass species mature, grow rank, and become less palatable, causing the rhinos at MNP to become semi-browsers (Sinha and Ghosh 2000). During this period, rhinos browse on tree twigs, leaves, and fruits of the small plants such as *Bombax ceiba*, *Butea monosperma*, *Careya arborea*, *Dillenia pentagyna*, *Gmelina arborea* and *Macaranga denticulata* (Dutta et al. 2016).

Applying the standard body condition scoring system for rhinos (Heidegger et al. 2016), experienced frontline field staff and researchers at MNP have observed that, during late monsoon to winter, a noticeable deterioration of the body condition occurs in the rhino population. It is hypothesized that this may be due to a reduction in the nutritional content of food

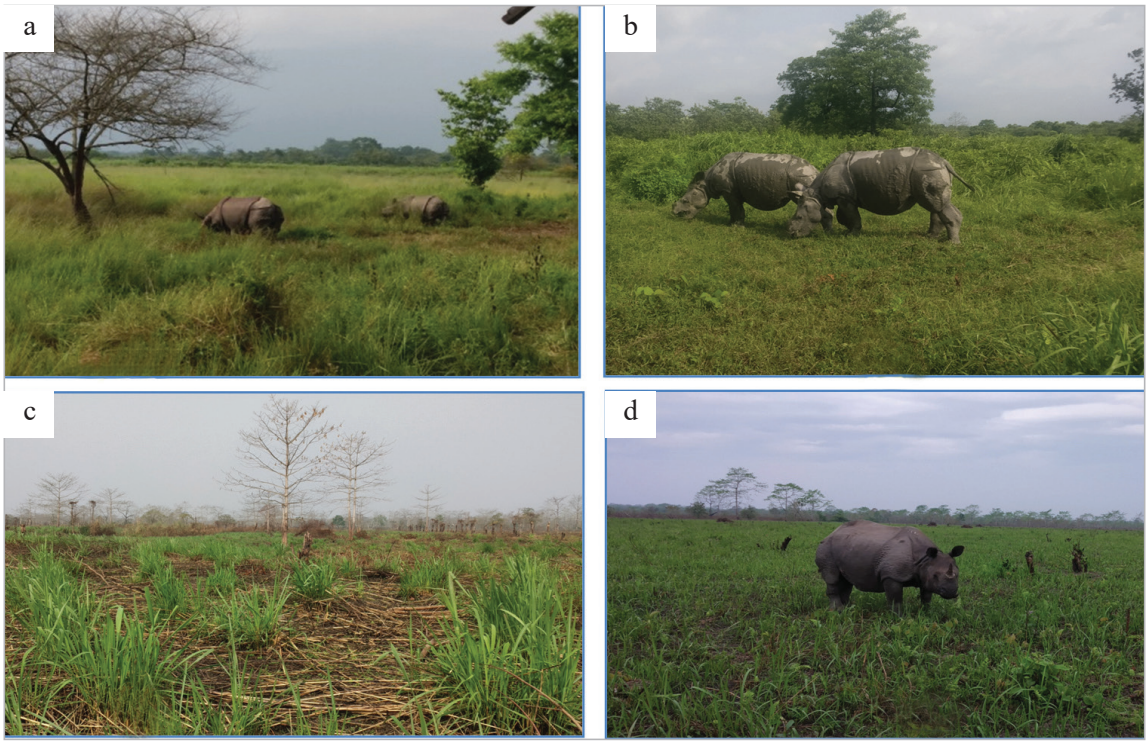

Figure 1. (a) GOH rhinos grazing in their natural grassland habitat in MNP; (b) rhinos grazing in the short grasses in MNP; (c) tender leaves and twigs of tall grasses which emerge after grassland burning (early-monsoon); (d) rhinos grazing on tender leaves and twigs of tall grasses following grassland burning.

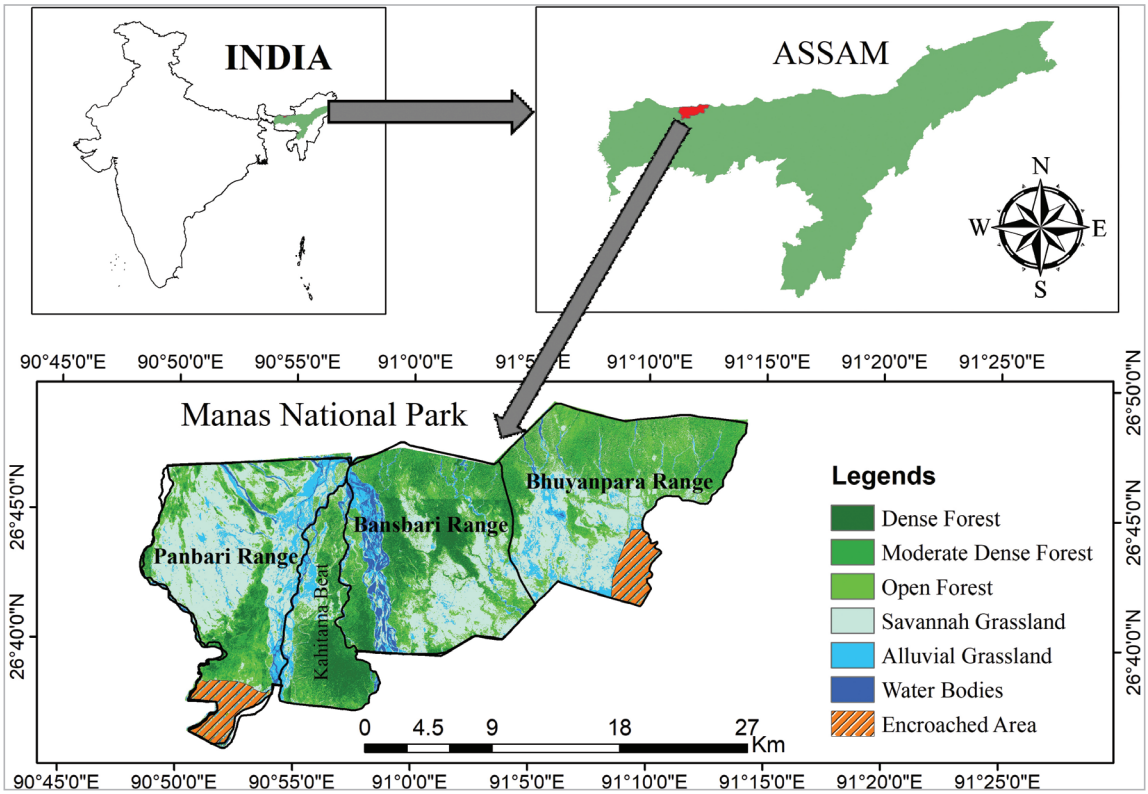

Figure 2. Map of Manas National Park in Assam, India.

plants. The deterioration of rhino condition occurs before annual grassland burning carried out by the Forest Department. Rhino condition recovers after annual burning, when the animals feed on newly emerged leaves and young shoots of tall grasses and on new growth that continues until the following early monsoon period. However, detailed and comparative analyses of nutritional profiles of the food plants of free-ranging rhinos in MNP before and after burning are lacking. To fill this data gap, we analysed the nutritional parameters of the leaf blades of five grass species preferred by rhinos and compared the parameters before and after burning. The species analysed included three tall grasses, namely *S. spontaneum L.*, *S. narenga Hack.*, *Imperata cylindrica L Raeusch* and two short grasses, namely *C. dactylon (L.)* and *A. compressus (Sw.)*. Our purpose was to evaluate whether there were significant variations in nutritional profiles of those grasses before and after burning that could account for the differences in the body condition status of rhinos.

Methods

Study area

The MNP falls under the administrative jurisdiction of the Chirang and Baksa Districts of the north-eastern state of Assam in India (26°35′–26°50′N, 90°45′–91°15′E) and is located at the intersection of the Indo-Malayan, Indo-Gangetic, and Indo-Bhutan biogeographic realms. It is a strategic conservation area that occupies 500 km^2 in the southern foothills of the eastern Himalayas (Wikramanayake et al. 2001) and forms the central area of the Manas Tiger Reserve (2,837 km^2) (Fig. 2). The MNP is bound to the north by Bhutan's international border, to the south by several heavily populated settlements, to the east by the Daodhara Reserve Forest, and to the west by the First Addition to MNP. The MNP is located on both sides of the Manas River, in the eastern Duars (floodplains) at the foothills of the Himalayas, and is divided into three zones known as the Panbari (Western), Bansbari (Central) and Bhuyanpara (Eastern) ranges. The altitude varies from 50m asl

on the Southern border to 250m asl in the hills of Bhutan.

MNP has a tropical monsoon climate. The average yearly rainfall is 3,430 mm and the typical annual temperature range is between 10° and 37°C, while the humidity can reach up to 76%. The monsoon (June–September) is the hottest and wettest period of the year, while winter (December–February) is characterized by chilly temperatures and fog. The pre-monsoon season (March–May) and the retreating monsoon (October–November) are transitional periods (Barthakur 1986). The MNP is famous for its rich faunal diversity, including species such as the tiger (*Panthera tigris*), pygmy hog (*Sus salvanius*), golden langur (*Trachypithecus geei*), hispid hare (*Caprolagus hispidus*), Bengal florican (*Houbarogsis bangalensis*) and white-winged duck (*Cairina scutula*). The MNP consists of a mix of moist mixed deciduous and semi-evergreen forests, confined mainly to the northern and extreme south-west sections of the Park (Sarma et al. 2008), and extensive savannah grasslands. The latter are dominated by tall species such as *Saccharum porphyrocoma, Imperata cylindrica, Phragmites karka, S. spontaneum, A. donax, Themeda arundinacea, S. procerum* and *Vetiveria zizanioides*, interspersed with trees such as *Bombax ceiba* and *Dillenia pentagyna* (Fig. 1).

Sample collection

Five abundant grass species, namely *S. spontaneum, S.narenga, I. cylindrica, C. dactylon* and *A. compressus*, which are the preferred food grasses of rhinos (Dutta 2016), were collected in triplicate from five different sites in the central Bansbari Range using stratified random sampling (Birnie-Gauvin et al. 2017). Samples of mature grasses were collected in September (pre-burning). Following burning, which took place between mid-January and mid-February, the grasses regrew (up to 0.3 to 0.5 m tall) and samples of the resprouted leaf blades were collected in March (post burning). Collected samples, in batches of about 500 g, were dried in a hot air oven and then ground and subjected to different biochemical analyses to assess their organic and inorganic nutrient content.

Biochemical analyses

Total nitrogen was estimated using the micro-Kjeldahl method as described by the Association of Official Analytical Chemists (AOAC 1985). Crude protein was calculated as Kjeldahl N × 6.25 (based on the assumption that nitrogen constitutes 16.0% of protein). The contents of crude fat, crude fibre, total ash, acid-insoluble ash, and minerals were also estimated using the methods described by AOAC (1985).

For calcium (Ca), approximately 35 ml ash solution was first digested with concentrate HCl and methyl red indicator was added. Then an ammonium oxalate solution was gradually added, followed by ammonium hydroxide to make the contents alkaline. The solution was then boiled and, after settlement of the precipitate, filtered into a beaker. The filter paper was carefully transferred to the same beaker and washed. After that, 10 ml H_2SO_4 was added, and the contents of the beaker were titrated against a potassium permanganate solution (N/10 $KMnO_4$). Calcium was determined using the following formula:

$$1 \text{ ml N/10 } KMnO_4 = 0.002 \text{ g Ca}$$

For the estimation of phosphorus (P) content, about 25 ml ash solution was treated with HNO_3 concentrate and ammonium molybdate. After settlement, the content was filtered, and the precipitate was washed with 2% HNO_3 followed by a KNO_3 solution. The filter paper was transferred along with the precipitate to the same beaker and N/10 NaOH was added. Subsequently, phenolphthalein and standard alkali were added and titrated against N/10 HCl. Phosphorous was determined using the following formula:

$$1 \text{ ml N/10 NaOH} = 0.000135 \text{ g P}$$

Chemicals used in biochemical analyses are shown in Table 1.

Table 1. Table of chemicals used in authors' analysis, and formulas.

Sulphuric acid	H_2SO_4
Potassium permanganate	$KMnO_4$
Nitric acid	HNO_3
Potassium nitrate	KNO_3
Sodium hydroxide	NaOH
Hydrochloric acid	HCl
Ammonium molybdate	$(NH_4)2MoO_4$

Statistical analyses

All determinations were performed in triplicate and the values were expressed as mean ± 1 standard deviation, calculated using MS-Excel. Least significant difference (LSD) and Tukey's significance tests ($p = 0.05$) were performed using the statistical software SPSS.

Results and discussion

Protein content

S. narenga, which is strongly preferred by rhinos at MNP, had the highest crude protein content compared to all other grass species both before (13.38 ± 0.45%) and after burning (8.73 ± 0.03%). Among the short grasses, crude protein content was higher in *C. dactylon* compared to *A. compressus* in the monsoon period. However, after burning, protein content of *C. dactylon* decreased significantly, and that of *A. compressus* increased significantly, while remaining lower than that of *S. narenga*. Protein is an essential macro-nutrient for all life forms and is a necessary part of the protoplasm in all cells (Schaefer 1946). Low protein content in the diet adversely affects health and may cause anorexia, slow growth rate, decreased feed efficiency, low birth weight, lower milk production, and other disorders. During the monsoon (June–September) and retreating monsoon (October–November), when the tall-grass species mature and become less palatable, rhinos are observed to increase the time spent grazing and expand their range size to maintain their nutrient intake and diet (Laurie 1978; Dutta et al. 2017). The range of crude protein content (2.63 ± 0.01% to 13.38 ± 0.45%) in the fodder plant samples from MNP was lower but similar to the range of 6–15% found in the fodder plants of rhinos in Pobitora Wildlife Sanctuary in Assam by Deka et al. (2002). Differences in crude protein content of fodder at the two sites might be due to soil types or other ecological factors, or to variations in the protein content of grasses at different growth stages. The significant increase in the crude protein content of *A. compressus* after burning corroborates the results of Dutta et al. (2016), as well as the year-round preference of rhinos for *C. dactylon*, which had the second highest protein content (11.31 ± 0.70%) before burning (Table 2). *S. spontaneum*, *S. narenga* and *C. dactylon* were preferred by rhinos in MNP, Kaziranga NP and Bardia NP due to their significantly higher crude protein content compared to other grasses, rendering them more nutritious in the monsoon season (Dutta et al. 2016; Jhala et al. 2021).

Fat content

In addition to contributing to body weight, dietary fat provides essential fatty acids and/or fat-soluble vitamins, which are crucial components in the synthesis of various hormones, including the steroid hormone that plays an essential role in reproductive cycles in both males and females (Hariyadi 2016). The results of the LSD and Tukey's significance tests indicated that the fat content of all five grasses did not change significantly following burning. The fat content after burning was the highest in the tall grass *S. spontaneum* (3.16 ± 0.05%), among the species studied, followed by *S. narenga* (2.349 ± 0.006%). This suggests that these newly emerging tall grass species play an important role in restoring the health of rhinos after burning (Table 2).

Fibre content

Fibre is a necessary component of the diet to maintain normal physiological functions in the digestive tract (Gunstone et al. 1986). Although the crude fibre content in *S. narenga* was the lowest (34.5 ± 0.31%) among the tall grasses in the pre-burn period, it increased significantly after burning (36.48 ± 0.21%), unlike *S. spontaneum* and *I. cylindrica*, which both showed significantly lower crude fibre content after burning (Table 2). This increase in fibre content will contribute to the restoration of the health of rhinos that feed on the emerging leaves of *S. narenga* after burning.

The high contribution of *Saccharum spp.* in the rhino diet is probably due to these species' constant sprouting throughout the year (Lehmkuhl 1994) and their high standing biomass (Jnawali 1995). The burning of tall grasslands from mid-January to early February is followed by a lush regrowth of *S. narenga* and other tall grasses, which dominate the tall grassland for about two to three months before reaching maturity in the monsoon season. The tender leaves rich in protein, fat and fibre content emerge from the charred stems of grasses and become available only after routine burning (Laurie 1978).

Table 2. Proximate composition of rhino food grasses before and after grassland burning in MNP.

Species	Type of grass (short/tall)	Crude protein (%)		Crude fat (%)		Crude fibre (%)	
		Before	After	Before	After	Before	After
S. spontaneum	Tall	6.12 ± 0.88	6.55 ± 0.05	3.54 ± 1.04	3.16 ± 0.05	52.5 ± 0.30	32.87 ± 0.02
S. narenga	Tall	13.38 ± 0.45	8.73 ± 0.03	2.5 ± 0.06	2.35 ± 0.006	34.5 ± 0.31	36.48 ± 0.21
I. cylindrica	Tall	6.01 ± 0.40	5.24 ± 0.003	1.1 ± 0.05	1.07 ± 0.006	47.5 ± 0.58	40.3 ± 0.1
C. dactylon	Short	11.31 ± 0.70	5.25 ± 0.006	0.87 ± 0.15	0.39 ± 0.007	15 ± 0.69	7.93 ± 0.02
A. compressus	Short	2.62 ± 0.01	5.69 ± 0.006	0.84 ± 0.002	1.50 ± 0.01	49.5 ± 0.06	32.69 ± 0.01

Table 3: Ash and mineral composition of rhino food grasses before and after grassland burning in MNP.

Species	Total ash (%)		Acid insoluble ash (%)		Calcium (%)		Phosphorus (%)	
	Before	After	Before	After	Before	After	Before	After
S. spontaneum	4.47 ± 0.06	20.97 ± 0.01	2.25 ± 0.25	12.69 ± 0.02	0.203 ± 0.006	0.145 ± 0.001	1.897 ± 0.025	0.863 ± 0.006
S. narenga	7.3 ± 0.1	20.38 ± 0.07	2.3 ± 0.2	13.21 ± 0.01	0.4 ± 0.03	0.067 ± 0.006	1.323 ± 0.057	0.896 ± 0.005
I. cylindrica	9.07 ± 0.08	31.54 ± 0.05	2.45 ± 0.05	14.96 ± 0.05	0.133 ± 0.035	0.148 ± 0.002	1.350 ± 0.026	0.907 ± 0.010
C. dactylon	8.42 ± 0.12	25.61 ± 0.02	3.97 ± 0.06	23.83 ± 0.12	0.107 ± 0.021	0.207 ± 0.006	0.41 ± 0.010	1.322 ± 0.002
A. compressus	3.51 ± 0.02	6.06 ± 0.006	2.04 ± 0.006	5.0 ± 0.001	0.087 ± 0.002	0.216 ± 0.003	0.93 ± 0.001	1.074 ± 0.005

Ash and mineral content

The total ash content and the acid insoluble ash content increased significantly in post-burning samples of all five grasses. The ash content was the highest in *I. cylindrica* both before and after burning. Regarding the mineral elements, *S. narenga* was found to contain the highest Ca content (0.4 ± 0.03%) before burning, while *A. compressus* showed the highest Ca content (0.216 ± 0.003%) after burning. The Ca content decreased significantly in two tall grasses, that is, *S. narenga* and *S. spontaneum*, while there was no significant difference in calcium content of the other tall grass *I. cylindrica*. The P content was the highest in *S. spontaneum* (1.897 ± 0.025%) before burning, and in *C. dactylon* (1.322 ± 0.002%) after burning (Table 3). The P content decreased significantly in all three tall grasses and increased significantly in two short grasses after burning. Total ash content and Ca content increased significantly in the new shoots of *A. compressus* after burning, possibly explaining why this is one of the short grasses most preferred by rhinos in MNP, even though this species low in crude protein.

The total ash of plants usually represents the inorganic mineral content of the plants, including elements such as Ca, Na, K, Cl, and P that are essential for a healthy growth of animals (Tambe and Kadam 2010). Mineral elements are an essential part of a mammal's diet for the body's physiological functions and metabolic processes, including reproduction. Mineral deficiencies, including subclinical ones, can result in significant reductions in bone density and formation, hormone synthesis, immune function, and the creation of blood, as well as affecting heart function (Fisher 2008; Kumar et al. 2021). Minerals are important bioactive molecules and also cofactors of enzymes. Ca is essential for strengthening bones, skeleton, and teeth, as well as affecting many functions such as milk production, maintenance of cell membranes, and metabolism of enzymes and hormones (Pandey 2011). Short grasses showed

higher Ca and P contents after burning, while the content of these two minerals decreased in tall grasses after burning. This highlights the significant contribution of these short grasses to the observed improvement of the health status of this megaherbivore after routine burning.

Conclusion

The presence of grassland habitat is crucial for GOH rhinos in the wild and therefore for all PAs with GOH rhino populations, where habitat restoration activities are prioritized. Moreover, the nutritional profiles of grassland food plants have significant effects on the health and population dynamics of wild animals. This study advances our knowledge of the nutritional dynamics of GOH rhinos' diets due to variations in the nutritional profiles of their preferred food plants before and after burning. Biochemical analyses showed the highest crude protein content in *S. narenga* before and after burning, while *S. spontaneum* and *S. narenga* had the highest and second highest fat contents, respectively, after burning. The crude fibre content in *S. narenga* increased significantly after burning, unlike in the other two tall grasses. Total ash content and the acid insoluble ash contents increased significantly in post-burning samples of all the five grasses. Short grasses *A. compressus* and *C. dactylon* showed the highest Ca and P contents, respectively, after burning, highlighting their importance in the diet of GOH rhinos along with tall grasses with higher proximate nutrient content, and their contribution to the improvement of the health status of rhinos after burning.

The results of this study provide baseline information for implementing measures to improve the habitat quality and availability of the preferred grasses of rhinos in the MNP. However, more in-depth studies are needed to correlate the rhinos' body condition scores with the nutritional profiles of preferred food plants before and after grassland burning. The influence of other associated factors, including the nutritional profiles of other less preferred food plants ingested by rhinos should also be considered. Furthermore, rhino parasitic load/infection in different seasons also impact on the health of rhinos, and would be worth investigating in a follow-up study. Studying the above three parameters in combination with the nutritional profiles of preferred food plants in two different seasons of the year would provide an even more detailed picture of factors affecting the health of rhinos in MNP.

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Sex differences in home range and habitat use by savannah elephants in Gonarezhou National Park, Zimbabwe

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Abstract

Protected areas (PAs) in southern Africa provide refuge to important megafauna such as the savannah elephant (*Loxodonta africana*). Sections of these protected areas are often transfrontier conservation complexes, whose objective is to facilitate historic patterns of animal dispersal. Knowledge of megafauna home ranges, habitat use, and dispersal in key PAs can inform vital decision-making for elephant conservation. Location data were derived from satellite collars fitted on 26 savannah elephants from 2016 to 2022 in Gonarezhou National Park, Zimbabwe to investigate seasonal and sex differences in elephants' home range sizes, home range overlap, and their interaction with environmental variables. Differences in the size of home ranges between sexes in all seasons were not significant. Both male and female elephants had high site fidelity, retaining 60% of their home ranges between consecutive seasons. Only females, possibly tracking forage quality, showed reduced overlap of home ranges between the hot dry and hot wet seasons. Male elephants preferred vegetation types dominated by *Colophospermum mopane*, whereas females used more diverse upland vegetation types, showing a preference for higher elevations than males over all seasons. In areas where elephant movement is restricted by fences and human settlements, continuous monitoring of elephant space use is recommended, and research dynamics should be taken into account when developing site-specific management plans.

Résumé

Les zones protégées en Afrique australe représentent des refuges pour une importante mégafaune telle que l'éléphant de savane (*Loxodonta africana*). Il est fréquent que des sections de ces zones protégées soient des complexes de conservation transfrontaliers, dont l'objectif est de faciliter les schémas de dispersion historiques des animaux. La connaissance des domaines vitaux de la mégafaune, de l'utilisation de leur habitat et de leur dispersion dans des zones protégées clés peut contribuer à des prises de décision essentielles pour la conservation des éléphants. Des données de localisation ont été extraites de colliers émetteurs installés sur 26 éléphants de savane entre 2016 et 2022 dans le parc national de Gonarezhou au Zimbabwe, afin d'étudier les variations éventuelles, selon la saison et le sexe des animaux, sur la surface et le chevauchement de leurs domaines vitaux ainsi que sur leur interaction avec les variables environnementales. Les dimensions des domaines vitaux chez les mâles et les femelles n'ont pas montré de différences significatives, toutes saisons confondues. Tous ont fait preuve d'une grande fidélité au site en conservant 60% de leur domaine vital sur les saisons consécutives. Seules les femelles, probablement en recherche d'une certaine qualité de fourrage, ont présenté un chevauchement plus faible de leurs domaines vitaux entre la saison sèche et la saison humide en période chaude. Les éléphants mâles ont affiché un goût plus prononcé pour un type de

végétation dominée par *Colophospermum mopane*, contrairement aux femelles qui se tournaient vers une végétation d'altitude plus variée, indiquant une préférence pour les hauteurs sur toutes les saisons. Dans les zones où les déplacements des éléphants sont contraints par des clôtures et des installations humaines, nous recommandons une surveillance continue de l'utilisation de l'espace par les éléphants et une prise en compte des résultats lors du développement de plans de gestion de site spécifiques.

Introduction

African savannah elephants (*Loxodonta africana*) are relatively more abundant in southern Africa than in eastern and central Africa (Henley et al. 2023). 70 to 80% of the current elephant range is located outside Protected Areas (PAs), and this distribution outside of PAs accounts for 17% of the potential elephant range areas in Africa (Ihwagi 2019; Wall et al. 2021). The range of African savannah elephants is increasingly being reduced and they are gradually becoming dependent on PAs (Stoldt et al. 2020). Therefore, it is critical to have effectively managed PAs to protect the future of African savannah elephants and also to improve the capacity of unprotected areas to host elephant populations co-existing with humans.

This study contributes to effective management of elephant ranges in PAs in southern Africa and elsewhere by investigating seasonal and sex differences in elephants' home range sizes, home range overlap, and their interaction with environmental variables, in Gonarezhou National Park (GNP), Zimbabwe. Movement is essential to animal biology, and the decisions made by animals have profound consequences at individual and ecosystem levels (Beirne et al. 2021). African savannah elephants use their home ranges in different ways, with some dispersing seasonally and others favouring the same core area throughout the year (Leggett 2006). Home ranges of male elephants that are sexually mature are different from those of females (mature and immature) and immature male elephants. Males in musth have significantly larger home ranges than females (Whitehouse and Schoeman 2003), due to the nutritional and hormonal requirements of breeding males (Wilkie and Douglas-Hamilton 2018). Seasonal movements and variation in habitat use are associated with the availability of rainfall and forage preference (Babaasa 2000). The distribution of food resources for large herbivores in natural environments is not consistent (Leggett 2006) and it is postulated that the impact of elephants on vegetation is reduced by seasonal space use (Babaasa 2000).

The distribution of African savannah elephants is influenced by a combination of factors such as soil type, topography, elevation, rainfall, and latterly interference by humans (Bailey and Provenza 2008; Bohrer et. al 2014; Williams et. al 2018; MacFadyen et. al 2019; Benitez et. al 2022). Seasonal change in the distribution of forage influences the use of space and movement patterns of elephants (Wittemyer et al. 2007). Elephants migrate from one area to another within the landscape to maximize food intake (Prins and Van Langevelde 2008). These movement are considered to arise from (1) natural selection acting over generations (Regan et al. 2020); and/or (2) new behaviours that are learned by animals during their lifespan (Laca 2008). Like other large herbivores who are generalists, savannah elephants employ mixed feeding strategies (on herbaceous and woody vegetation) (Staver et al. 2021; Troup 2021).

The interaction of elephants and humans results in serious conflicts, mostly in areas adjacent to PAs (Hoare 1999; Buchholtz et. al 2019; Adams et. al 2021). When such conflicts occur, fencing elephants out of human-dominated landscapes is a common solution, but this can accelerate the destruction of natural habitats as elephant populations are compressed into PAs (Douglas-Hamilton et al. 2005). Furthermore, savannah elephant ranges are declining due to habitat fragmentation resulting from the increase in human population and associated land-use changes (Ipavec et al. 2007). The mosaic of bushland and woodlands in and around GNP is no exception. The designation of conservation landscapes and their spatial arrangement determine the fate of both elephants and their habitats (Huang et al. 2024).

Movement behaviour and home-range use of savannah elephants is relatively well documented (Presotto et. al 2019; Sach et. al 2020; Grogan et. al 2020; Mlambo et. al 2021). Savannah elephants in ecosystems such as the Samburu–Laikipia ecosystem

in Kenya have home ranges of about 10–80 km^2 in fenced areas and about 90–800 km^2 in open areas (Dolmia et al. 2007; Douglas-Hamilton et al. 2005; Leggett 2006). Elephants have been documented travelling very long distances, including migrations of over 400 km by elephants in Mali (Blake and Douglas-Hamilton 2003), and long migrations by desert elephants in Namibia between their dry and wet season ranges (Leggett 2006).

There are no previous studies of the home ranges, site fidelity, and relationships between environmental variables and home range sizes of elephants in the GNP. Previous research used GPS tracking data to understand elephant occurrence away from water sources (Ndaimani et al. 2017), but sampling was only done for the northern section of the GNP and during the dry season. Mukomberawa et al. (2023) report on vegetation types used by elephants but do not consider differences by sex or season. This study filled this gap by monitoring and analysing the ranging patterns of elephants in the GNP landscape, and comparing differences between sexes and seasons

For most mammals, water is required for osmo- and thermoregulation. In hot areas where water is also scarce, elephants use evaporative cooling for thermoregulation resulting in a high daily water debt; therefore, elephants' movement patterns reflect the need for regular access to water sources (Dunkin et al. 2013). However, their maximum distance from water follows a distinct seasonal pattern (Chamaillé-Jammes et al. 2013). Thaker et al. (2019) found that elephants in Kruger NP were rarely more than 1.5 km from water and spent about 22% of their time close to water sources, dwelling adjacent to water for longer periods during the dry season than in the wet season. The objectives of this study were to: i) investigate the variation in home range sizes between male and female elephants across seasons; ii) determine the overlap of the home ranges between consecutive seasons as a measure of spatial use intensity; and iii) establish how environmental variables (distance from water, and vegetation productivity) influence home range sizes of elephants.

Materials and Methods

Study area

Gonarezhou National Park (Fig. 1) is located in the low-veld south-east of Zimbabwe, between 21°00′–22°15′ S and 30°15′–32°30′ E. It was established in the early 1930s as a game reserve and was upgraded to a national park, covering an area of 5,053 km^2, under the Parks and Wildlife Act of 1975 (Jakarasi et al. 2014). GNP borders a privately owned reserve to the northwest, communal lands of the Chiredzi district to the north, south, and west, and communal lands of the Chipinge district to the northeast, and shares a border of more than 100 km with Mozambique to the east. The GNP is part of the Greater Limpopo Transfrontier Conservation Area (GLTFCA) (Gandiwa et al. 2013). The altitude ranges between 160 and 560 m above sea level. Three climatic seasons can be recognised in the Gonarezhou landscape, the hot wet (HW) season (November to March, when 90% of annual rain falls); the cool dry (CD) season (April to August); and the hot dry (HD) season (September to October) (Gandiwa 2014; Republic of Zimbabwe 2016). Data from a local weather station show that long-term mean monthly maximum temperatures range between 26°C in July and 36°C in January, while mean monthly minimum temperatures range between 9°C in June and 24°C in January. The mean annual rainfall is 552 mm. The two principal vegetation types are woodland savannah and scrubland, covering 59% and 40% of GNP, respectively. Woodland savannah comprises dry deciduous vegetation, characteristic species being *Colophospermum mopane* and woodlands of *Julbernadia globiflora*, *Brachystegia glaucescens* and *Guiborrtia conjugata*. Scrublands are dominated by mixed shrubs and herbaceous vegetation. (Gandiwa et al. 2011; Martini et al. 2016). The Park contains a wide variety of large mammalian herbivore species, including common eland (*Taurotragus oryx*), South African giraffe (*Giraffa camelopardalis giraffa*), nyala (*Tragelaphus angasii*), and blue wildebeest (*Connochaetes taurinus*), as well as savannah elephant (Dunham 2012). The elephant population density was 2.22 individuals per km^2 in 2022 and has been increasing in the recent years (Dunham 2022). Elephant poaching in the GNP is not well documented, but the number of elephants poached has declined, from 58 poached elephants recorded in 2015 to only two in 2023 (B Mandinyenya, pers. obs. 2022).

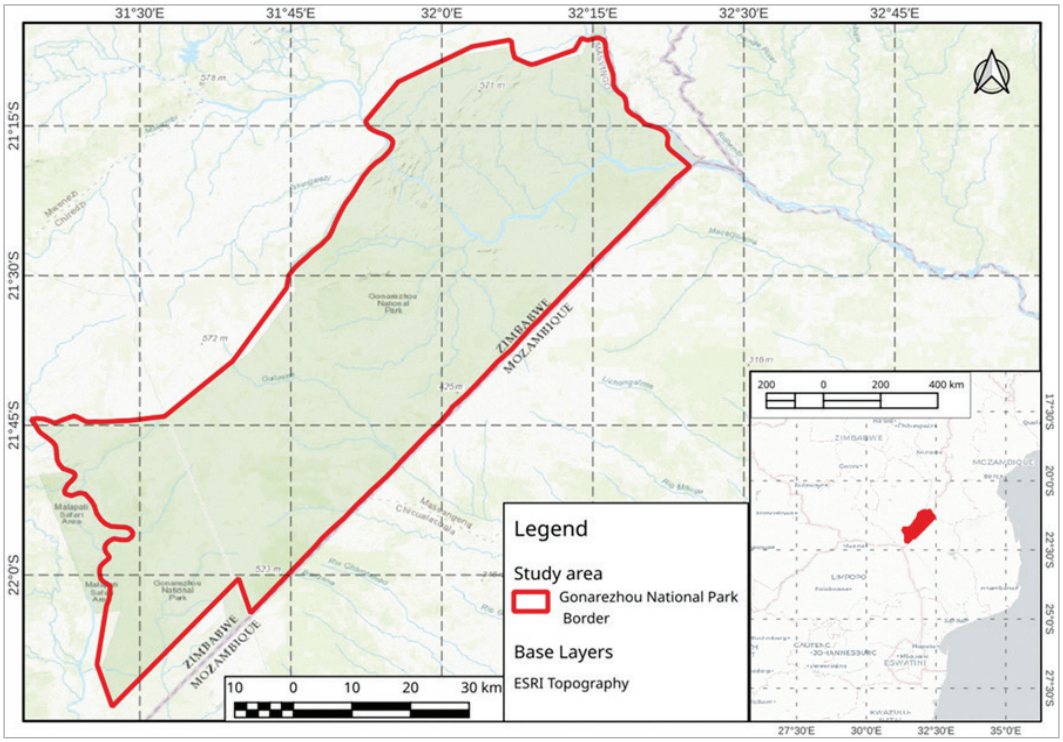

Figure 1. The study site: Gonarezhou National Park in southeast Zimbabwe.

Elephant movement

A total of 26 African savannah elephants were immobilized and collared with Africa Wildlife Tracking GPS collars (model SM 2000E; https://awt.co.za) between February 2016 and November 2022. Collars were programmed to take a GPS coordinate at 4-hour intervals. In this study, seven adult females from different herds and 19 solitary adult bull elephants were tracked during two distinct periods: 2016–2018 and 2020–2022. The gap in data collection coincided with the Covid-19 pandemic.

The average period an individual was tracked was 503 days (minimum: 36 days; maximum: 849 days). The number of GPS fixes per individual elephant ranged from 335 to 5,015 with a median value of 2,914 points, corresponding to 486 days. Data from the first day collar tracking was eliminated from each data set to remove the typical movement behaviour caused by collaring (Northrup et al. 2014). Telemetry locations were classified into three seasons and combined across years. The HW season was defined as December–March; the CD season as April–July, and the HD season as August–November (Gandiwa 2014b).

Environmental variables

Data related to environmental variables were obtained from globally available Earth Observation (EO) datasets in raster format. All environmental variable data sets were resampled at a 0.25 × 0.25 km spatial resolution, for the entire study area and a 10-km buffer area surrounding the square that contains all GPS locations. All datasets were obtained and pre-processed using the Google Earth Engine Code Editor, a web-based IDE for the Earth Engine JavaScript API (https://code.earthengine.google.com/) (Fig. 2).

Normalised Vegetation Index (NDVI)

As a proxy for vegetation productivity, we used the Normalized Difference Vegetation Index (NDVI), obtained from a transformation of the reflectance values in spectral bands closely related to photosynthetic activity. The NDVI ranges in value from –1.0 to +1.0 and index values were computed using Landsat 8 composites from reflectance values for red and near-infrared (NIR) bands as (NIR – red) / (NIR + red).

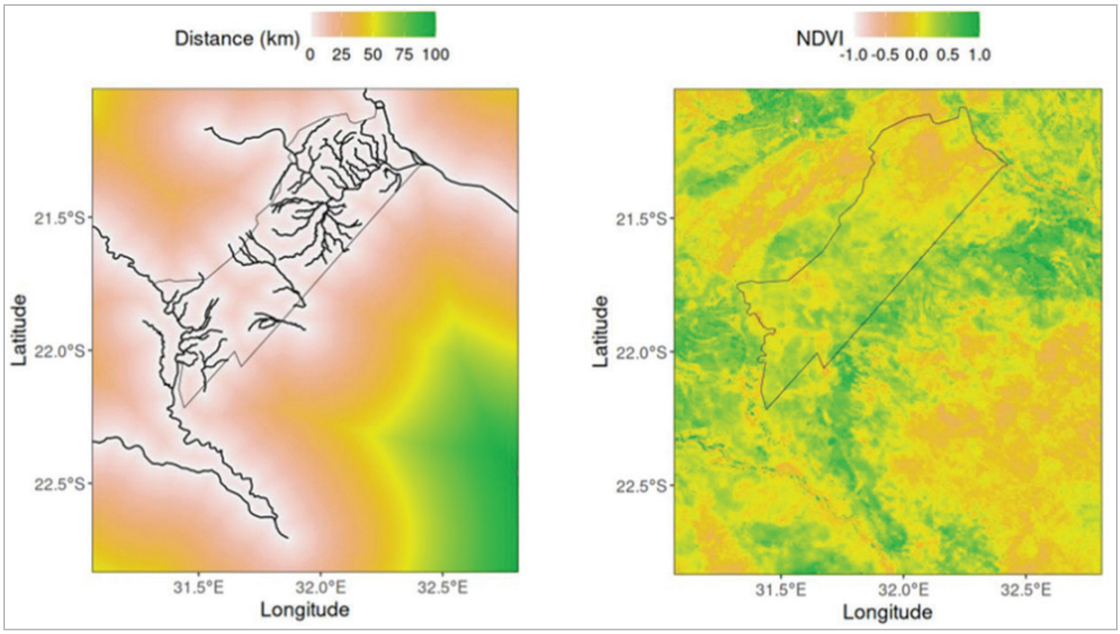

Figure 2. Representation of the environmental variables used in our analyses: (left) distance from water (in km), and (right) Normalized Difference Vegetation Index (NDVI) values.

For this study, NDVI values were obtained from Landsat 8 Collection 1 Tier 1 monthly composites, made from Tier 1 orthorectified scenes, using the calibrated top-of-atmosphere (TOA) reflectance (Landsat 8 courtesy of the U.S. Geological Survey: https://www.usgs.gov/landsat-missions/landsat-collection-1). Composites were created from all images once every 32 days beginning from the first day of the year and continuing to Day 352. The last composite of the year, beginning on Day 353, overlaps with the first composite of the following year by 20 days. All images available for the 32 days are included in the monthly composite. We computed NDVI values for the whole study period, from 2016 to 2021 inclusive. The seasonal averages were obtained by computing the median NDVI values of each raster pixel over the entire time series for every season. Values for the closest raster cell, were assigned to individual elephants for each time point, based on distance from the elephant's GPS location to the centroid of the raster cell.

Vegetation

The vegetation classes were defined following the classification of GNP vegetation by Cunliffe et al. (2012) and reclassified into five categories by joining classes that occur on similar geology and those with the same dominant woody plant species. The five categories, in order of spatial cover-age, were: *C. mopane* (2025 km^2), *Upland sandveld* (1774 km^2), *Upland igneous* (824 km^2), *Androstachys johnsonii* (168 km^2), and *Alluvium* (115 km^2).

Distance from water sources

The distance from the closest permanent water source required some additional preprocessing. Starting from a shapefile that was created by digitizing a basemap in ArcGIS Pro (ESRI 2022) and then including the location of all major rivers and water sources in the area, we created a raster of the same spatial resolution as the one of NDVI, and we calculated the minimum distance of each raster cell to a perennial water source. Afterwards, we assigned these values to elephants' GPS locations, once again using the closest raster cell centroid.

Data analysis

All analyses were conducted in the R environment for statistical computing (R Studio Team 2020). Estimation of home ranges categorized by season (HW, HD,

CD) and sex was done with the 'adehabitatHR' package for utilization distribution, using kernel density estimators (KDE) at 95% (Fleming and Calabrese 2017). The utilization distribution is the bivariate function giving the probability density that an animal is found at a point according to its geographical coordinates. This model defines the home range as the minimum area in which an animal has some specified probability of being located (Worton 1995). A 2-way ANOVA was used to determine whether there were significant differences between the sizes of the home range by sex and season. A kernel home range overlap method (Fieberg and Kochanny 2005) was used to assess the spatial interaction of seasonal home ranges for both sexes. We estimated the extent of overlap using the Bhattacharyya Affinity (BA; Bhattacharyya 1943) method, whereby BA index values measure the similarity between the utilization distribution. This method was chosen because home ranges were not utilized evenly, hence shared use of space is best measured as overlap in terms of activity rather than in terms of extent (Millspaugh et al. 2004; Fieberg and Kochanny 2005). The BA index provides a practical way to compute the overlap between the utilization distributions of two seasons A and B.

Once all data from environmental variables were collated, statistical analysis was straightforward as the elephant's location is known for each time point, as well as the corresponding features of the surrounding environment. Chi-square analysis was used to determine whether there were significant differences between the vegetation types used by male and female elephants and whether there were significant differences in the vegetation types used by elephants between seasons. A multinomial logistic regression with pairwise comparison was used to determine whether male and female elephants used vegetation types differently during different seasons.

Results

Mean home range sizes for both sexes across all seasons were less than 500 km^2. Comparison of home ranges in the three seasons showed no significant differences in home range sizes of male and female elephants ($F_{2,128}$ = 0.996, p = 0.372). The effect of sex on home range sizes (in km^2) was not significant (p = 0.206) and season also did not have a significant effect on the size of home ranges (p = 0.184) (Fig. 3; Table 1).

Both male and female elephants showed high site fidelity, retaining an average of 59.31% of their home ranges throughout consecutive seasons (Fig. 4; Table 2).

For female elephants, there was a noticeable difference in their home ranges between the HD and HW seasons (BA = 0.42096, SD = 0.218795). Outliers in data for male elephants are cases where there was little to no overlap of home ranges during consecutive seasons, probably representing animals that travelled long distances in and out of the NP.

Our results show that both male and female elephants remained relatively close to rivers (Table 3), with females remaining closer (mean = 1.82 km, SE = 0.023) during the HD season.

There was a significant difference (χ^2 = 6344, df = 4, p < 0.001) in use of vegetation types by male and female elephants during different seasons. The females used mainly Mopane (33%), Upland igneous (32.5%), and Upland sandveld (27.9%) vegetation types, while males mostly used the *C. mopane* (62.9%) vegetation type (Fig. 5; Table 4).

There were minor differences that were observed by season (χ^2 = 609.2, df = 8, p < 0.05), and by sex and season combined (Table 5), but not for all types of vegetation. Both male and female elephants selected areas with similar NDVI values across all seasons. Seasonal mean NDVI values for females were: HW = 0.397, CD = 0.383 and HD = 0.380; and for males: HW= 0.395, CD = 0.401 and HD = 0.389 (Fig. 6).

Discussion

To understand elephant range patterns, this study examined how collared elephants in the GNP used their space. It quantifies the use of space by savannah elephants in GNP and determines the variation in the use of space across seasons and between sexes. The results showed that most of the space that the study elephants used was within the boundaries of the PA and there were no significant differences between the home ranges of male and female elephants during different seasons. This is similar to the findings by Mlambo et al. (2021) who found no significant differences in the home ranges of elephants in Hwange NP between the

Table 1. Effect of sex, season, and interaction between sex and season on the size of elephant home ranges using a 2-way ANOVA. (df = degrees of freedom)

Source of variation	df	Sum of squares	Mean square	*F*-value	p-value
Sex	1	108,388	108,388	1.619	0.206
Season	2	229,592	114,796	1.714	0.184
Sex:Season	2	133,330	66,665	0.996	0.372
Residuals	128	8,571,235	66,963		

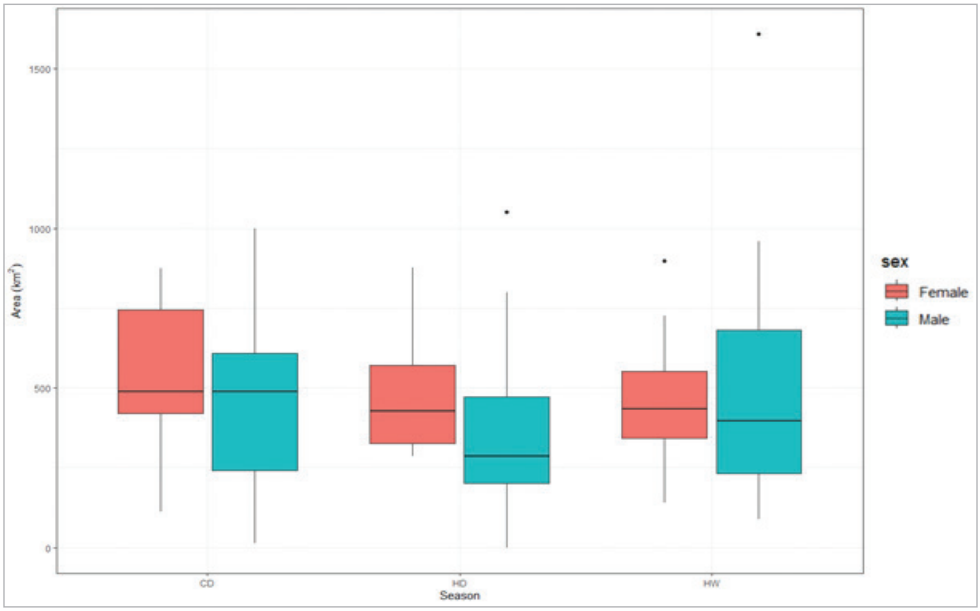

Figure 3. Home range area (KDE 95%) for male and female elephants in the GNP for all years (2016–2018 and 2020–2022) disaggregated by season. In the box-and-whisker plots, horizontal bars indicate means, the boxes show the interquartile ranges, and the whiskers show 95% confidence limits. Black points are outliers. CD = cool dry, HD = hot dry, HW = hot wet.

Table 2. Seasonal overlap of elephant home ranges by sex and based on the Bhattacharyya Affinity (BA) index. Seasons are: CD = cool dry, HD = hot dry, HW = hot wet. N = Number of combinations within the data for when there is a transition from one season to another, SD = Standard Deviation from the mean BA index, SE = Standard Error, CI = Confidence Interval.

Seasonal transitions	Sex	N	BA index value	SD	SE	CI
CD to HD	Female	10	0.630	0.165	0.052	0.118
CD to HD	Male	20	0.589	0.248	0.055	0.116
HD to HW	Female	11	0.421	0.219	0.066	0.147
HD to HW	Male	32	0.583	0.219	0.039	0.079
HW to CD	Female	11	0.712	0.128	0.039	0.086
HW to CD	Male	25	0.623	0.179	0.036	0.074

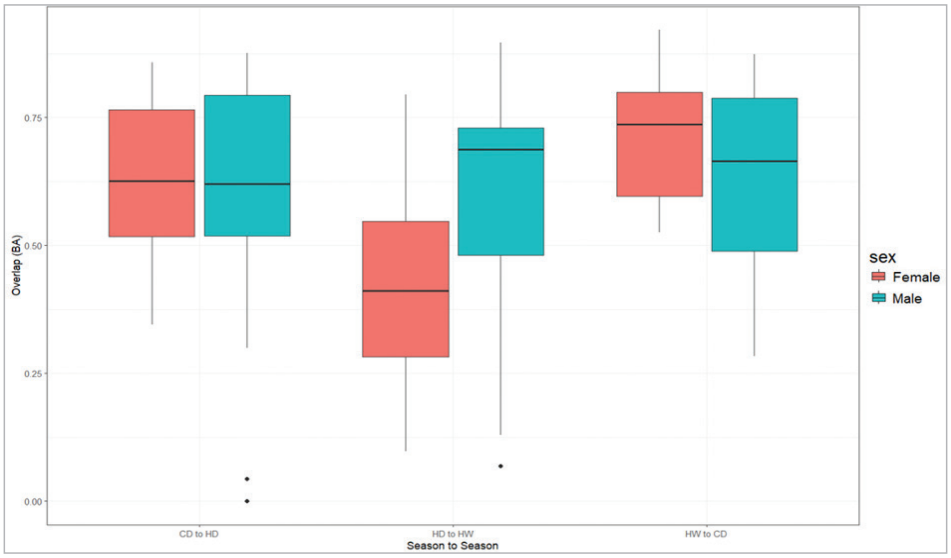

Figure 4. Overlap of home ranges for female and male elephants in GNP, and between consecutive seasons. Data here are across years. The overlap is measured using the Bhattacharyya Affinity (BA) index, where zero and one indicate no similarity and complete similarity, respectively. For explanations of box-and-whisker plots and abbreviations, see the Figure 3 legend.

Table 3. Mean distance (km) of male and female elephants from major river systems in different seasons, based on composite data for 2016–2018 and 2020–2022. N = Number of elephant data points, SD = Standard Deviation, SE = Standard Error, CI = Confidence Interval.

Season	Sex	N	Mean (km)	SD	SE	CI
HW	Female	5,253	2.558	2.274	0.031	0.062
	Male	14,127	2.003	2.146	0.018	0.035
CD	Female	7,401	2.272	2.158	0.025	0.049
	Male	14,602	2.832	6.454	0.053	0.105
HD	Female	6,992	1.824	1.890	0.023	0.044
	Male	18,627	3.730	3.729	0.027	0.054

wet and dry seasons. However, male elephants are known to utilize larger spaces than females, mostly when they are in musth and seeking females in oestrus far outside their non-musth ranges (Whitehouse and Schoeman 2003; Leggett 2006). Wall et al. (2021) found that human activities overwhelmingly determine overall elephant ranges within a PA, while environmental conditions, mainly vegetation productivity and water availability, are the principal factors affecting short-term changes in the use of space. Other studies report similar movements in response to the spatial distribution of resources, with elephants in unfenced PAs utilizing lands outside PAs as corridors between core areas in different PAs (Douglas-Hamilton et al. 2005; Tshipa et al. 2017). In this study, three bulls travelled long distances to Kruger NP and into Mozambique towards Banhine NP, but returned to GNP after about three months (unpublished data).

Our results showed that the studied elephants retained at least 60% of their home range between consecutive seasons. GNP is fenced along the northern and western boundaries where it borders communities of the Chiredzi rural district, which likely contributes to high fidelity to the Park by elephants in these areas. Linear infrastructure such as fences may act as barriers to seasonal movements, forcing elephants to use the same landscape across consecutive seasons.

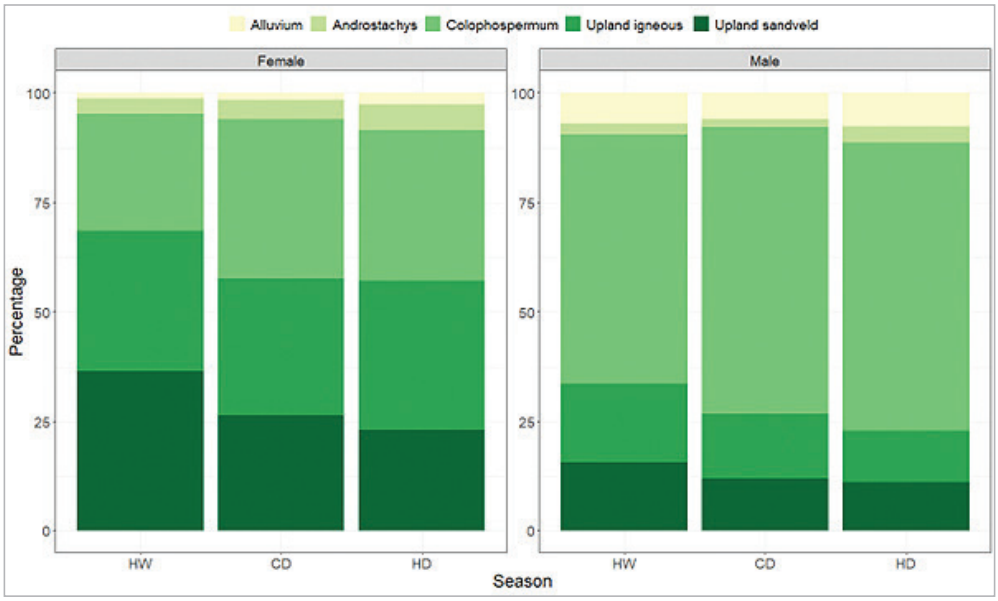

Figure 5. Vegetation use (%) by male and female elephants in different seasons, based on composite data for 2016–2018 and 2020–2022.

Table 4. Total utilization (%) of different vegetation types by female and male elephants over the entire study period.

	Vegetation Type				
	Alluvium	***Androstachys***	***Colophospermum***	**Upland igneous**	**Upland sandveld**
Female	1.97	4.61	33.1	32.5	27.9
Male	6.99	2.8	62.9	14.6	12.7

Table 5. p-values for differences between sex, season, and their joint effect resulting from a multinomial logistic regression having Alluvium as the reference category.

Vegetation type	(Intercept)	Sex male	Season CD	Season HD	Sex male:season CD	Sex male:season HD
Androstachys	0	0	0.982	0.547	0.798	0.019
Colophospermum	0	0	0.571	0.005	0.186	0.002
Upland igneous	0	0	0.113	0	0.197	0.538
Upland sandveld	0	0	0	0	0.009	0

This can interfere with elephant access to preferred foods by concentrating them in certain areas, likely increasing their impact on certain vegetation communities (Grant et al. 2007). The spaces used by the elephants tracked for this study overlapped significantly over consecutive seasons, indicating high site fidelity. There was a significant difference in the areas occupied by female elephants between HD and HW seasons, although the sizes of home ranges remained similar. The decrease in the proportion of repeated visits (overlap) from the HD to the HW season might reflect changes in female elephants' seasonal preferences and movements from dry season woody food sources to grasslands during the wet season (O'Connor et al. 2007). However, the high degree of overall site fidelity shown by elephants in GNP raises some concerns. Repeat visits by elephants to the same areas during

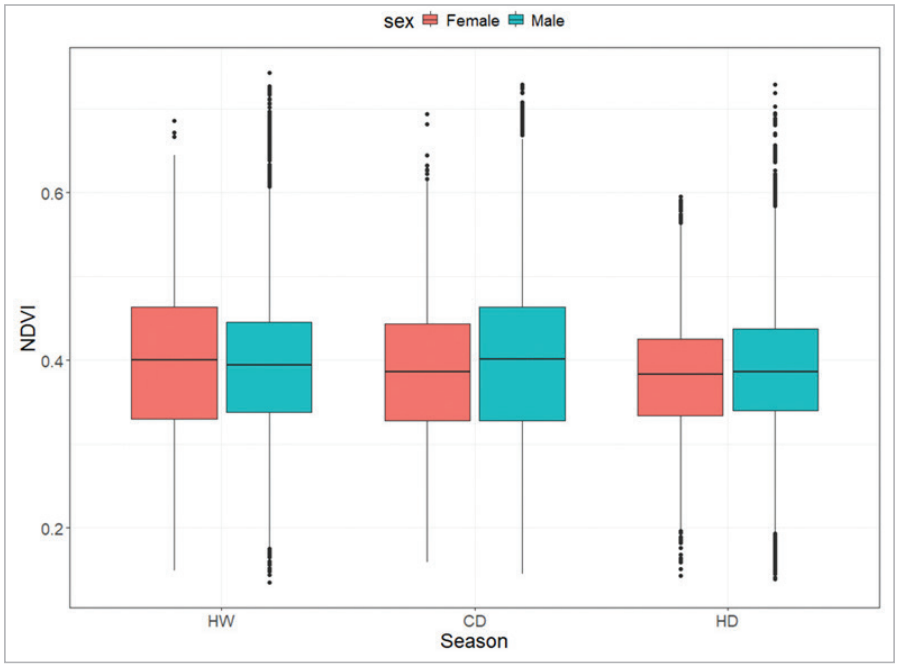

Figure 6. Seasonal selections of vegetation productivity (NDVI) of different areas by male and female elephants. For explanations of the box-and-whisker plots and abbreviations, see the Figure 3 legend.

consecutive seasons and years can have negative impacts on vegetation (Owen-Smith et al. 2006; O'Connor et al. 2007; Owen-Smith et al. 2019), particularly woody vegetation (Guldemond and van Aarde 2008). Furthermore, elephant foraging on woody seedlings and saplings can depress the regeneration of woodland areas (Baxter and Getz 2005). These impacts of elephants on vegetation in Gonarezhou NP are not yet fully understood and more work in the field is required to address this knowledge gap.

Both male and female elephants remained close to water during this study, with females staying closer to water, particularly during the HD season. Adult males can roam farther from water; while females, whose movements are constrained by their offspring, gather in areas close to permanent surface water (Stokke et al. 2002). During the HW season, elephant breeding herds are less dependent on the distribution of permanent surface water sources. Therefore they may range farther and wider than during dry seasons, when they typically remain near surface water to provide for the needs of neonate and young elephants (Stokke and du Toit, 2002; Wittemyer et al. 2007; Young et al. 2009). Mlambo et al. (2021) found that elephants in Hwange NP roam over larger areas during the wet season than in dry season. Surface water is more widely available during the wet season allowing elephants to occupy more extensive ranges, while the shift to a smaller core seasonal range during the dry season is probably a way of optimizing energy expenditure by reducing the distance travelled to water points. Consequently, surface water availability defines key resource areas and shapes the seasonal restriction of the foraging range (Chamaillé-Jammes et al. 2007). In GNP, there are fewer rainfall events during the CD season than during the preceding HW season, but surface water sources may still contain water that is accessible to elephants. However, our study, based on elephant tracking data, did not provide information on this possibility.

Although most male elephants in GNP remained close to surface water, some of the study males spent more time farther from water, especially when travelling long distances. In Chobe NP, Stokke and du Toit (2002) found that male elephants roam widely in the dry season between widely scattered patches of high quality resources, to which they have exclusive access. These include drainage sumps, ephemeral pans, and watercourses that no longer contain surface

water but where the water table is close enough to the soil surface to sustain green grass and forbs well into the dry season. In our study, the results relate only to available data on main drainage and river systems. Smit et al. (2007) identified the presence of large areas in Kruger NP that were used exclusively by bulls and suggests that these bulls live in smaller groups with lower collective feeding requirements and a wider habitat tolerance. This also enables them to avoid conflict with other bulls in musth, which occurs in areas with mixed herds. Resource and spatial segregation between male and female elephants results in differential impacts on vegetation due to differences in the size between male and female elephants and in feeding behaviour between the groups of bulls and females in mixed herds (Stokke and du Toit 2002). Male elephants with larger bodies are known to be less selective feeders than females (Stokke 1999). Our results showed that male elephants preferred vegetation types dominated by Colophospermum mopane, while females preferred upland vegetation types that have a diverse composition of woody plant species, possibly roaming these areas in search of high-quality forage. In northern Botswana, Stokke and du Toit (2000) found that bulls have lower dietary diversity, in terms of woody plant species, than female elephants and use vegetation patches with lower woody plant species richness.

On average, both males and females utilized areas with moderately green vegetation across all seasons and both sexes used the Upland sandveld less during the dry seasons than during the wet season. Loarie et al. (2009) found that elephants consistently seek out greener vegetation throughout the year and manage to do so by utilizing vegetation with different phenologies and by selecting landscapes greener than their surroundings. The results suggest a correlation between vegetation productivity/greenness (NDVI) and space use by savannah elephants that does not vary depending on seasonal resource constraints, since both elephant sexes selected areas with similar NDVI values across seasons, most likely due to forage preferences. While the link between NDVI and vegetation quality is complex, there are several reasons to suspect that green vegetation has higher nutritional quality because vegetation stands that are green are likely to contain more standing biomass and higher nitrogen content (Thoma et al. 2002). Our results suggest that even at low NDVI values, female elephants were able to obtain their nutritional requirements. This difference in the distribution, stability, and quantity of vegetation productivity as a coarse measure of food availability (Murwira and Skidmore 2005; Chamaille´-Jammes et al. 2007a; Wittemyer et al. 2007b), explains differences in the spatial patterns of use of different areas by savannah elephants between wet and dry seasons.

Conclusion

Understanding elephant preferences in spatial and temporal dimensions is critical in the management of PAs for the sustainability of both elephant populations and biodiversity. This study increases our understanding of the seasonal use of male and female elephant ranges in GNP. Repeat visits to the same study sites within consecutive seasons and over three years highlighted the potential impact of elephants on vegetation in some areas of the Park, and there is a need for further field studies to determine these impacts. One factor we were unable to consider was the possible influence of elephant densities on the relationship between elephants' use of space and vegetation productivity. Taking density into account may yield additional insights into how the use of space by elephants relates to the availability of water and food resources. There is a need for continuous monitoring of elephant use of space, especially in range areas where elephant movement is restricted by changing land use practices and fences. Therefore, differences in patterns of elephant spatial use between sexes and across seasons should be considered when developing site-specific objectives and PA management strategies, to ensure the long-term sustainability of a healthy elephant population in Gonarezhou National Park and elsewhere in African range States.

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Exploring implications of elephant movements between land use types in a semi-arid savannah landscape

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Abstract

While the numbers and distribution of African savannah elephants (*Loxodonta africana*) have declined in many African range States, they have been steadily increasing in much of southern Africa. In Namibia's arid north-west, elephants are expanding beyond Protected areas (PA) into multiple types of land use, leading to socio-economic implications, both positive and negative. Our study aimed to quantify cross-land use movements and fence breaches and to explore the institutional, legislative and policy implications of fencing, as well as a new conservation paradigm for the area. We used satellite movements of eight collared elephant herds in multiple types of land use to the south and west of Etosha National Park for one year. Of these herds, seven had home ranges spanning multiple PA/communal/commercial landscapes, often crossing fences with management or disease significance. The implications of the movements between land uses are assessed in the context of relevant policy regarding management and economics. We conclude that despite challenges to livestock disease control and fencing damage, the expansion of elephant range has resulted in economic benefits to landowners and communal conservancies through tourism and possible consumptive use opportunities, as well as an improvement in general wildlife conservation practices in the area. Regardless of these benefits and the growing interest among rural residents in supporting the establishment of elephant corridors and the removal of fences, Namibia's legal and policy framework creates numerous implications for landowners and managers when considering fence breaches by elephants. We conclude with recommendations for holistic situational analysis of policy, law and practice and the consideration of amendments to outdated fencing requirements, thereby unlocking the economic and conservation benefits of elephant range expansion in the area.

Résumé

Alors que le nombre d'éléphants de savane (*Loxodonta africana*) et leur distribution géographique ont décliné dans la plupart des pays africains de l'aire de répartition de cette espèce, une augmentation régulière est constatée dans presque toute l'Afrique australe. Dans la région aride du nord-ouest de la Namibie, les populations d'éléphants se déploient au-delà des zones protégées, sur des espaces aux usages multiples, avec des implications socioéconomiques positives comme négatives. Notre étude a pour objectif de quantifier les

mouvements liés à cette utilisation croisée des terres ainsi que la fréquence des incidents de brèches dans les clôtures, et d'explorer les conséquences institutionnelles, législatives et politiques de la mise en place de telles clôtures. Un nouveau paradigme en ce qui concerne la conservation dans cette région est également examiné. Nous avons analysé pendant un an les déplacements de huit troupeaux d'éléphants munis d'un collier GPS sur des terres aux multiples usages se trouvant au sud et à l'ouest du parc national d'Etosha. Sept des huit hardes présentaient des domaines vitaux qui s'étendent sur plusieurs zones protégées, communales ou commerciales et qui traversent fréquemment des clôtures, avec des conséquences en termes de gestion et de transmission de maladies. Les implications de ces mouvements sont évaluées dans un contexte de politiques pertinentes au regard de la gestion et de l'économie. Nos conclusions montrent que, malgré les défis relatifs au contrôle des maladies du bétail et aux dommages infligés aux clôtures, l'expansion de l'aire de répartition de l'éléphant a contribué au développement d'avantages économiques pour les propriétaires fonciers et les réserves grâce au tourisme, aux potentielles opportunités de consommation, ainsi qu'à l'amélioration des pratiques générales de conservation dans la région. En dépit de ces bénéfices et de l'intérêt grandissant des habitants des territoires ruraux pour la création de corridors et la suppression des clôtures, le cadre juridique et politique de la Namibie contient de nombreuses implications pour les propriétaires terriens et les gestionnaires des zones protégées lorsqu'il s'agit d'examiner les destructions de clôtures par les éléphants. Nous concluons notre article par des recommandations en faveur d'une analyse situationnelle et holistique de la politique, de la loi et de la pratique, et d'un examen des amendements comportant des exigences obsolètes en matière de clôtures. Ces actions permettraient de débloquer les bénéfices de la conservation ainsi que les avantages économiques associés à l'expansion de l'aire de répartition des éléphants dans la région.

Introduction

It is well-known in ecology that the main strategy for the survival of large mammals in arid landscapes is movement (Bailey 2004; Wato et al. 2018). Herbivores disperse to find growing vegetation, followed by carnivores seeking migrating prey. In southern Africa, impressive migration of large springbok (*Antidorcas marsupialis*) herds was regularly documented in the 19th and 20th centuries, and John Skinner was convinced that fences would not have stopped the movement of these large herds (Skinner 1993). Rinderpest and breech-loading rifles, together with habitat fragmentation, largely laid waste to the herds and their ancestral migration. Humans have used a similar strategy of regular movement in arid areas, and even today the Ovahimba pastoralists outwit the unpredictable droughts of northern Namibia and southern Angola by following scattered rain-fed grasslands (Gibson 1977). African Savannah elephants (*Loxodonta africana*) are well known for being migratory across much of their range (and, unsurprisingly the desert-adapted Namibian north-west elephants, the subject of this study, are no exception (Leggett 2006, 2010; Leggett et al. 2003).

Namibia's elephant population is currently estimated at around 24,000 with a growth rate of 5.4% (between 4.20% and 6.53%) over the past 25 years (Craig et al. 2021). There are four main population groups: i) the Etosha National Park (NP); ii) Mangetti, northern Kavango; Khaudum/Nyae-Naye; iii) Zambezi; and iv) north-west (Fig. 1). The north-west population inhabits areas entirely outside of national PAs, spanning communal conservancies and commercial farmland in the Kunene and Erongo regions (Craig et al. 2021; Viljoen 1987) (Fig.1). With a growth rate of 3.86% (between -0.08% and 7.95%), this population has been expanding its distribution into commercial farmland in the Kunene region to the south and west of Etosha NP, resulting in extensive human-elephant conflict (HEC) (Hauptfleisch et al. 2024; Luetkemeier et al. 2023).

This expanded distribution has resulted in elephants moving across different land use systems in the Kunene region. The resultant conflict between landowners, farmers and elephants surrounding Etosha NP as well as the contiguous zones between communal and freehold land has been well documented (Luetkemeier et al. 2023). To date, however, it seems that the movement ecology of the north-west elephants has been studied in isolation in communal conservancies (Leggett 2010) and Etosha NP (De Beer et al. 2006; Lindeque and Lindeque 1991).

This study presents novel findings quantifying and exploring some of the potential implications of

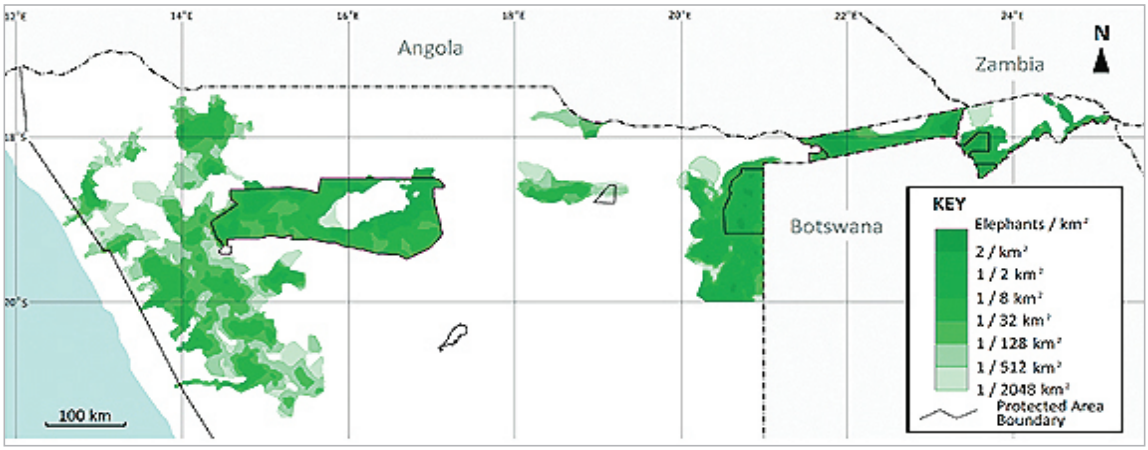

Figure 1. Elephant Distribution and density in Namibia showing both the Etosha and north-west populations in the west of the country (Craig et al. 2021).

elephant movement in different land use systems. Subsequently, the study aims to:

1. analyse the movements of eight satellite-collared adult female elephants in separate breeding herds in southern Etosha and the adjacent Kunene region (freehold and communal land) to quantify the extent of cross-land use movement as part of their survival strategy; and
2. explore the possible legislative and policy implications of this multiple land use movement.

The communal and free-hold agricultural land of the south-west of Etosha NP and Kunene (Fig. 2) is the ideal study area for this type of research, as wildlife movement and associated ecosystem services have been recorded and all rural land use systems of Namibia are represented.

Study area

The diverse land use and management context of the Kunene region and south-western Etosha that covers more than 30,000 km^2 defines the study area (Table 1, Fig.2). This region provides an ideal opportunity to compare the ecological, economic and social linkages within and between each land use type accommodating wildlife, and elephants in particular. This includes Ehirovipuka, Orupupa, Omatendeka, Huab and Audi and Khoadi–Hôas Communal Conservancies, Etosha NP (over 22,000 km^2), the Palmwag Government Tourism Concession area, Etosha Heights Private Reserve (EHPR) (a larger fenced area of 500 km^2) and individually fenced freehold cattle and wildlife farms with an average size of +/- 50 km^2 each. HEC has been reported widely across the area, with studies suggesting that it is increasing (Luetkemeier et al. 2023).

The area is considered hyper-arid with an average annual rainfall below 250 mm and is prone to frequent severe droughts (Mendelsohn et al. 2022). Average maximum temperatures are between 32 and 36^o C. Rainfall and surface water availability are a key driver of wildlife distribution and movement.

The landscape also includes a unique and significant barrier to wildlife movement, namely the Veterinary Cordon Fence (VCF). The VCF stretches from west to east through the country (red line in Fig. 2) and runs along the southern boundary of Etosha NP. It was constructed in the 1960s after the foot and mouth disease (FMD) outbreaks in northern Namibia. According to the Animal Health Act Regulations (GRN 2018), the area south of the cordon fence today is declared free of contagious bovine pleuropneumonia (CBPP) and FMD, the latter being a highly infectious disease that can be transmitted from wildlife to livestock and vice versa (Gadd 2012). FMD is a highly infectious, high-morbidity low-mortality disease, leading to severe reductions in livestock production. For example: the 2001 outbreak in the United Kingdom resulted in the need to cull over six million animals (Davies 2002). CBPP is both high morbidity and high mortality and is estimated to cause losses of € 44.8 million annually (Tambi et al. 2006). Only beef originating from this area south of the fence is accredited for import to

Table 2. Characteristics of different land use units with potential benefits from wildlife utilization.

Land use system	Tenure type	Livelihood commodities	Management of wildlife	Benefits from wildlife
National Park	Government-owned, proclaimed national park	Wildlife only	Extensive passive management and fortress conservation	National reputational benefits in protecting critically endangered species, tourism, source of breeding stocks for other parks and communal conservancies, wildlife research
Government Tourism Concession	Government land under lease to commercial tourism concessionaires	Wildlife and landscapes	Managed by the regional MEFT office	Tourism and occasional trophy hunting
Private nature reserve	Private ownership of multiple farms amalgamated without internal fencing. Private concessions for tourism and/or hunting with tourism or hunting operators. No formal proclamation	Tourism and hunting (wildlife only)	Privately managed, consumptive use of wildlife is regulated by government through the Nature Conservation Ordinance 4 of 1975 (GRN 1975)	Exclusive 'high-end' ecotourism, occasional hunt for staff food rations, possible trophy hunting in isolated instances
Commercial farm	Private ownership by an individual or a closed corporation	Mostly mixed wildlife and livestock.	Privately managed, consumptive use of wildlife is regulated by government through the Nature Conservation Ordinance 4 of 1975 (GRN 1975)	Trophy hunting, commercial meat hunting, products from wildlife skins
Communal conservancy	Owned by government but managed by an elected conservancy committee as mandated by the Nature Conservation Amendment Act of 1996 (Act 5 of 1996), (GRN 1996)	Mixed wildlife and livestock, and occasionally crop production for own use	Managed by conservancy committee with support from Namibian and INGOs. Tourism ventures are operated primarily through concessions by recognized tourism specialist companies	Tourism, trophy hunting, meat hunting, products from wildlife skins

the lucrative European Union market (Gadd 2012). Elephants in the landscape are known to consistently damage the VCF to access resources such as forage and water when driven by rainfall variability (Hauptfleisch 2022; Luetkemeier et al. 2023). This also enables the movement of many other animals in search of resources and the predators that follow them (Hauptfleisch et al. 2024). Therefore, the implications of the integrity of the fence in the context of elephant movements will also be discussed below.

Methodology

To achieve research goals (i) and (ii), this research applied the following animal movement tracking and literature review methods.

Tracking of elephant movements

Hourly GPS positions of eight female elephants in separate herds during the time period from 1 April 2022 to 31 March 2023. Two elephants were collared specifically for this study, while we also used data from

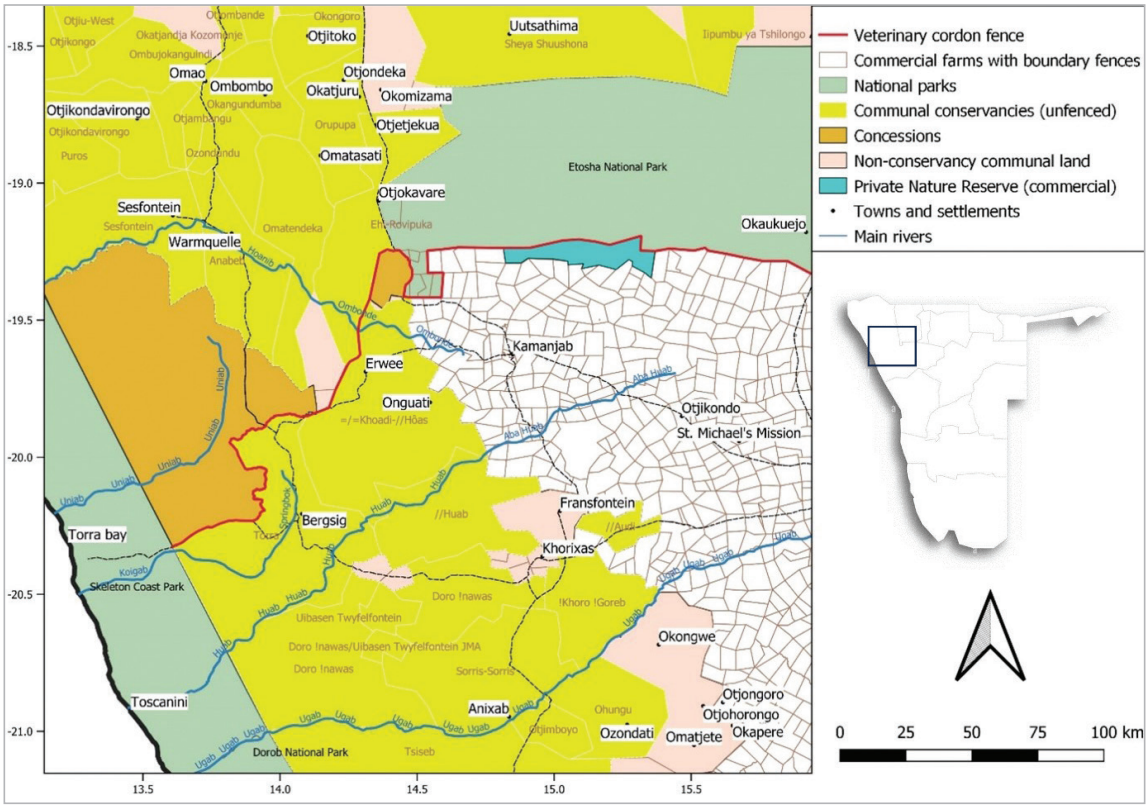

Figure 2. Etosha West and South Landscape study area.

six other elephants collared for other reasons, but within the same timeframe. No elephant was collared less than one month before the first data points considered, to prevent data from being biased by the animal's response to capture.

The Quantum Geographic Information System (QGIS) 2.18 was used for spatial analysis. The AniMove plugin and its Point-to-Path, Kernel Density Estimation, and Minimum Convex Polygon applications were used to determine the movement ecology characteristics of each study animal over the 12-month period. The System for Automated Geoscientific Analyses (SAGA) Intersection tool was used to determine how many times the animals crossed selected boundaries.

Legislative and policy review

This study aims to better understand elephant movements and their implications. Crossing boundaries has a physical dimension, as well as land use policy and legislative dimensions. To

Table 1. Study animals

Collar ID	Sex	Collared by/ information from:	Frequency of location recording
Fransi	Female	Existing data	Hourly
Iris	Female	Existing data	Hourly
4794	Female	Authors	Hourly
4792	Female	Existing data	Hourly
4793	Female	Existing data	Hourly
4788	Female	Existing data	Hourly
4962	Female	Existing data	Hourly
Sara	Female	Authors	Hourly

identify these, an analysis of relevant legislation relating to wildlife management or movement was conducted in the different land use and management units in the study area.

Open-source spatial data from the Namibia Statistics Agency (NSA) as published in the Atlas of Namibia (Mendelsohn et al. 2022) were used to identify the geographic distribution of land use systems, PAs and the VCF. From there, different types of land use and land tenure, livelihood commodities, management regime, and potential benefits were identified. Relevant legislative and policy provisions were analysed to inform the potential socio-economic implications of movements across the differing land use systems. These included the Nature Conservation Ordinance (GRN 1975), Fencing Proclamation (Namibia, 1921), Animal Health Act (GRN 2011), the National Elephant Conservation and Management Plan and the Revised National Policy on Human Wildlife Conflict Management 2018–2027.

Results

The results are separated into two outcomes, namely the spatial movement of elephants across the land use types (research aim i) and a comparative understanding of different land use type characteristics. Subsequently, Table 2 summarizes the different types of land use and tenure based on wildlife, as well as their relative livelihood, management, and potential benefit characteristics, while Fig.3 shows the characteristics of elephant movement.

All eight collared elephants crossed between different types of land use during the study period, and none of the elephants moved exclusively within a communal, concession area, or national park (Fig. 3, Table 3). Only elephant 4788 utilized a single land use type, this being commercial farmland. Interestingly, this elephant had a considerably smaller home range of 455.53 km^2 than the mean of 1,621.86 km^2 for all the elephants. Fransi and Iris used three types of land use while the other animals used two. There were a total of 1,300 fence breaches during the 12-month study period (Table 4), with 719 between individual commercial

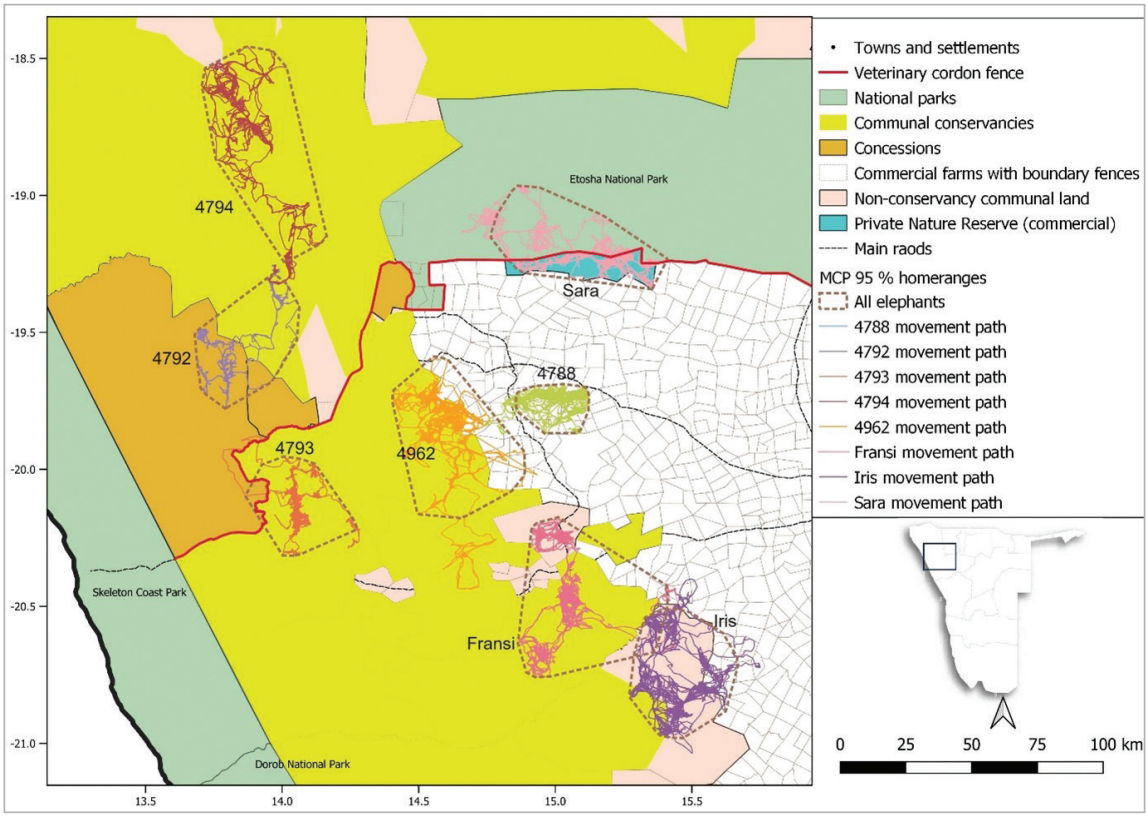

Figure 3. Home ranges and movement paths for eight female elephants during the period April 2022 to March 2023.

Table 3. The extent of total home ranges (MCP 95%) in different types of land tenure.

Elephant	Total home range size (MCP 95) km²	Portion of home range on communal conservancy in km² (and % of total home range in brackets)	Portion of home range on non-conservancy communal land in km² (and % of total home range in brackets)	Portion of home range in national park in km² (and % of total home range in brackets)	Portion of home range on commercial farms in km² (and % of the total home range in brackets)	Portion of home range on government concessions in km² (and % of total home range in brackets)
Fransi	2,615.79	1,962.71 (75.03%)	372.04 (34.23%)		281.04 (10.74%)	
Iris	1,607.56	164.42 (10.23%)	1,183.1 (73.60%)		260.04 (16.17%)	
4794	2,494.98	2,477.46 (99.30%)	17.52 (0.70%)			
4792	1,370.02	777.92 (56.78%)				592.10 (43.22%)
4793	1,084.12	1,007.13 (92.90%)				76.99 (7.10%)
4788	455.53				455.53 (100%)	
4962	2,178.94	1,471.31 (67.52%)			707.63 (32.48%)	
Sara	1,731.98			1,167.92 (67.43%)	564.06 (32.57%)	

Table 4: Number of times fence lines were crossed by eight elephant females between April 2022 and March 2023.

Elephant	Number of fence line crosses between Etosha NP and a commercial Farm	Number of times VCF was crossed	Number of fence line crosses between individual commercial farms	Number of fence line crosses between communal and commercial land
Fransi	0	0	13	5
Iris	0	0	57	93
4794	0	0	0	0
4792	0	0	0	0
4793	0	3	0	0
4788	0	0	608	0
4962	0	0	41	192
Sara	144	144	0	0
TOTAL	**144**	**147**	**719**	**290**

farms. The cordon fence was breached 147 times. Six of the eight adult females crossed fences, while the other two crossed boundaries that are geographically demarcated (between individual communal conservancies and between conservancies and unfenced government tourism concessions. Elephant 4788 was exclusively resident in a commercial farming area, continually breaching fences (or accessing farmland through the same damaged fence), with the second most breaches between communal/commercial boundary fences by three of the elephants. Sara was the only animal collared in the vicinity of Etosha NP and crossed the park boundary 144 times. This boundary also forms part of the VCF, and all but three of all VCF fence line crosses were by this elephant.

Discussion

The results indicate that elephants regularly move between multiple types of land use with home ranges of seven of the eight herds stretching across different types of land use and management. Often, elephants damage fences in their quest to access certain areas, indicating that drivers to find resources in this arid landscape outweigh potential threats from hostile residents and physical barriers. Growing populations of elephants compressed within PAs may also be driving more elephants into neighbouring non-conservation land (Craig et al. 2021). This study did not investigate these drivers but recognizes the importance for further study. It is well understood that the ability to move and track forage and water availability is a vital adaptation for elephants in arid parts of Africa where rainfall is erratic and patchy (uniquely Namibia and Mali) (Hauptfleisch et al. 2024; Wall et al. 2013). The drivers of the movements of the elephants considered in this study are important factors for future research on these elephants.

The sizes of the home ranges of the elephants were variable (455–2,615 km^2) as expected for an area with variable and erratic rainfall. The home ranges were mostly smaller than those found by Leggett (2006), whose work was in the communal land of the same region but comparable to Viljoen (1987). The elephant that crossed fence lines the most (4788) also had a considerably smaller home range than the others. This elephant is also likely to have encountered the most hostile landowners in the study area, being part of the Kamanjab 'problem' population. It would also have encountered the most fences since the farms are not only externally fenced, but often also internally fenced. Although elephants can easily breach fences, their movements are still hindered, especially since some fencing is electrified. There does not appear to be any relationship between the size of the home range of any of the other study animals and their use of specific land use areas.

The potential implications of cross-fence multi-land use movements

The implications of elephant movement policy were categorized based on the movement data shown in Fig.3 and Tables 3 and 4.

Movement between commercial farms

Besides possible tourism benefits, from a wildlife utilization perspective the movements of 'Fransi', 'Iris', '4788' and '4962' between commercial farms has potentially negative implications predominantly in terms of the Nature Conservation Ordinance (GRN 1975). These include the potential loss of elephants and other wildlife for utilitarian consumption (a 'resource') in terms of the requirement for adequate fencing to hunt on a farm (See Section 26(4)(a)). The adequate enclosure of wildlife is required for proof of ownership (See section 29.) Furthermore, these animals can, depending on the circumstances, be declared problem or damage-causing animals in terms of the ordinance and will have to be destroyed or removed according to the guidance provided by the revised policy on HWC management (MEFT 2018) (see also sections 53 and 54 of the ordinance (GRN 1975)). Following fence breaches by elephants, other wildlife often follows. Hauptfleisch et al. (2024) reported the movement of more than 9,000 large mammals at three elephant breach locations over a month. These included lion (*Panthera leo*), cheetah (*Acinonyx jubatus*), leopard (*Panthera pardus*) and nine species of wild ungulates. This could have further socio-economic implications for landowners, both as welcome resources but also negatively in terms of problem or damage causing animals. A philanthropic organization has taken advantage of the increased presence of elephants on commercial properties in the area represented by our study animal 4788; and has recently purchased three of the farms on which 4788 roams from cattle farmers who suffered conflict with the elephants. The intention is to provide sanctuary for elephants and connect movement corridors with neighbouring like-minded farmers and communal land to the west. This seems to indicate that the movement of elephants into commercial areas could affect landowners' decision to accommodate the elephants or sell their properties to individuals or organizations willing to incorporate wildlife into a diversified approach, together with farming practices. From an ecological perspective, the movements suggest that a single farming unit is too small to provide the resources and cater to the needs of elephants, making the consolidation of farms and establishment of corridors of even greater importance.

Movement between commercial and communal land

In terms of the movements between commercial and communal lands such as those depicted by Fransi, Iris, and 4962, the legal implications are similar to those discussed above except for the provisions of Section 24B of the ordinance, which grants the applicable conservancy committee the right on behalf of the community who resides on said communal land, to give effect to consumptive and non-consumptive use and sustainable management of wildlife in the area. Thus, elephants on communal land can be used as a resource following the ordinance prescripts and in line with management planning. Sustainable utilization of wildlife is strongly advocated in Namibia. The elephant management plan recognizes the important role that rural communities and communal conservancies play in elephant conservation while recognizing that such conservation success relies heavily on the benefits that communities can accrue from elephants in the form of consumptive and nonconsumptive uses.

Movement between Etosha NP and contiguous private land

Despite increased HEC between livestock farmers and elephants in the study area (Hauptfleisch et al. 2024; Luetkemeier et al. 2023), there has been a shift towards the incorporation of elephants and other wildlife into socio-economic activities. Of the 22 commercial farms that border Etosha NP in the south, only one, the Heellaas resettlement farm, does not have wildlife either for trophy hunting, hunting for meat or tourism. EHPR (blue in Fig. 3) has consolidated nine commercial farms and exclusively practices high-end tourism. Elephants are one of the top tourist attractions in the reserve. In tolerating fence breaches and maintaining conservation objectives similar to those subscribed by MEFT (for their national parks) the need to repair the fence between the Etosha NP and EHPR becomes less necessary. This has significant cost-saving implications for the Park which is responsible for maintaining a fence line of over 800 km on a limited budget. The above scenario is well illustrated by the movements of Sara, who moved across the Etosha NP and EHPR boundary a total of 144 times during the study period.

Movement across the Veterinary Cordon Fence (VCF)

The boundary between Etosha NP and private land to the south is also the VCF. Elephants in the landscape are known to consistently damage the VCF to access forage and water availability when driven by rainfall variability (Hauptfleisch 2022; Luetkemeier et al. 2023). This also enables the movement of many ungulates in search of resources, as well as the predators that follow them (Hauptfleisch et al. 2024). Despite the economic risk of reducing the integrity of the VCF and damage to farming infrastructure from cross-boundary movements, stakeholders in the landscape identified the elephants as a socio-economic opportunity in terms of their sustainable use and tourism value (Hauptfleisch 2024; Luetkemeier et al. 2021). This has already resulted in a shift from traditional commercial cattle ranching to tourism and trophy hunting across much of the landscape (Hauptfleisch 2024), as has been the case in other parts of southern Africa (Kreuter and Workman 1996). There are actors within the area (Pers. comms; Andre Nel, April 2023; Tinus Hansen, September 2024) who believe the southerly elephant movements can be a catalyst for wildlife movement corridors, expanding elephant and other wildlife ranges and connectivity across the landscape (Hauptfleisch 2022). Such corridors have been proposed as a solution in other parts of southern Africa (Songhurst et al. 2023).

The legal and socio-economic implications of this fence breach are numerous. Firstly, elephants crossing this fence become potential resources in accordance with provisions of the ordinance allowing for the trophy hunting of wildlife. The legal prescripts relating to problem or damage-causing animals also apply. The breach of the VCF has numerous negative implications for the disease-free status of commercial beef production south of the fence (GRN 2011). Despite the implications of the fence breach, the land-use system around EHPR is conducive to elephant movement, which it considers of potential non-consumptive tourist value.

The 147 breaches of the cordon fence that we identified (Table 4) provide an economic threat, but interestingly also an economic opportunity, which has been fully embraced by the landowners where the study animal Sara moves between. The crossing of the VCF creates several legal implications in terms of the Animal Health Act (GRN 2011), and the deceleration of the protected and quarantined areas separated by

the VCF (GRN 2018). Veterinary fences and strict controls allow commercial farmers to participate in lucrative international markets (McGahey 2011). In 2019, beef was exported to the value of approximately €44.8 million from Namibia to the European Union (Bennett and Rich 2022). However, the benefits and the long-term maintenance of this fence are increasingly under scrutiny among different interest groups: while the negative effects on wildlife ecology have long been observed (Martin 2005; Wall et al. 2013); the trade regulations set by the World Organization for Animal Health (OIE) implore the government to maintain the fence, which is frequently damaged by elephants and other wildlife. Interviews with local farmers in 2019 revealed their concerns about the dependency on the EU, as their business is controlled by the integrity of the anthropogenic fence. Considering the costs of maintaining the VCF, Scoones et al. (2010) suggest detachment from the fence-dependent strategy and instead apply another mechanism like commodity-based trade: setting the focus on an acceptable risk coming with the product to be traded. This may require seeking other international markets or lobbying the EU to amend strict disease control mechanisms. In this regard, certification was suggested to adapt to additional markets and allow more farmers to benefit. This strategy may be interesting for Namibia, whose vision is to also develop the livestock sector north of the VCF to integrate farmers into international markets (Meat Board of Namibia 2015).

This study could stimulate the debate around the question: *Should the fences be fixed?* For a commercial cattle farmer south of the VCF, the answer would undoubtedly be yes, but for the private nature reserve who has increased tourism value it is potentially no. A national study by the Ministry of Agriculture Water and Land Reform was recently commissioned to explore the possibility of removal of the VCF and its potential implications (New Era 2024). For conservationists (and trophy hunters), the expansion of elephant range onto private farmland is a rare and exciting occurrence, particularly since it is a catalyst for wildlife conservation and changes in land use tenure to accommodate wildlife. Where most elephant habitat across Africa is being lost or fragmented at an alarming rate (Chase and Griffin 2009) with a new approach attempted the movement of animals such as 4788 and 4962 onto areas they have not inhabited in recent times is of conservation value to the species, but at a cost to commercial livestock farmers. There is considerable cost to farmers when elephants damage water installations to access livestock watering holes and damage boundary and internal fencing designed to aid rotational grazing practices (Luetkemeier et al. 2023). Legislation currently favours fencing to control disease, as well as an animal containment tool to confirm ownership over wildlife or rights to their use. The National elephant Conservation and Management Plan (MEFT 2021) now advocates inter alia for considering removal of some fences in the wider Etosha ecosystem to facilitate the movement of elephants across the landscape and to cooperate with neighbours in PAs (MEFT 2021: 4 and 14).

Movement between communal conservancies

The situation where elephants move across communal conservancies, as depicted by the movement data in Fig.3, may have legal implications concerning which community has the right to utilize the elephants consumptively. Section 24A of the ordinance allows for the formation of communal conservancies and through Section 24A(4) for the consumptive and non-consumptive use and sustainable management of wildlife therein. Therefore, it follows that elephants within such areas are potential resources for the communities in whose conservancy they may be found. This is a valuable addition or alternative to subsistence livestock farming, which is becoming more marginal due to climate change. This also aligns with the visions of the elephant management plan which recognizes elephants as a potential resource for communities and conservation agencies and encourages sustainable use (MEFT 2021). Therefore, cooperative management of elephants and other wide-ranging species should be encouraged to determine use rights over an entire landscape and not an individual conservancy.

The elephant movement data used in this study were rudimentarily analysed to determine whether the elephants used multiple land uses and quantified their movements across fence lines. This provides a basis for the examination of possible policy implications. A follow-up study will further interrogate the spatial data to determine whether there are behavioural differences in different land uses or in the vicinity of fence lines compared to unrestricted areas. It will also look at

seasonal differences and investigate drivers of elephant movement such as water availability, density of human settlement and vegetation growth in response to rainfall.

Conclusions

This study used data from eight collared elephants in separate herds to show that there is extensive movement of elephants between different land uses in Namibia's Etosha West and South Landscape. Movement data show multiple breaches of fences, which, in addition to direct costs of repairs, may have negative legal and associated socio-economic implications. Despite this, the opening of the landscape through elephant fence breaches provides an opportunity for landscape-level conservation and ecotourism. To realize this potential, we highlight the following challenges and recommendations.

Aligning policy and legislative objectives across land use types: Implications of movements across land use types can be traced back to the level of alignment between land use objectives. Clearly, the implications of elephant movement across land use types with compatible tourism and conservation objectives (i.e. national parks, private nature reserves, communal conservancies) are more easily dealt with than less compatible land-use objectives such as commercial farming. To better align land use aims, an emphasis is needed on promoting certain objectives. These incentives could include cooperative eco-tourism opportunities, elephant movement servitudes, or wildlife credit schemes, but should ultimately support landowner expectations and the general utility of the land, whether owned by the state, communities, or individuals.

Providing for discretion and flexibility in the enforcement of policy and legislation across land-use types: The enforcement of legislation typically happens on a case-by-case basis as stipulated in law. However, the movement scenarios discussed in this paper highlight the high level of potential complexities for law enforcement related to the requirements of policy and legislation mentioned previously. Because of these complexities, enforcement requires higher levels of discretionary thinking and flexibility than what is currently provided for in the system taking advantage of a more open and connected landscape is also a means of decreasing pressure on enforcement systems, which are notoriously expensive and slow to respond to innovative opportunities.

Innovative fencing technologies and solutions: A notable obstacle to allowing for wildlife movements at landscape scale is the requirement for fencing of individual farm units to be permitted in order to utilize their wildlife resources and for livestock disease control. It is therefore recommended that revisions of these outdated regulations consider case-by-case proposals for fenceless landscape-level wildlife corridors across land units and between parks, conservancies, and wildlife areas if these land custodians or owners are willing and in agreement. However, the complete removal of fences will not be possible for certain corridor areas, especially when commercial farmland is concerned, and therefore innovative technological fencing designs and solutions should be considered and supported. Much thinking and technological development exists to selectively manipulate of animal movements through 'smart fencing' systems e.g. use of artificial intelligence to trigger alerts or opening of gates. Therefore, the complete liberation of the elephant movement will strongly depend on the development and implementation of such technologies. New fencing technology will require a rethink of current legal fencing requirements and specifications.

Although a limiting factor of this study is the small sample size, this paper provides a first attempt to highlight the implications of elephant movements across multiple tenures of land use for a particular region of Namibia. We trust that the results will have wider relevance in southern Africa and contribute to broader thinking about animal movement in complex land use systems. A better understanding of elephant movement in relation to land use policy and legislation has been identified as a key risk to conservation (Alberts et al. 2022; Retief et al. 2022; 2023) and could become an increasingly important consideration in effective wildlife management and conservation, not only in Namibia, but also across African elephant range States where space for wildlife is diminishing. Finally, we recommend more detailed analyses of elephant seasonal movements in relation to their behaviour and home range characteristics on different land uses, and the environmental factors/ecological drivers of their movements, for future study.

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Five strategies to mitigate human-elephant conflict in the Kasigau wildlife corridor of Kenya

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Abstract

Human interactions with elephants are increasing throughout the African savannah elephant's range as habitat loss and modification and a growing human population continue to bring people and elephants into contact. These interactions can become negative when elephants are tempted into farmland, consume farmers' crops, or destroy water supplies, leading to human-elephant conflict. Each community coping with regular wildlife conflicts faces unique socio-ecological circumstances and constraints. Therefore, understanding the challenges within each system is a crucial step in designing customized management plans and mitigation interventions, adapted to the situation. We used a combination of survey results and participatory fuzzy-logic cognitive maps from six farming communities in south-east Kenya from previous studies, to understand the complex drivers and consequences of conflicts with elephants and how farmers conceptualize these interactions. These data informed the creation of five main strategies for mitigating the impacts of crop-raiding by elephants: deterrent methods, climate-smart agricultural techniques, alternative livelihoods, safety around elephants, and environmental stewardship. We consulted with local experts to design and deliver workshops in the six communities to present potential solutions within the strategies and to provide the content for a take-home manual. Although no single solution has emerged as the ideal way to mitigate these encounters, the workshops demonstrated a variety of approaches that can alleviate farmers' financial and safety concerns. Future work should include understanding barriers to wider acceptance of such methods and evaluating the efficacy of multifaceted approaches. Creating a customized curriculum for workshops informed by social science data can provide vital information for local people who want to co-exist alongside elephants and other wildlife.

Additional Keywords: community-based conservation, conservation planning, conservation social science, human-wildlife co-existence

Résumé

Les interactions entre l'homme et les éléphants sont en hausse au sein de l'aire de répartition de l'éléphant de savane africain, en raison de la perte ou des modifications de son habitat et d'une population humaine croissante. Ces interactions peuvent s'avérer délétères lorsque les éléphants sont tentés de pénétrer dans les terres agricoles, ravagent les cultures ou détruisent les réserves d'eau. Chacune des communautés devant faire face à des conflits avec la faune sauvage est confrontée à des circonstances et des contraintes

socioécologiques uniques. C'est pourquoi la compréhension des défis propres à chaque contexte est une étape cruciale dans la conception de plans de gestion et d'interventions d'atténuation sur mesure et adaptés à la situation. Nous avons extrait de recherches précédentes des résultats d'enquêtes ainsi que des modèles mentaux établis par des groupes participatifs venus de six communautés d'agriculteurs au sud-est du Kenya, afin d'appréhender les moteurs et les conséquences complexes des conflits avec les éléphants et la façon dont les agriculteurs conceptualisent ces interactions. Grâce à ces données, cinq stratégies principales ont émergé pour modérer les impacts des dégâts occasionnés aux cultures par les éléphants: méthodes de dissuasion, techniques agricoles intelligentes sur le plan climatique, moyens de subsistance alternatifs, règles de sécurité autour des éléphants et gestion de l'environnement. Nous nous sommes entretenus avec des experts locaux afin de concevoir et d'organiser des ateliers au sein des six communautés, dans le but de présenter des solutions potentielles dérivant de ces cinq stratégies et de fournir le contenu d'un manuel à emporter chez soi. Bien qu'aucune réponse ne se soit imposée comme le moyen idéal d'atténuer les tensions, les ateliers ont mis en évidence diverses approches permettant de réduire les inquiétudes des agriculteurs en termes de revenus et de sécurité. De futurs travaux devraient se tenir sur les thèmes suivants : la compréhension des obstacles qui empêchent une plus vaste acceptation de telles méthodes et l'évaluation de l'efficacité d'approches multidimensionnelles. La création d'un programme éducatif sur mesure pour les ateliers, qui repose sur des données de sciences sociales, peut fournir des informations cruciales aux populations locales souhaitant coexister avec les éléphants et autres animaux sauvages.

Mot-clés supplémentaires: Conservation communautaire, planification de la conservation, sciences sociales de la conservation, coexistence homme-faune sauvage

Introduction

Across elephant ranges in Africa, interactions with African savannah elephants (*Loxodonta africana*) are prevalent in farming communities, especially those on the boundaries of protected areas (Wall et al. 2021). The most common form of these interactions occurs when elephants access farms with crops, generally at night, and consume or trample farmers' fields (i.e. crop foraging or crop raiding; Chiyo et al. 2005). Many farmers in these areas are subsistence farmers, consuming or selling what they grow, sometimes living in dire poverty. Therefore, farmers are understandably frustrated at the loss of their crops and may retaliate and attempt to harm elephants, especially if humans have been injured or killed (Nyirenda et al. 2018). These negative interactions, or human-elephant conflicts (HEC), threaten crop farmers' livelihoods and the conservation of Endangered African savannah elephants (Shaffer et al. 2019).

Although multiple solutions have been proposed to mitigate these interactions, no single solution has been found to work in all cases (Blackwell et al. 2016). The efficacy of crop foraging deterrents, such as fencing or traditional methods such as patrolling or burning fire, can vary depending on biotic or abiotic environmental factors, such as wind or rain. Additionally, other socioeconomic barriers remain that limit the use of physical deterrents including the financial cost of deterrents, availability of deterrent materials, community acceptance, and know-how of available effective deterrent types (Snyder and Rentsch 2020; Von Hagen et al. 2024a). This variation can result in the need to use a combination of approaches or mitigation methods customized to the geographical area and the needs of the community to reduce conflict (Shaffer et al. 2019; Sitati and Walpole 2006). Without proper ways to deter elephants from crop foraging, communities can experience multi-dimensional social, cultural and economic impacts. These can include lost opportunity costs, missed work or poor school attendance, food insecurity, and compromised well-being (Barua et al. 2013). Therefore, an important step in planning how to mitigate HEC is understanding the local context and impacts surrounding interactions with wildlife.

To understand how HEC and its impacts vary by community, several social science methodologies are in practice that allows for engagement with community members (with free, prior, informed consent) such as surveys, interviews, focus group sessions, and participatory modelling or mapping (Bennett et

al. 2017). Any planned interventions should be co-designed in conjunction with affected communities, their leaders, and local experts to reflect the complexity often found within these issues (Parsons et al. 2016). One method of customizing information for a geographical area to address HEC is to conduct workshops that bring ecosystem actors together to learn about different techniques that can be incorporated within their households or communities (Treves et al. 2009). However, moving from understanding the specific and complex challenges of HEC in a community to deciding which potential interventions to apply can be challenging, particularly when considering that most types of mitigation solutions need to be affordable, practical, and effective (APE) to be widely adopted and sustainable (Corde 2022). This process involves evaluating data collected from community members and deciding which of the available mitigation measures could be the most valuable to communicate to affected farmers.

In the Kasigau Wildlife Corridor (KWC) in south-east Kenya, elephant interactions are common, and elephant crop-raiding remains a contentious issue between farmers and local wildlife-focused agencies (Kagwa 2011; Von Hagen 2020; Corde 2022). Our previous work in this arid area focused on six farming communities impacted by repeated elephant visits to their crops. Through interviews, surveys, and participatory group sessions, we collected information on the drivers and consequences of these interactions, whether or not crop farmers used techniques to deter elephants, impacts on farmers' livelihoods, and how farmers conceptualized conflicts with elephants. Some of the findings included that farmers lived in fear of elephants, most had not received information on how to build deterrents or live safely with elephants, and crop foraging had a major impact on financial security for farmers (Von Hagen et al. 2023; 2024a; b; Table 1). Using this information, our goals were to create: 1) community workshops to provide information to farmers that would help them mitigate the impacts of elephant crop-raiding in their specific area, increasing co-existence; and 2) a manual to be distributed locally and available electronically for other communities seeking potential solutions.

Methods

The Kasigau Wildlife Corridor lies between the Tsavo East and West National Parks in south-east Kenya in the Greater Tsavo Ecosystem and contains 14 community-owned ranches and one community conservancy. In addition to an increasing human population (some of whom have immigrated from less arid areas), the region is home to the country's largest and growing population of approximately 15,000 African savannah elephants (Waweru et al. 2021), which use the wildlife corridor to transit between the safety of the Parks. A national highway (Nairobi–Mombasa) and the Standard Gauge Railway divide portions of Tsavo East. Rukinga Wildlife Sanctuary (RWS), operated by Wildlife Works, is part of the community ranch complex within the corridor. This area is home to almost 120,000 people, and the preponderance of villages, farms, and nomadic pastoralists create many opportunities for wildlife interactions. The area is mixed-use, containing both businesses and small shareholder farms that typically also keep livestock. Several different types of crops are grown, with maize being the main crop type (much preferred by elephants). Rainfall follows a biannual pattern in this area with long rains typically lasting from March to May and short rains lasting from October to December; the annual average is 1,037 mm. The area is often plagued by drought and soils that have been farmed without replacing nutrients, causing crop losses and exacerbating food insecurity (Kagwa 2011; Von Hagen et al. 2023).

Members from six communities (n = 206) surrounding RWS were the focus of previous studies (Von Hagen et al. 2023; 2024a; b), and the same individuals from the following villages were invited to the workshops: Itinyi and Kombomboro (combined due to the small population size and geographic proximity, hereafter referred to as Itinyi), Bungule, Miasenyi, Kisimenyi, Buguta and Makwasinyi (Fig. 1).

To decide which types of interventions or strategies should be included for discussion in the workshops and the corresponding manual, we examined the data collected from our surveys and participatory sessions in the six respective villages. These sessions included the creation of fuzzy-logic cognitive maps by farmers, revealing several impacts and consequences that were under-represented in other HEC literature. We used generalized linear models to determine if there were demographic categories that identified more common users of deterrents but generally found

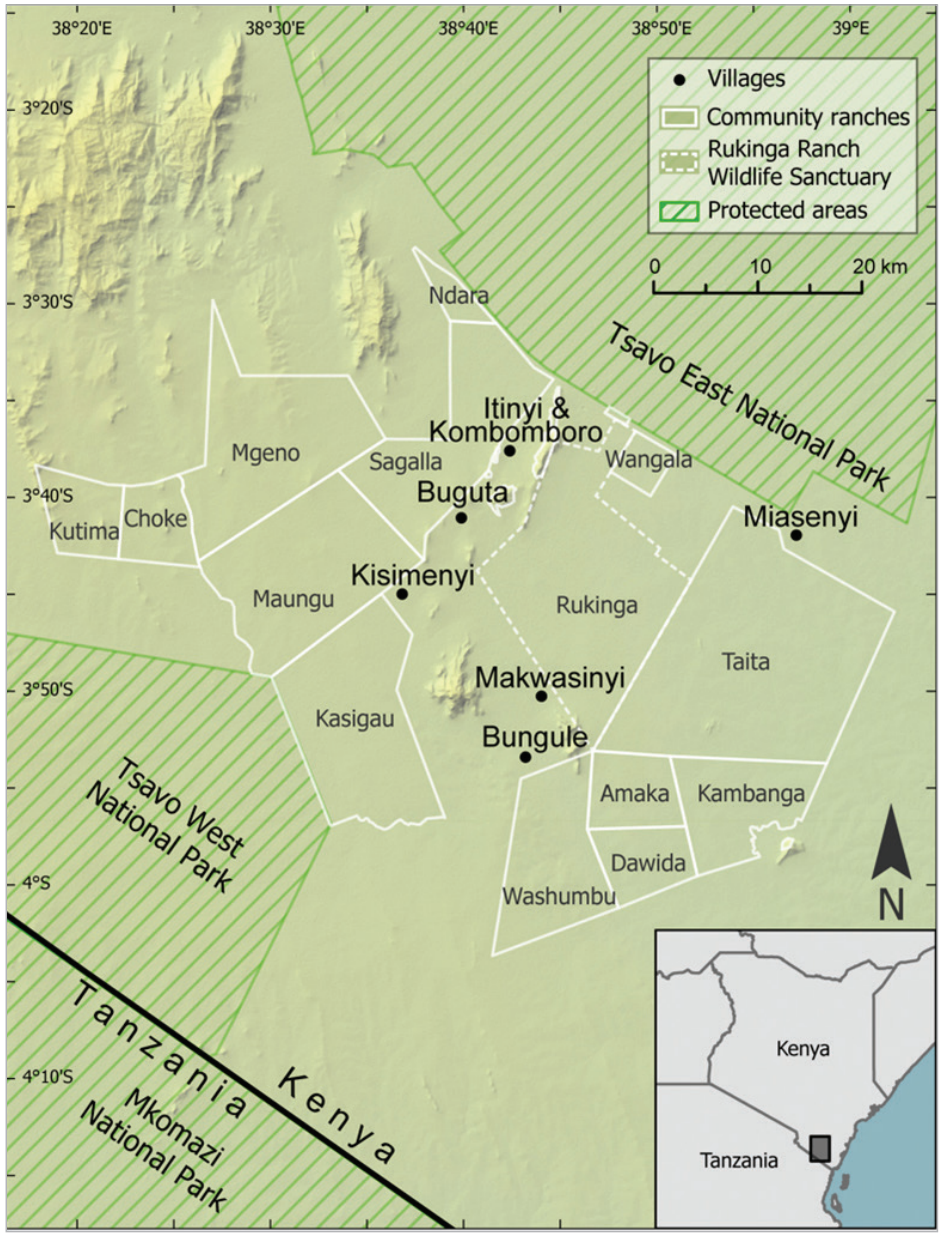

Figure 1. The Kasigau Wildlife Corridor indicating the six villages which participated in the workshops.

homogeneity amongst these results. Therefore, we looked at simple percentages from each survey question to identify where farmers had strong feelings, attitudes, or needs about HEC in their communities (n=206). We considered all results that could logically be addressed by some type of intervention. We then assigned the relevant results of the surveys and group models to five key intervention categories, compiled from the literature and our collective experiences, and these categories helped inform how we developed the curriculum for the workshops (Table 1).

Firstly, we found that very few farmers used effective deterrents (such as beehives, electric, metal strips, or chili fences), and that the vast majority had never received information on such methods (Von Hagen et al. 2024b). Secondly, few farmers had received information on or knew about alternative crops types

or other ways to improve their crop yields, as drought and poor soil quality are major threats to harvests. Thirdly, few farmers had access to information on alternative ways to earn a living other than by farming (Von Hagen et al. 2023). We also found that most farmers lived in some level of fear of elephants and the vast majority had never been given information on ways to act safely around elephants (Von Hagen et al. 2024b). Lastly, in this ecosystem, there are issues with the overexploitation of forest resources such as bushmeat poaching and the unsustainable harvesting of firewood, for illegal charcoal operations. This creates conflict with local agencies and can contribute to greater HEC (Githiru et al. 2017). Environmental interactions also emerged as one of the main themes of the group models (Von Hagen et al. 2024a).

After classifying the data into the five categories (of strategies) that were feasible for this landscape and the affected communities, we contacted local experts in these areas (see Results section). We consulted on the types of methods and discussions to be given at

Table 1. Results of surveys and participatory group mental models conducted in six crop farming villages of the Kasigau Wildlife Corridor of Kenya (n=206), and their corresponding strategy categories

Finding	Strategy Category
54% of farmers used one or more deterrents, 87% of which were traditional methods[1]	Deterrent methods
22% of farmers had received information on how to construct and implement deterrents, and 10% on specific fencing types[1]	Deterrent methods
40% of farmers believed they could invest in deterrents, for the 60% who did not, 100% of them cited economic constraints[1]	Deterrent methods, Alternative livelihoods
84% of farmers had some level of fear of elephants[1]	Safety around elephants
16% of farmers had received information on how to live safely with elephants[1]	Safety around elephants
55% of farmers had no agricultural training outside of schooling or family[2]	Climate-smart agriculture
81% of farmers believe that climate change negatively affected their lives[2]	Climate-smart agriculture
99% of farmers grew maize (corn, a crop favoured by elephants) in addition to other crops[2]	Climate-smart agriculture
82% of farmers showed interest in growing other types of crops	Climate-smart agriculture
39% of farmers had not heard about new agricultural techniques or were unsure[2]	Climate-smart agriculture
66% of farmers had learned of other ways to earn income outside of growing crops[2]	Alternative livelihoods
79% of farmers stated that drought affected their crops every season[2]	Climate-smart agriculture
91% of farmers did not use any type of irrigation[2]	Climate-smart agriculture
Income levels were an important impact of elephant crop raiding by elephants[3]	Alternative livelihoods
Farmers' feelings of security were a major impact when elephant crop-raiding occurred[3]	Safety around elephants
Farmers believed that extensive crop-raids or the presence of elephants caused soil compaction, causing them to have to rent equipment to till soil[3]	Climate-smart agriculture, Alternative livelihoods
Environmental interactions were an important theme that emerged from group mental models with farmers[3]	Environmental stewardship

[1]Von Hagen et al. 2024b
[2]Von Hagen et al. 2023
[3]Von Hagen et al. 2024a

the workshops and which interventions would be included in the take-home manuals. The manual was designed to be visually instructive so that illiteracy or language barriers would not prevent people from learning the techniques. Workshops were planned in conjunction with local leaders and experts, and we used a local facilitator to organize the dates and conduct the workshops, using visual aids such as a projector and fencing components for different presentations. The survey methods described in this manuscript are based on previous studies (Von Hagen et al. 2023; 2024a; 2024b).

Results

Most of the information planned for the workshops were also reflected in the accompanying manual: *Community-Based Mitigation Strategies for African Savannah Elephant Crop Raiding*. The manual was produced in Swahili and English[1]. The first strategy focused on deterrent methods: finding affordable, practical, and effective methods to prevent elephants from entering crop farms. Locally, we had trialled several methods and found that beehive fences and the Kasaine metal strip fence were both helpful (Von Hagen et al. 2021; Corde 2022), (Fig. 2). Demonstrations were arranged and held by specialists from Wildlife Works and Save the Elephants (Elephants and Bees Team), where these two techniques originated. The manual had explicit instructions for the construction and maintenance of these two techniques, as well as more traditional methods such as guarding or patrolling and noise making. We included instructions for making chilli bricks and explained why not to use acacia fences, as our previous study had found them ineffective (Von Hagen et al. 2021). We also provided alternative ideas such as planting chillis as buffer crops or bio fences among other crops recommended that are not favoured by elephants.

The second strategy introduced was climate-smart agricultural (CSA) techniques that could improve crop yields through sustainable farming practices. It should be noted, however, that even though these techniques can improve crop yields to benefit incomes and food security, without implementing deterrent methods or planting crops that are not favoured by elephants, improved crop yields could attract elephants (Weinmann 2018). Since this is a drought-prone area, these techniques were specifically selected to retain and make the most of rainfall when it arrives. The local agronomist from the Ministry of Agriculture of Taita Taveta County shared his expertise at the workshops by demonstrating two techniques that

[1]DOI:10.13140/RG.2.2.28281.34404 (English) and DOI:10.13140/RG.2.2.13181.84965 (Swahili)

Figure 2. Two deterrent methods used in the Tsavo ecosystem that were demonstrated at community workshops (a) the Kasaine metal strip fence, and (b) beehive fences.

originated in Burkina Faso: Zai pits (Fig. 3) and half-moons or U-bands (see manual for full descriptions). Zai pits have been shown to be an effective technique for increasing maize yields in this area (Bowers et al. 2024). As part of the second strategy, we also provided information in the manual on crops that are unpalatable to elephants, how to make organic pesticides (since insect pests in this area are also a source of crop losses), availability of drought-resistant seeds and crop alternatives, such as sorghum and millet which are more resilient to climate change. Additionally, the manual provided information on two methods for establishing kitchen gardens, which are used throughout Africa to create small, elevated gardens for vegetables that can be easily managed in a variety of settings.

The third strategy was alternative livelihoods; sustainable ways to earn money other than farming, so that when elephant crop foraging does occur, farmers have other income sources to help compensate. We introduced the workshop participants to the local basket-weaving cooperative Hadithi, which trains and employs local women to make baskets from sisal and other handicrafts such as beading and sewing. These crafts are sold both locally and internationally, paying a fair market value to local villagers. Another technique featured in the manual is for fodder production. Following harvesting, plant remnants (such as maize stalks) can be left to help fertilize soil or fed directly to livestock. The manual demonstrated how to make simple, affordable fodder bales for later consumption by livestock or to be sold for income-generation. However, not leaving plant remnants (mulch) reduces nutrients returning to the soil, suggesting a need to add fertilizer from livestock manure. Another representative joined the workshops from Zawadisha, a local cooperative, and talked about a micro-loan programme that helps to provide items such as solar lamps, water tanks, and clean cooking stoves, improving living quality. Even if farmers do not use beehive fences to protect their crops, beekeeping can also be profitable for farmers, and apiculture was discussed and included in the manual as an alternative source of income.

The fourth strategy addressed behaviour around elephants so that farmers would feel safer and potentially avoid direct interactions with elephants. A local ranger from Wildlife Works taught key safety behaviours around elephants and how to act when encountering elephants. The same instructions were listed in the manual, as well as information provided on how to secure food and water stores to discourage elephants from accessing these reserves. For example, instead of engaging with elephants by shouting or throwing stones, it was encouraged to back away slowly in the event of an unexpected elephant encounter.

The fifth and final strategy focused on environmental stewardship. The discussions and information in the

Figure 3. An example of Zai pits, a climate-smart agricultural technique used to increase crop productivity.

Figure 4. Five strategies to mitigate African savannah elephant crop raiding, were developed in conjunction with local experts and distributed in manuals to participants from communities in the Kasigau Wildlife Corridor of Kenya.

manual highlighted the importance of elephant presence for a healthy ecosystem (such as providing seed dispersal) and other ways to keep the area productive and beneficial for the community. Ideas presented included using eco-friendly charcoal, ways to sustainably harvest wood, and reducing bushmeat poaching. The five strategies are summarized in Figure 4.

Discussion

The workshops in the local villages were well attended, farmers appeared to be engaged with the materials, and many expressed their appreciation after receiving the training and information. These reactions may be due in part to the fact the curriculum was customized to fit the needs farmers previously identified. Using social science methods is an important component in developing a greater understanding for outside actors or managers about the variation in impact of HEC and other conservation issues for local communities. Incorporating the knowledge of people from local communities affected by HEC is an invaluable component in creating management plans that will benefit their communities (Bennett et al. 2017) and for sustainability. Another factor involved in this process was the use of local facilitators and experts who were trusted community members who advised on the practicality of the methods and were fundamental to connecting with farmers during the workshops. Using local facilitators and experts can help build trust between local people and conservation agencies, which can often be difficult in places where conflict with wildlife or agency personnel has been consistent (Young et al. 2016). Our previous work with these stakeholders and other wildlife agencies within the community also helped establish a level of trust, but in other communities, it may take time,

which can also impact the adoption of methods and the well-being of both people and elephants.

Once information has been distributed to the communities, follow-up surveys are essential to evaluate which aspects of the workshops were successful. Specifically, it is important to determine which participants were able to implement some (or all) methods and why they selected these particular strategies or mitigation methods over others. Likewise, understanding the barriers to implementation or adoption is helpful, including whether these are the same as they were historically. (Furthermore, a new area of potential research is to determine if drought or other environmental factors are more of a threat to harvests than elephants). In our previous interactions, farmers had already identified economic constraints that reduced their wide acceptance of deterrent methods, which is common, especially in communities with limited resources (Shaffer et al. 2019). Another previous finding was that farmers had not received certain information they needed, so understanding communication pathways and effectiveness is also valuable. Critical evaluation of the success in identifying strategies that improve food security and feelings of safety in the short and long term is still needed. This final step is important for revising and improving future workshops so that the mitigation strategy selection process can be iterative, as some techniques may provide initial success but then wane.

Using the process we outline here, conservation managers in other communities can create tailor-made strategies. Given the variability of factors that affect human-wildlife conflict in general, and HEC more specifically, using one approach rarely works for all stakeholders involved in an area. Thus, multi-pronged strategies give farmers options for their lifestyle or financial situation. Financial barriers can be addressed through outside funding or through local microloan programmes (Kaaya and Chapman 2017). Without an integrated approach to mitigation methods, farmers may resort to traditional means where they need to be present, such as patrolling, which may be less effective, time-consuming and more dangerous. Although using all five strategies at once is ideal, it may not be feasible or sustainable for each farming family. Therefore, a stepwise integration of selected strategies can still improve farmers' feelings of security and reduce income losses. Providing multiple strategies as demonstrated in these workshops is necessary to help local communities mitigate elephant crop-raiding and is an important part of incorporating human-elephant co-existence into conservation planning, which can both improve livelihoods for farmers and the conservation of elephants.

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REVIEW

The political, economic and institutional context of wildlife trafficking networks in Africa and a description of how they operate

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Abstract

This review follows on from a description of the main transnational organized crime (TOC) ivory trafficking networks published in *Pachyderm* 63. It provides the broader political, economic and institutional contexts in which these networks originated, to advance a deeper understanding of how these TOC trafficking networks are created. The article also describes how the networks are structured along trade chains, from poachers to foreign importers and distributors, and how they operate, presenting case examples from the 1970s in Kenya and comparing them to the Kromah and Xaysavang TOC networks of eastern and southern Africa operating from 2010. The review concludes that state-level corruption has expanded over time, facilitating the operation of these TOC trafficking networks and frustrating their elimination. African nations lose billions of dollars annually to illicit financial flows resulting from various TOC activities which end up in offshore accounts and asset buying. Despite international conventions aimed at stopping corruption and TOCs, the situation is getting worse, not better.

Résumé

Cet article fait suite à la description des principaux réseaux du crime organisé transnational (COT) spécialisés dans le trafic d'ivoire, qui avait été publiée dans le volume n° 63 de *Pachyderm*. Nous fournissons ici des informations sur les contextes plus larges — politiques, économiques et institutionnels—dans lesquels ces réseaux tirent leur origine, afin de mieux comprendre les fondements de leur création. Nous nous attachons également à détailler la façon dont ces réseaux sont structurés tout au long de la chaîne commerciale, depuis les braconniers jusqu'aux importateurs et distributeurs étrangers, ainsi que leur mode opératoire. Nous nous appuyons sur des exemples concrets des années 1970 au Kenya, en les comparant à l'organisation de COT Kromah and Xaysavang des années 2010 en Afrique australe et de l'Est. Les conclusions de cet article soulignent que le degré de corruption au niveau des États s'est intensifié au fil du temps, facilitant le fonctionnement de ces réseaux et empêchant leur élimination. Les pertes subies par les nations africaines du fait de flux financiers illégaux se comptent par milliards de dollars par an — résultat des diverses activités de ces réseaux et qui finissent dans des comptes offshores et dans l'acquisition d'actifs. Malgré les conventions internationales qui visent à mettre un terme à la corruption et au COT, la situation, loin de s'améliorer, s'aggrave.

Introduction

In *Pachyderm* 63 the author summarized the main transnational organized crime (TOC)[1] ivory trafficking networks that led to the poaching of tens of thousands of elephants in Africa in recent years, along with thousands of rhinos, pangolins and big cats (Stiles 2022a). In this review, the author will present the broader political, economic and institutional contexts in which these networks originated to advance a deeper understanding of how these TOC trafficking networks are created in the first place. The article will also describe how the networks are structured along trade chains from poachers to foreign importers and distributors and how they operate, presenting case examples.

Context of African wildlife trafficking networks

Illicit economic gain and corruption to obtain it are at the core of organized crime. The ultimate stimulus is the avoidance of laws that are designed to protect the public good, which in the realm of natural resources usually means the prevention of the overexploitation of a given resource. Many wild animal species bear the blessing or curse, depending on the context, of possessing body parts that have an economic demand of some kind in commercial markets. To prevent overexploitation of these natural resources that could lead to local extirpation or even extinction of a species, laws are passed to manage and control the offtake of the body part/product in question, which would usually involve the killing of the animal.

Every nation in Africa has a set of laws and/or decrees that relate to the use of wildlife, in many instances inherited and amended from the colonial era. These laws typically regulate the hunting or killing of various species of wildlife. Using elephants as an example, range States each have their own set of laws that restrict the legal killing of this animal species and the economic uses of the derivative ivory, meat and other body parts.

When there is a situation in which demand for a product exceeds its legal supply, pressure is naturally exerted by those involved in the trade to increase supply. If this cannot be achieved through adherence to existing laws, the ground is set to increase economic gain through illegal and corrupt acts. What has occurred with ivory is a classic example of this dynamic. Paradoxically, the same state government that created the laws now has government actors who use their powers to abuse those laws.

Every elephant range State has its particular history of who the actors were, but in the past they commonly involved ivory traders (those who first bought the raw ivory), wildlife/game departments (those who sold the ivory), poachers and transporters (these overlap with the preceding), law enforcement and the judiciary (who are corrupted to facilitate and protect the traffickers), and finally political leaders, who abuse their positions of authority to profit from the illegal trade in some way.

Over time an organized criminal network evolves linking suppliers with buyers, exporters, international transporters, importers, processors and distributors to consumers. These networks exist for a large number of wildlife commodities and are flexible and adaptable. Political leaders at the top, if corrupt, are usually involved in a variety of criminal activities aimed at enriching themselves, with wildlife trafficking being just one income stream among many.

The situation with TOC networks involving arms, drugs, human trafficking, wildlife and hardwood timber became so serious that nations came together at the beginning of the current millennium to draft and adopt two international conventions: the United Nations Convention against Corruption (UNCAC) and the United Nations Convention against Transnational Organized Crime (UNTOC) (UNODC 2003a; 2003b). These were intended to clean up and prevent state participation in corruption and organized crime that resulted in losses of billions of dollars annually in illicit financial flows to secret offshore accounts and asset buying.

[1]Following the UN Convention Against Transnational Organized Crime, organized crime is defined as the actions of a group of three or more persons who operate in a structured way or network and are repeatedly involved in the commission of serious crime for profit. Organized crime becomes transnational in nature if 1) it is committed in more than one State; 2) it is committed in one State, but a substantial part of its planning or perpetration takes place in another State; 3) it is committed in one State, but involves a criminal group that engages in criminal activities in more than one State; 4) it is committed in one State, but has substantial effects in another State. UN General Assembly Resolution 55/25 (November 15, 2000), UN Doc. A/RES/55/25, Annex I, art. 2.

For example, a study of capital flight—the proceeds of corruption and TOC activities—from a representative sample of 30 African countries from 1970 to 2015 estimated that a total of USD 1.8 trillion was lost. This amount greatly exceeded the debt owed by these countries as of 2015 (USD 496.9 billion). Evidence also showed that these countries lost more through capital flight than they received in the form of foreign aid or foreign private investment. In other words, these countries would gain considerably more from stopping corruption and organized crime than from all forms of foreign financial assistance (Ndikumana and Boyce 2018). The World Bank concurs, "Corruption hinders economic development by reducing domestic investment, discouraging foreign direct investment, encouraging overspending in government, and distorting the composition of government spending away from education, health, and infrastructure maintenance towards less efficient but more manipulable public projects." (Wei 1999).

The UNCAC held its 10th Conference of the States Parties in December 2023 in Atlanta, USA. The Global Initiative Against Transnational Organized Crime (GI-TOC) presented a disheartening observation at the COSP.[2] "Since the adoption of the UNCAC, and its sister convention, the UNTOC, the strength of corrupt and criminal networks has grown and evolved beyond recognition. Our 2023 Organized Crime Index shows that the most prevalent and potent group of organized criminal actors are those that are embedded in the state… More than 20 years into the lives of the UNTOC and UNCAC, and as we approach the target achievement date of the Sustainable Development Goals in 2030, the situation is critical and things have gotten worse, not better" (GI-TOC 2023a).

The GI-TOC's 2023 Organized Crime Index ranks in order the Democratic Republic of the Congo (DRC), Nigeria, South Africa and Kenya as the most criminal countries in Africa, all highly active in illegal ivory and rhino horn trafficking (GI-TOC 2023b).

In this context, illicit markets for ivory and other wildlife products operate. Between 2006 and 2014 in only a few southern African countries, a study the author carried out with Zimbabwean Rowan Martin estimated that a total of more than USD 727 million worth of ivory and rhino horn alone was lost (Martin and Stiles 2017). If all sub-Saharan African countries were included, the loss would be measured in billions of dollars. Criminal government and private sector actors were the beneficiaries.

Structure of Transnational Organized Crime networks

There are many different ways in which TOC networks can be structured, depending on the type of criminal activity in question (Wyatt et al. 2020; Breuer and Varese 2023). Illicit wildlife trade is the criminal activity of focus here, and the network structure is based on the trade chain, also called the supply or value chain. To demonstrate how different wildlife commodities can vary from one another, rhino horn will be included.

There is a common perception that all ivory and rhino horn entering into illegal trade is obtained through poaching, i.e. illegal killing. In fact, significant proportions of the two commodities under consideration have in recent times originated from a variety of legal sources that subsequently entered the illicit trade chain. These include found tusks or horn from natural mortality, tusks obtained from problem elephant control exercises, pieces not delivered to government storerooms and sold by rangers or wildlife officers, theft or leaks from government stockpiles or private collections, hunting trophies, and horn cut from tranquilized live rhinos. All of these sources can contribute to illegal exports.

Trade chains are structured in levels based on the roles of the actors in obtaining, transporting and trading a given commodity from source, through middlemen to exporters on the supply side, and importers/wholesale traders, intermediaries, distributors, processors, retail vendors and consumers on the demand side. Fig. 1 illustrates the general levels of those actors, for ivory and rhino horn trade on the African supply side, that applies to the three case studies to be described. In any particular trade situation, the levels may vary in personnel composition and nature of the transaction, but the levels can be defined.

[2]GI-TOC is an international civil society organization headquartered in Geneva, with staff and offices around the world, which focuses on research and analysis on all types of illicit markets (Stiles 2021).

Level 1—Comprising the source of the product as supplied by one of various actors, which can be the poacher or poaching gang, stockpile thief, trophy hunter, or rhino horn harvester (or his agent). These players sell or transfer the product to Level 2. An exception is rhino breeders in South Africa. They can sell illegally hunted trophy horns or rhinos they illegally killed, i.e. poached, directly to an exporter with no middleman.

There are basically two types of poachers, independent specialists who self-finance and sell to any buyer they can find, or dependent gangs who are hired and subsidized by what is termed in French *commanditaires*. These 'commanders' are Level 2, although the money to finance the hunt could originate higher up the trade chain at Level 3 or even Level 4 (Stiles 2011).

Level 1s are the most numerous and geographically widely distributed in the trade chain. They also tend to be opportunistic and ephemeral, often only supplying the product once or twice. The actor turnover is high.

Level 2—A person usually living in the vicinity of the poaching area and familiar with community leaders and members will purchase the product from the poacher(s). These players are often termed 'runners' in southern Africa, 'brokers' in East Africa, or 'commanders' in francophone Africa (if they have ordered and financed the hunt). They are the first middlemen in the trade chain. The Level 2s might also be small businessmen running a shop or restaurant, a member of law enforcement (ranking local police or wildlife ranger), a military officer, and even a clergyman (priest, pastor, imam).

Level 2s will sell (if they purchased with their own money) or transfer (if money was provided) the product to Level 3. If transferred, the Level 2 will be paid a service fee by the Level 3 (e.g. runners in South Africa). Transporters are indicated in the Facilitator box in Fig. 1. The Level 2 will aggregate products over a limited geographical area from several poaching gangs.

This level is less numerous than Level 1s and they tend to last longer than Level 1s in wildlife trafficking work.

Level 3—This level usually works at the national level and is often based in a large urban area. It may be one person or a partnership between two or more people. They will aggregate and sell the product to Level 4. They can be termed 'middleman' or 'dealer'. In some instances, this level could be the exporter, and the characteristics would be those described for Level 4 below.

There are relatively few Level 3s in a given country and they tend to specialize in the wildlife products in which they trade. They are often engaged in other businesses or lines of work and usually know influential people in politics, the military and/or business.

Level 4—This person or persons—the level might be a partnership or company—purchases the aggregated product from Level 3 and carries out the illicit packing, paperwork and export of the product in collaboration with clearing and transport company facilitators. Other facilitators can be bribable port officials, customs agents, or law enforcement officers. They may make use of specialist packers who perform what is termed a 'dragon service' (EIA 2017), making use of building stones, hollowed out logs, plastic waste, dried fish, etc. to conceal the product. These players will often be based in a city with an international airport or seaport. The horn and ivory can be shipped in containers by sea or air freight, carried by couriers by air in personal luggage or concealed on the body, or sent in packages by courier service or even in the post. Cases of the use of diplomatic bags are even known (Rademeyer 2016). This level would include players who could be called 'kingpins', and linked to importers in Asia.

Level 4s are often foreigners, usually eastern Asians, who may have other businesses in the African country of residence (e.g. hotel, restaurant, mining, timber, marine products). They have contacts in the destination countries (e.g. China, Vietnam), sometimes kin-based.

Level 5—As represented in Fig. 1 this level conflates several levels of the trade chain in the importing country. Another series of boxes in reverse could be constructed, made up of the relatively few importers, the wholesaler dealers (middlemen) who buy from the importers and distribute to the workshops or traditional medicine companies that process the products, the retail outlets or online sites that sell finished products, and finally the consumer. These levels are located primarily in the South East or East Asia (for ivory and rhino horn).

Levels 1 to 5 represent what could be termed a 'network' in which a trade chain operates. Others have used the terms 'syndicate', 'cartel' or 'mafia', but these terms imply a degree of organization and

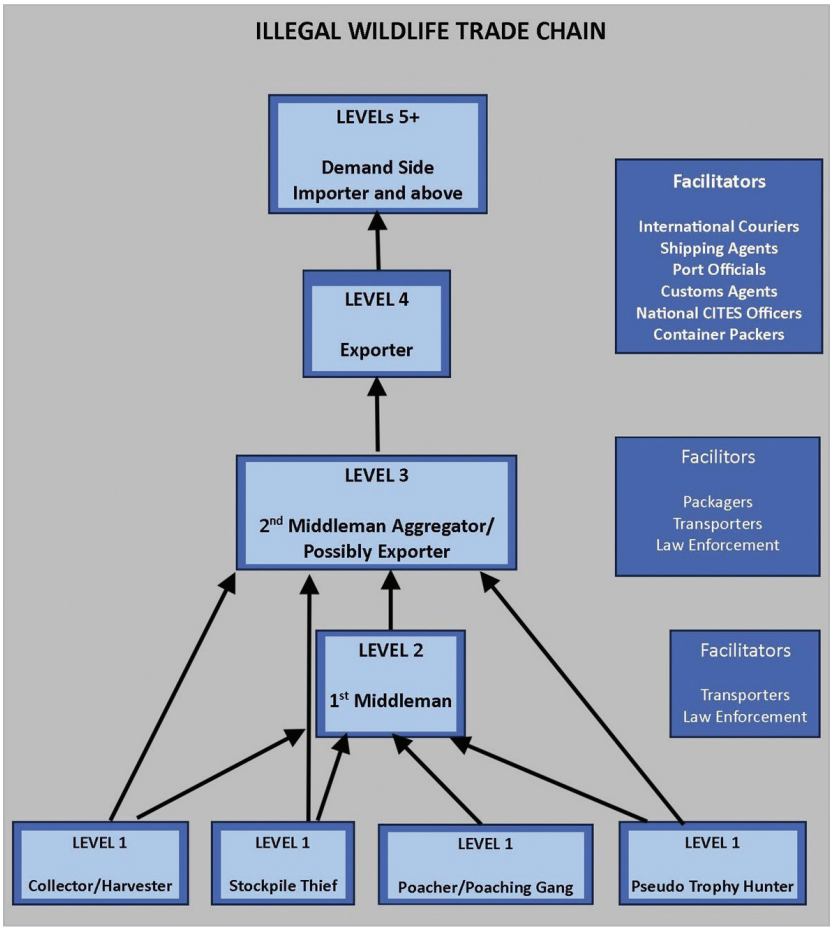


Figure 1. A schematized trade chain for ivory and rhino horn.

management that are generally absent from the flexible, transitory nature of the poaching/trafficking networks. Most often, Level 1 will not even know who the players in Level 3 and above are and vice versa.

Case study describing context: Kenya in the 1970s

Exporting ivory and rhino horn from East Africa, and Kenya in particular, was big business from the 19th century onwards (Parker 2004; Somerville 2016; 2024). On 31 May 1912, the British colonial government of Kenya decreed its laws concerning ivory:

"No ivory could be legally possessed except
(1) under the Game Laws; and
(2) purchased from Government for export."

Tusks could not be sold without a Sale Permit and trading in ivory was barred except for those in possession of a Dealer's Permit, both issued by the Game Department. A complicating factor was that a considerable proportion of available ivory was due to natural mortality (Parker and Graham 2020a). Rural people found dead elephants with tusks in the bush and from precolonial times tradition allowed these tusks to be removed and sold. So, the government created a system of providing a 'porterage fee' to anyone who brought found tusks to the Game Department, typically 10% of the commercial value of ivory. The Chief Game Warden Richard Woosnam observed presciently in 1912 (Parker and Graham 2020a):

"All we have achieved with the ivory laws is created the illegal ivory trade."

After World War II, most of the ivory and rhino horn dealers were South Asians (Parker 1974). South

Asians, along with coastal Swahili people (mixed African-Arab populations), also ran many different kinds of shops in both rural and urban areas. It was a simple matter for rural Africans who found tusks, and dead rhinos with horns, to sell them at a higher price to these Asian businessmen, who would in turn sell them to the Asian wildlife traders in Nairobi and Mombasa. The traders had Dealer's Permits and there were ways to manipulate the paperwork to export the product legally with Sales Permits, even though it had not been purchased from the Game Department. The rather more complicated trading situation than presented here can be found in Parker and Graham (2020a; 2020b).

Kenya became independent in 1963 and by about 1970 Kenyan Africans with influence were forming rather cryptic relationships with both the Game Department, now headed by an indigenous Chief Warden, and the Asian wildlife dealers. In 1970 the Game Department began issuing Collector's Permits to certain people connected with influential government individuals who were supposed to collect tusks from elephants that died naturally and receive a reward for turning them in. Rumours of extensive poaching of Kenya's estimated more than 165,000 elephants began to emerge. The collector's permits provided cover for people possessing them to trade in poached ivory (Parker 1974).

Parker (1974) documented huge increases in ivory exports from 1970 onwards in Kenya, coinciding with the issue of collector's permits, or letters issued by the Game Department allowing ivory possession and trade, and the commencement of ivory movement by air freight from Nairobi. Parker also documented unexplained large purchases of ammunition for use by Game Department rangers, suggesting that they were involved in poaching.

The income made from illegal ivory acquisition, which consisted of poached or undeclared found tusks, was distributed throughout the TOC network, with the lion's share going to those at the top, made up of senior Game Department officers and political leaders and their families.

In 1973 the government began attempts to obtain a state monopoly on ivory and corner the market, and in 1974 it banned elephant trophy hunting and all ivory exports. The international average price of ivory escalated from USD 14.75/kg in 1972 to USD 38.43/kg in 1977, showing the effect of supply uncertainty on overseas buyers (Parker and Graham 2020b). Although not well documented, similar uncertainty of rhino horn exports probably occurred, as average international prices leapt from USD 88.50/kg in 1972 to USD 230.58/kg in 1977 (Parker and Graham 2020b). The CITES Convention came into force in 1975, with African elephants listed in Appendix II and rhinos listed in Appendix I. Of the biggest importers, only Hong Kong was affected from 1976, when the UK joined, as other countries joined the agreement later, so CITES had little affect on the price rises from 1972 to 1977.

The largest ivory exporter was the United Africa Corporation, which continued exporting ivory even after the declared ivory export ban in 1974, including 50 tonnes to China (Tinker 1975). The daughter and wife of a high-office political elite had prominent roles in the ivory trade, the former controlled the United Africa Corporation, and the latter allegedly used a large sum of money generated from illegal enterprises to purchase 21 properties in cash in 1973–1974 in London. She also accumulated vast tracts of land in Kenya and used government power to steal a lucrative gemstone mine from an American investor (Hardin 1987).

In 1977 Kenya banned all hunting and in 1978 banned the possession and sale of any wildlife products, although permits could be obtained for private ownership of wildlife items owned before the 1978 ban.[3]

In terms of the levels in Figure 1, the actors in the 1970s ivory and rhino horn TOC network extending into the 1980s would have been the following:

Level 1—Game Department rangers, poachers and rural people who found natural mortality elephant and rhino carcasses.

Level 2—Game Department officers, who would aggregate tusks or rhino horn found or poached in communal areas or private lands, and Kenyan national park wardens who would aggregate found ivory and rhino horn from protected areas. Both transferred the

[3]The Convention on International Trade in Endangered Species of Wild Fauna and Flora banned international trade in rhino horn from all five species in 1977, but the Convention's provisions did not come into effect in Kenya until December 1979.

ivory/horn to the Game Department. Those with Collector Permits or Game Department letters authorizing 'collecting' and possession would turn the product/s into the Game Department for reward. Much of this came from illegally killed pachyderms (and other wildlife). Asian shopkeepers who illegally bought ivory and rhino horn from poachers in rural areas would sell it on to Asians who held legal dealer's permits.

Level 3—Kenya Game Department. They aggregated all the ivory and rhino horn from poaching, natural mortality, problem animal control, etc. and sold it on, ostensibly legally, to Level 4s.

Level 4—Those with Dealer and Sales Permits who purchased ivory and rhino horn from the Game Department for export. One of the main Level 4s was the United Africa Corporation.

Up to 1978 in Kenya, the trade chain comprised both legal and illegal ivory and rhino horn. After 1978, all wildlife products exported from Kenya were therefore illegal and were smuggled out. Poaching of pachyderms continued relentlessly and by 1989 Kenya's elephants were down to an estimated 16,000 (Thouless et al. 2008), a loss of more than 90% of the population from 1970. The number of black rhinos decreased proportionally even more, from an estimated 20,000 in 1970 to an estimated 550 animals in 1984 (Western and Vigne 1985).

A state-controlled wildlife trafficking TOC network came close to wiping out Kenya's pachyderms in the 1970s and 1980s.

Case Study 1 illustrating operations—the Kromah Network, 2010–2017

The Kromah TOC network was briefly described in Stiles (2022a). According to a statement made by Moazu Kromah to the Ugandan police after his arrest in 2017 for possession of 1.3 tonnes of ivory, cutting machines and packing materials in his house, he left his birth country of Liberia in 1990 and after a period in a refugee camp in Guinea, he entered Uganda in 1995 from Ariwara, DRC, to Arua, then on to Kampala. These towns, along with nearby Aru, have been active illicit goods smuggling centres for decades, especially ivory and gold (Vira and Ewing 2014; Titeca 2018).

Kromah probably became involved in ivory and possibly rhino horn trafficking in the north-east DRC in the early 1990s. Apobo (2004) describes in detail how officers in the DRC national army were behind the poaching of large numbers of elephants in north-eastern DRC during this period and into the 2000s. Poached ivory also came from southern Sudan and the Central African Republic. The northern white rhinos (*Ceratotherium simum cottoni*) in Garamba National Park were heavily poached during this period, down to only four survivors by 2005 and by 2008, none were left (Hillman Smith 2018). Most of the illicit products came into Uganda via Aru to Arua, and were then moved to Kampala.

Kromah began working for an influential Malian in Kampala, who smuggled in ivory and diamonds from the DRC (confidential informant-1 (CI-1), pers. comm., 2023). A large West African population of businessmen (mostly from Mali, Guinea and Senegal) developed over the 1990s and 2000s in Uganda. They were mainly traders who dealt in a wide variety of products, including illegal wildlife. They operated out of shops, often in malls, especially Ovino Mall in Kampala, where Kromah had a shop, which supposedly sold shoes (Kromah's 2017 police statement and CI-1, pers. comm., 2023).

In the late 2000s, Kromah became more independent and built his own TOC network, while remaining in contact with the other West Africans in Uganda. By 2010, it would appear that Kromah's network was established to traffic ivory from Kampala to both Jomo Kenyatta International Airport in Nairobi and Kilindini Harbour, Mombasa's seaport, and overseas to eastern Asia (Morris 2010). Between 2010 and 2017 more than 20 seizures of ivory, pangolin scales, and rhino horn were made, linked to Ugandan and/or Kenyan export locations that are believed to have involved Kromah (for many of them, see GI-TOC 2022).

In many of the seizures, the same names were given of clearing and forwarding agents, shipping agents, transport companies, and the same Kenya Revenue Authority agents were involved in multiple cases. Some were arrested, but the prosecution outcomes have been disappointing (Stiles 2022b). In many of the most significant court cases, the same defense lawyers represented the various defendants. This suggests that Kromah and his assistants had put together teams of facilitators in Uganda and Kenya to

traffic wildlife products out of Africa. By 2015, evidence existed that Kromah had collaborators, some West Africans, working for him in Mozambique buying and smuggling out ivory, rhino horn and big cat parts. He was a supplier for South East Asian wildlife dealer companies such as Vixay Keosavang's Xaysavang Trading, Vannasang Trading and Vinasakhone Trading, all based in Laos (Davies and Holmes 2016), and he occasionally travelled to Thailand and Laos to meet with some of them. Loy Chantamvongsa, named as a 'fixer' for the South East Asian TOC network in Davies and Holmes, was Kromah's main contact (CI-2, pers. comm., 2021).

Seized ivory DNA analysis showed that most of Kromah's ivory originated in southern Tanzania, northern Mozambique and Kenya, with some from Zambia and north-east DRC (Wasser et al. 2022). There is no evidence that Kromah's network included Level 1 actors, therefore, he had to buy ivory from Level 2 actors or higher. This suggests that Kromah had at least three suppliers for his ivory: the Yang-Shuidong network (based in Tanzania, after 2015 in Mozambique), the Hsieh-Wang/Lin-Zhang network (based in Malawi) and DRC Congolese suppliers in the north-eastern of the country. Some of Kromah's Guinean relatives and close associates have been arrested for possession of ivory in Kenya and Tanzania, adding credence to the aforementioned (Stiles 2023); and a Ugandan CI told the author that West Africans have purchased ivory and rhino horn from Chinese suppliers in Malawi (CI-1, pers. comm., 2023). Ivory which was stolen from the 87-tonne Burundi government stockpile has been found in at least four seizures associated with Kromah, another source of his ivory (Morris 2021). It is unknown how much ivory remains in the original stockpile, but a Burundian government official is still selling this ivory to a businessman who supplies the Burundian army with food and other goods at prices as low as USD 50 per kg. The government official, in turn, has been selling it on to West Africans at a negotiated markup (CI-1, pers comm., September 2024). See Milledge and Nuwamanya (2004) for a history of the creation of the Burundi stockpile.

The hypothesized operation of Kromah's TOC network along the trade chain is described below:

1. Kromah operatives purchased wildlife products from the sources named above and transported them to Kampala, where they were packaged and containerized for transport by lorry to Nairobi or Mombasa. Some, mostly raw ivory, was transported from parts of Kenya and Tanzania directly to Mombasa or Nairobi, as many smaller ivory seizures have been made in a wide radius around these cities. Ivory was also leaked from the Burundi government stockpile and transported to Kampala.
2. The ivory and occasionally other illicit wildlife goods were transported in sealed containers by lorry to Nairobi or Mombasa. If the shipment was less than a tonne, it could be transported in an empty water tanker truck (Morris 2014) or another vehicle. In 2014, Feisal Mohammed Ali was arrested and in 2016 convicted of transporting 2.2 tonnes of ivory in a container from Kampala to Mombasa. (In 2018, the conviction was overturned on appeal (Karani 2018)). In 2015, two large seizures were linked to companies owned by the son of another of East Africa's Presidents (Morris 2020).
3. Once in Nairobi, the ivory would be secreted in private houses for repacking in air transport crates. Kromah had corrupt facilitators working at the airport to assist in the loading of the crates onto flights that would eventually end up in eastern Asia. Based on seizures, Turkish and Qatar Airlines were the preferred carriers. Not all of the shipments made it through successfully (e.g. Morris 2010; 2023a). If Mombasa was the destination, the containers would eventually make their way into the port through the efforts of the facilitator team there, which could include repacking into new containers with different cover loads and paperwork. There is evidence that at least one private house was used for aggregating ivory that was probably accumulated from smaller packets of poached tusks from Tanzania and Kenya and transported to Mombasa to be put together into containers for shipping (Morris 2023b). Cover materials for concealment have included dried fish, plastic waste, coffee, tea, hollowed-out logs, timber planks and stones for construction.
4. Whether transported by air or sea, the ivory most often ended up in South East Asia, Hong Kong or China. Malaysia and Singapore were common

transit points where wildlife products would often change ship or plane and assume new shipping documents to conceal the African origin of the cargo, lowering the risk of a seizure. A Malaysian Chinese named Teo Boon Ching was involved in the transit handling of many illicit wildlife shipments before his arrest in 2022 (Anon. 2022). If the destination was South East Asia, the individuals described in Davies and Holmes (2016) and EIA (2018) would receive the product.

5. Once in Asia, the buyers would sell the raw ivory, rhino horn, or other products on to middlemen distributors or directly to workshops that would process the product into retail items for sale to consumers. A middleman ivory and rhino horn distributor in Vietnam is described in WJC (2022a).

Case Study 2 illustrating the operations of the Xaysavang Network in southern Africa, 2005–present

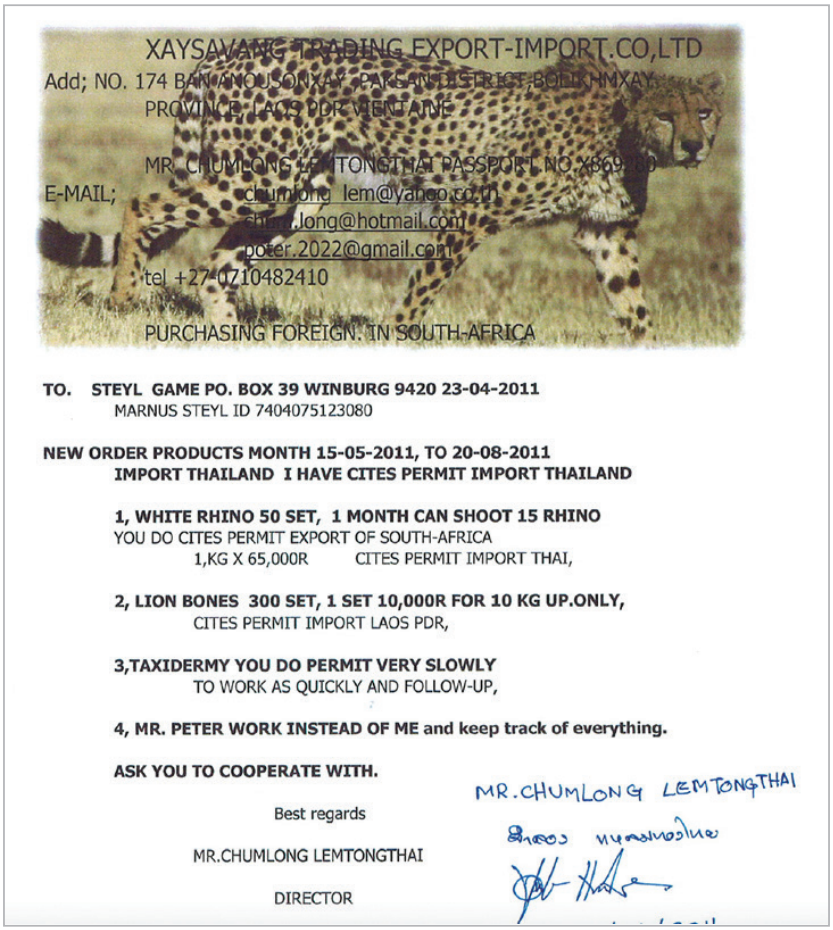
This case example will focus on rhino horn trafficking in South Africa. The 'pseudo-hunting' rhino TOC network operations that were in place from 2003 until 2011 have been inextricably linked to the trade in lions, both live and derivative products, mainly bones (Rademeyer 2016). South Africa differs from most other African countries in that private landowners with secure fencing can own wildlife on their property and have the right to derive income from consumptive utilization, including the killing and sale of live wild animals or their products (Lindsey et al. 2007). The game ranching industry expanded greatly between the late 1960s and 1990s when successive laws gave private landowners ever-expanding utilization rights. Lions and rhinos were first bred on game ranches for the trophy hunting industry (Lindsey et al. 2007) and live sales were made to other ranchers or zoos (Scriven and Eloff 2003). In the early 2000s, newcomers from South East Asia transformed the exploitative business model of South Africa's commercial wildlife trade.

Tiger bone and rhino horn have a long history of use in eastern Asia in traditional Chinese medicine (TCM) (Milliken and Shaw 2012). In Vietnam and China, in particular, demand in the early 2000s began to outstrip supply. Tiger bones, with a few exceptions, are indistinguishable from lion bones. It is legal to export hunting trophies for non-commercial purposes from countries where hunting is legal. CITES and national laws of South Africa, South East Asian countries and China permit the export and import of hunting trophies, even of Appendix I rhinos, (limited numbers of Appendix I black rhinos (Diceros bicornis) and Appendix II white rhinos (*Ceratotherium simum*), as long as local regulations are respected.

The first of what became known as 'pseudo-hunts' took place on a private game ranch in South Africa in 2003, with Vietnamese 'hunters'. Rhino horn trophies were legally exported with CITES permits to Vietnam to be kept as a trophy by the hunter, but it is suspected that the horns entered the illicit market (Rademeyer 2016). In the same year, a Bangkok fruit seller with ambitions to trade wildlife named Chumlong Lemtongthai met with the brothers Bach Mai (aka Boonchai) and Bach Van Limh, both traffickers. Chumlong knew where to source African rhino horn and South East Asian tiger bone. He began supplying the Bach brothers and later established a relationship with a large Laos animal trading company, Xaysavang Trading, established by Vixay Keosavang in 2002. By 2005, Chumlong was finding it harder to obtain everything he needed in Thailand, and he moved to South Africa, where he became the official representative of Xaysavang Trading (Davies and Holmes 2016).

Chumlong began meeting South African game ranchers who owned lions and rhinos and found a large number of receptive business partners willing to supply him with 'lion bone sets' (i.e. the entire skeleton) and 'hunted' rhino horn trophies. One, named Marnus Steyl, became a 'finder' for Chumlong to locate ranch owners willing to supply the desired products. Chumlong would make formal orders for Steyl to fulfil (Fig. 2).

The rhino horn was supplied—ostensibly legally—through trophy hunting on participating game ranches. Some ranches carried out their own hunts, finding clients who were deceived into believing that they were shooting 'problem animals' and told that the horns could not be taken as trophies. Clients paid reduced fees and could only take home photos of themselves with the dead rhino. The horns ended up with Chumlong. Chumlong began to carry out his own


XAYSAVANG TRADING EXPORT-IMPORT.CO,LTD
Add; NO. 174 BANANOUSONXAY ,PAKSAN DISTRICT,BOLIKHMXAY
PROVINCE, LAOS PDR VIENTIANE
MR. CHUMLONG LEMTONGTHAI PASSPORT NO.X869[illegible]
E-MAIL; chumlong_lem@yahoo.co.th
chum.long@hotmail.com
peter.2022@gmail.com
tel +27 0710482410
PURCHASING FOREIGN. IN SOUTH-AFRICA

TO. STEYL GAME PO. BOX 39 WINBURG 9420 23-04-2011
MARNUS STEYL ID 7404075123080

NEW ORDER PRODUCTS MONTH 15-05-2011, TO 20-08-2011
IMPORT THAILAND I HAVE CITES PERMIT IMPORT THAILAND

1, WHITE RHINO 50 SET, 1 MONTH CAN SHOOT 15 RHINO
YOU DO CITES PERMIT EXPORT OF SOUTH-AFRICA
1,KG X 65,000R CITES PERMIT IMPORT THAI,

2, LION BONES 300 SET, 1 SET 10,000R FOR 10 KG UP.ONLY,
CITES PERMIT IMPORT LAOS PDR,

3,TAXIDERMY YOU DO PERMIT VERY SLOWLY
TO WORK AS QUICKLY AND FOLLOW-UP,

4, MR. PETER WORK INSTEAD OF ME and keep track of everything.

ASK YOU TO COOPERATE WITH.

Best regards

MR.CHUMLONG LEMTONGTHAI

DIRECTOR

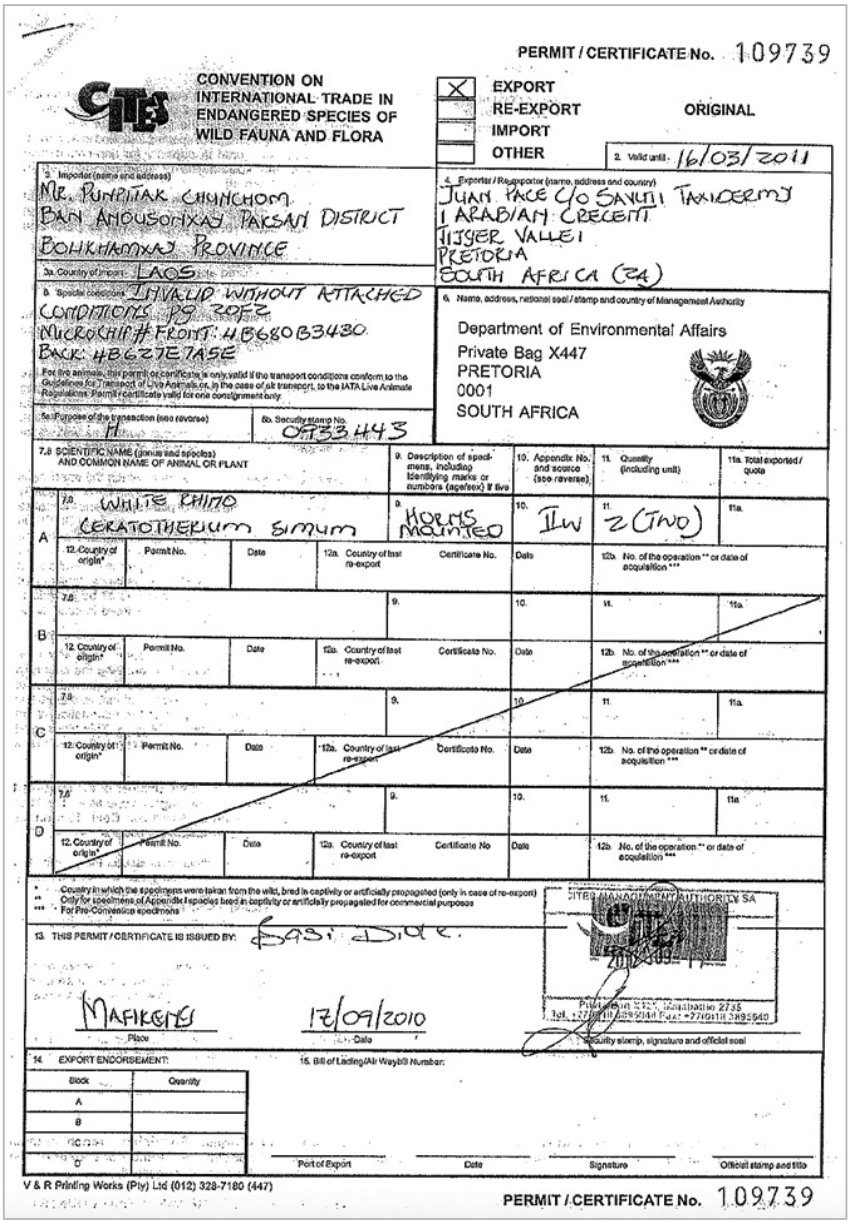
MR.CHUMLONG LEMTONGTHAI

Figure 2. In the above document, an order was sent from Chumlong to Steyl for the procurement of 50 rhino horn sets (front and back horns) and 300 lion bone sets. (ZAR 65,000 equivalent to USD 9,000; ZAR 10,000 equivalent to USD 1,385, 22.08.2011).

hunts, using his Thai associates and even Thai sex workers from Johannesburg to put their names on the hunting permits and CITES export permits. The rhinos were actually shot by professional hunters, but several photos of young Thai women posing as hunters were taken (Rademeyer 2016). The horns were shipped to Thailand with CITES permits (Figs. 3 and 4).

Chumlong continued to supply the Bach brothers, one of whom was based in Nakhon Thanom in north-east Thailand on the Mekong River opposite Laos, and the other in Son Tay in Laos on the border with Vietnam. These illicit products would arrive in Thailand or Laos and be transported to Vietnam, with the assistance of Loy Chantamvongsa. Chumlong also supplied Xaysavang Trading until his arrest in June 2011. He was sentenced to 40 years in prison in 2012, later reduced to 13 years on appeal. Bach Van Limh allegedly offered USD 600,000 to a key official in Johannesburg to release him, which initially failed (Davies and Holmes 2016), but Chumlong's early release in 2018 suggests that the bribe may eventually have worked.

Chumlong's laptop contained a wealth of documents, videos and photos that incriminated Vixay Keosavang, the Bach brothers, Marnus Steyl and other South African game ranchers, trophy hunters and Thai associates of Chumlong in the illegal shooting of rhinos and the trafficking of their horns. Freeland, an NGO based in Thailand, had been investigating the Bach brothers and Vixay Keosavang for some time and shared their information with the US government. The result was that the US Department of State in late 2013 offered a reward of up to USD 1 million leading to the


PERMIT / CERTIFICATE No. 109739

CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA

EXPORT
RE-EXPORT
IMPORT
OTHER

ORIGINAL

2. Valid until: 16/03/2011

1. Importer (name and address)
MR. PUNPITAK CHUNCHOM
BAN AMOUSORIXAY PAKSAN DISTRICT
BOLIKHAMXAY PROVINCE

4. Exporter / Re-exporter (name, address and country)
JUAN PACE C/O SANUTI TAXIDERMY
1 ARABIAN CRESCENT
TIGER VALLEY
PRETORIA
SOUTH AFRICA (ZA)

3a. Country of import: LAOS

5. Special conditions: INVALID WITHOUT ATTACHED CONDITIONS PG 20F2
MICROCHIP # FRONT: 4B680B3480
BACK: 4B627E7A5E

For live animals, this permit or certificate is only valid if the transport conditions conform to the Guidelines for Transport of Live Animals or, in the case of air transport, to the IATA Live Animals Regulations. Permit / certificate valid for one consignment only.

6. Name, address, national seal / stamp and country of Management Authority
Department of Environmental Affairs
Private Bag X447
PRETORIA
0001
SOUTH AFRICA

4. Purpose of the transaction (see reverse): H

5b. Security stamp No. 0733443

	7.a SCIENTIFIC NAME (genus and species) AND COMMON NAME OF ANIMAL OR PLANT	9. Description of specimens, including identifying marks or numbers (age/sex) if live	10. Appendix No. and source (see reverse)	11. Quantity (including unit)	11a. Total exported / quota
A	7.a WHITE RHINO CERATOTHERIUM SIMUM	9. HORNS MOUNTED	10. IIW	11. 2 (TWO)	11a.
B	7.a	9.	10.	11.	11a.
C	7.a	9.	10.	11.	11a.
D	7.a	9.	10.	11.	11a.

	12. Country of origin*	Permit No.	Date	12a. Country of last re-export	Certificate No.	Date	12b. No. of the operation ** or date of acquisition ***
A							
B							
C							
D							

* Country in which the specimens were taken from the wild, bred in captivity or artificially propagated (only in case of re-export)
** Only for specimens of Appendix I species bred in captivity or artificially propagated for commercial purposes
*** For Pre-Convention specimens

13. THIS PERMIT / CERTIFICATE IS ISSUED BY:

SITES MANAGEMENT AUTHORITY SA

MAFIKENG — Place
17/09/2010 — Date
Authority stamp, signature and official seal

14. EXPORT ENDORSEMENT:

Block	Quantity
A	
B	
C	
D	

15. Bill of Lading/Air Waybill Number:

Port of Export | Date | Signature | Official stamp and title

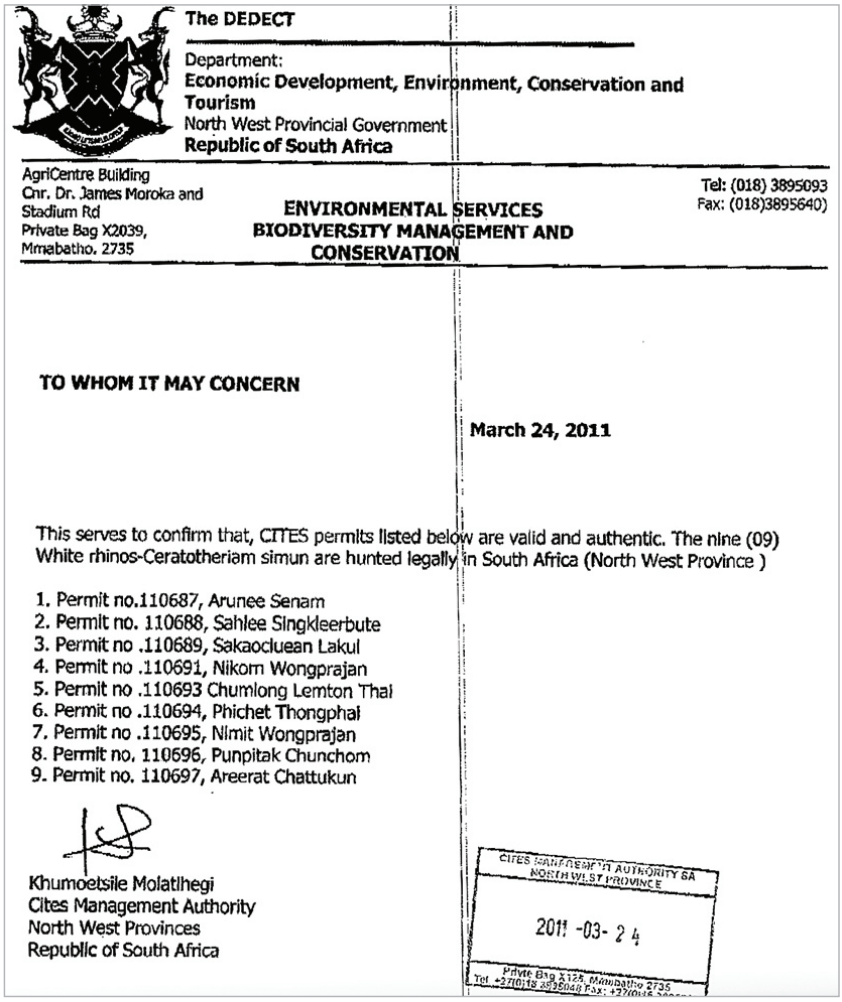
V & R Printing Works (Pty) Ltd (012) 328-7180 (447)

PERMIT / CERTIFICATE No. 109739

Figure 3. Punpitak Chunchom, aka Peter, was a Thai who assisted Chumlong with the supply of lion bone and rhino horn.

dismantling of the Xaysavang network. Vixay withdrew from wildlife trafficking operations and was replaced by two other Laos companies, Vannaseng Trading and Vinasakhone Trading, mentioned above in the Kromah Network section. Marnus Steyl and others implicated in illegal rhino killing by Chumlong's laptop evidence were never prosecuted (Rademeyer 2012).

With Chumlong and the pseudo-hunter operation closed, the Xaysavang Network adapted its operations to begin buying rhino horn from a variety of sources, both in South Africa and Mozambique. Other criminal groups were continuing with pseudo-hunts, such as the Groenewald brothers (Hübschle and Salamanca 2017), Chu Dang Khoa (Rademeyer 2016), Hugo Ras (Rademeyer 2016), and others. Some of the game ranchers with rhinos were also staging poaching incidents, but illicitly selling the horns they



The DEDECT

Department:
Economic Development, Environment, Conservation and Tourism
North West Provincial Government
Republic of South Africa

AgriCentre Building
Cnr. Dr. James Moroka and
Stadium Rd
Private Bag X2039,
Mmabatho. 2735

Tel: (018) 3895093
Fax: (018)3895640)

ENVIRONMENTAL SERVICES
BIODIVERSITY MANAGEMENT AND
CONSERVATION

TO WHOM IT MAY CONCERN

March 24, 2011

This serves to confirm that, CITES permits listed below are valid and authentic. The nine (09) White rhinos-Ceratotheriam simun are hunted legally in South Africa (North West Province)

1. Permit no.110687, Arunee Senam
2. Permit no. 110688, Sahlee Singkleerbute
3. Permit no .110689, Sakaocluean Lakul
4. Permit no .110691, Nikorn Wongprajan
5. Permit no .110693 Chumlong Lemton Thai
6. Permit no .110694, Phichet Thongphai
7. Permit no .110695, Nimit Wongprajan
8. Permit no. 110696, Punpitak Chunchom
9. Permit no. 110697, Areerat Chattukun

Khumoetsile Molatlhegi
Cites Management Authority
North West Provinces
Republic of South Africa

CITES MANAGEMENT AUTHORITY SA
NORTH WEST PROVINCE
2011 -03- 24
Private Bag X125, Mmabatho 2735

Figure 4. Chumlong also participated in these pseudo-hunting deceptions. Note that there is a second rhino for Punpitak. Nikorn Wongprajan (aka Wongchan) worked at Bangkok's Suvarnabhumi Airport and is accused of picking up a case containing rhino horn and bypassing a Customs check before passing it on to a Vietnamese courier (Chayutworakan 2017).

claimed poachers had taken. Another source was harvested horns sawn off tranquilized rhinos, operations which were carried out to protect rhinos from being poached, as well as harvesting programmes such as conducted at the Platinum Rhino Project (previously Buffalo Dream Ranch) (AfRSG 2023). These horns were supposed to be microchipped, registered with the RhODIS database and stored away securely (Harper 2011), but a certain proportion were being sold before registration. After South Africa allowed the legal domestic sale of rhino horn in 2017, even some registered horn was sold and exported illicitly (EMS and BAT 2018; WJC 2022b).

Rhino horn was also obtained from rhinos poached in national parks and reserves in South Africa and neighbouring countries. Kruger NP and Hluhluwe-iMfolozi GR in South Africa were the main rhino poaching locations, with notorious Level 2 brokers such as Dumisani Gwala (EIA 2023), Petros 'Mr Big' Mabuza, Joseph 'Big Joe' Nyalungu and in Mozambique Simon Ernesto Valoi (aka Navara) selling large numbers of horns bought off the poaching gangs to whomever offered the money (EMS 2021; Valoi 2022).

Intelligence sources indicate that at least by 2015, possibly earlier, elements of the Kromah Network began operating in collaboration with the Xaysavang

Network in Mozambique, buying and smuggling rhino horn, ivory and big cat parts to South East Asia. Moazu Kromah and Loy Chantamvongsa travelled to Mozambique several times, and Kromah's sister and other West Africans took up residence in Maputo, Mozambique's capital (Freeland, in litt., 2021), but Nampula was also used to export wildlife products. Teo Boon Ching handled the transport of many of the larger, non-courier shipments from southern Africa as he had for those from eastern Africa (Nuwer 2023).

Rhino horn poached in Kruger NP was often transported through Massingir in Mozambique, where Navara was based, to Maputo. Horn from all other sources, including stockpile thefts and leakages, also appeared in South Africa and Mozambique (EMS 2021; 2024), where the Xaysavang–Kromah network smuggled it to Vietnam, using a variety of air routes and shipping methods, including couriers and unaccompanied luggage. Vietnamese and Chinese traffickers not associated with Xaysavang also operated in South Africa and Mozambique, but due to the clandestine nature of the business, it is not possible to assess their relative importance in exporting wildlife products.

One of the main receivers of illegal rhino horn was the village of Nhi Khe, near Hanoi, in northern Vietnam. By 2014 Nhi Khe had developed into a major processing and marketing centre for products made of rhino horn, ivory and big cat parts. When the Wildlife Justice Commission investigated it in 2014 it estimated that it found products representing 573 rhinos (Stoner et al. 2017). Busloads of Chinese tourists came every day to Nhi Khe to stock up on wildlife products to take home, and several traffickers sold products online from Nhi Khe. Chinese dealers also came to this village to buy ivory items wholesale and smuggled suitcases of trinkets and carvings home to mainland China for illegal sale (Vigne and Martin 2016; 2018). From 2010 to late 2020, when Covid-19 effectively closed down Nhi Khe, horn products from thousands of rhinos must have been sold.

In 2017 Boonchai Bach was arrested at his base in north eastern Thailand, receiving 14 rhino horns in a controlled delivery sting. Corruption delayed his prosecution, but finally he was convicted and sentenced to five years in prison in September 2022. Boonchai absconded and his whereabouts are still unknown (Nuwer 2023; Steven Galster, pers. comm., June 2023). The Kromah Network was disrupted by the conviction of Kromah and his associates in 2021 and 2022 (Stiles 2022a) and Teo Boon Ching was arrested, prosecuted and sentenced to 18 months in September 2023 in the US (WJC 2023).

Moazu Kromah was released from prison in the US on 1 December 2023 and four others prosecuted with him will be released in 2024 and 2025. Ching will probably be released before the end of 2024. The current status of operations of the Xaysavang network is unknown, but elements of it are no doubt continuing wildlife trafficking. Will it reconstitute itself?

Discussion

According to the investigations of Parker (1974) and Tinker (1975), in the 1970s there was clearly presidential involvement, and their families and political elites were directly behind the state-sanctioned pachyderm poaching and product trafficking.

For the 2008–2017 'poaching crisis' years that the Kromah and Xaysavang networks were operating, the evidence is less clear of the involvement of a highly organized criminal State. In eastern Africa, there is evidence that points to relatives of Idi Amin, President of Uganda 1971–1979, and the brother of the current Ugandan president being involved in ivory and other trafficking, and of connections to Arua. The brother of the Ugandan president, a former army commander, was specifically implicated in a report by the UN Security Council that he was involved in the illegal exploitation of natural resources, including ivory, from DRC during the 1998 civil war in the east (Anon. 2003). Ugandan troops did not return from the DRC to Uganda until 2003. CI-1 (pers. comm. 2023) alleged that both were involved in trafficking ivory and other illicit products from South Sudan and the DRC to Kampala and using West Africans to export them.

Titeca (2018) states that international West African traffickers in Kampala had high-level government and military connections and that officials in the Uganda Wildlife Authority were also allegedly corrupt and involved in ivory trafficking, mainly from the DRC. Informants told Titeca that Ugandan army soldiers were involved in elephant poaching in the DRC 2008–2012, when they were there chasing the Lord's

Resistance Army, and that army lorries were transporting poached tusks from the DRC to Kampala. However, no direct connection has been established linking the trafficking of the Ugandan army to individuals related to former and current Ugandan presidents.

Titeca (2018) concluded: "My findings, based on the research among illegal ivory traders in Uganda, aimed to unpack the transnational organization of the illegal ivory trade. Empirical understanding …. suggests that a transnational organization—a 'criminal syndicate' or 'gang' is responsible for this [ivory] trade".

In Kenya, there are reports linking various relatives of recent presidents to ivory and rhino horn trafficking (Kenya Times 2014; Anon. 2016; Morris 2022; Stiles 2022b), but no allegations of direct presidential involvement. UNODC (2013) concluded that transnational organized crime was involved in ivory trafficking in eastern Africa, but their report did not provide details of the actors involved.

In southern Africa, systemic corruption and State actors linked to wildlife crime have been extensively reported in both South Africa and Mozambique (Rademeyer 2023; Mahadevan and Nelson 2022), but no high-level political leader has been named as directly involved in the trafficking of ivory or rhino horn. In Zimbabwe, however, the wife of the former president was allegedly deeply involved in ivory and rhino horn trafficking (Somerville 2018; Thornycroft 2018). As in eastern Africa, anyone with the right connections or sufficient bribe money—or both—could operate. For example, Dawie Groenewald and associates were arrested in 2010 for rhino horn trafficking. Their trial has been postponed more than 30 times and Groenewald was re-arrested in 2021 while out on bail in possession of 19 illegal rhino horns, but he is still out on bail (Stoltz 2021). Groenewald's trial has been postponed again until 9 February 2026 (Viljoen 2024).

While progress has been made in identifying and disrupting the operations of TOC networks for wildlife products, there is much more to do. Education for Nature Vietnam states that there are currently at least 14 known 'kingpins' behind the trafficking of large amounts of ivory, rhino horns, and pangolin scales into, or through Vietnam and China (ENV 2023).

Conclusions

From the evidence gathered to date, the biggest difference between the ivory and rhino horn trafficking organization of the 1970s in Kenya compared with the 2010s Kromah and Xaysavang networks is the degree of direct, high-level State control over the operations. In the 1970s, the most senior government officials exerted a higher degree of direct involvement in and control over the supply of ivory (and rhino horn) and its export than existed in the 2010s Kromah and Xaysavang networks, which operated over a much wider area in eastern and southern Africa.

Wildlife trafficking in the current millennium operates within a culture of corruption as the norm. It is fluid and ever adapting, in which anyone with influence and money can traffic wildlife products with impunity. Even if named in the media and prosecuted in the courtroom, those with connections to the right people or with enough money to bribe can stall court cases indefinitely, have them dismissed, be acquitted, or if the international spotlight is too bright, be convicted and pay a court fine to go free. Even if extradited to the US and convicted, the sentences to date have been light.

The UNCAC and UNTOC were created to prevent governments from perpetrating transnational organized crime, but as GI-TOC observed at the UNCAC 10th Conference of the States Parties: "…. *the situation is critical and things have gotten worse, not better*" (GI-TOC 2023a).

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Pleistocene fossil elephant tracks in the Addo Elephant National Park, South Africa

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Abstract

Fossilized elephant tracks, along with other vertebrate tracks, have been identified at several sites in the coastal Woody Cape section within the Addo Elephant National Park, in South Africa's Eastern Cape Province. The tracks occur in aeolianites (cemented dunes). The track-bearing unit has been dated to 126 ± 8 ka, at approximately the boundary between the Middle Pleistocene and Late Pleistocene. In all probability, the trackmaker was the African savannah elephant (*Loxodonta africana*). Viewed in conjunction with the thirty-five elephant track sites that have been identified on South Africa's Cape south coast, a widespread Pleistocene elephant presence can be inferred, which is not obvious from the body fossil record. Collaboration with Park management is aimed at developing an interpretive exhibit, which can be complemented by the physical recovery and exhibition of suitable fossilized elephant tracks or the creation of replicas using photogrammetry data.

Résumé

Des empreintes fossilisées d'éléphant ainsi que des traces d'autres vertébrés, ont été identifiées sur plusieurs sites de la zone côtière de Woody Cape, dans le parc national des éléphants d'Addo (province du Cap oriental en Afrique du Sud). Les marques, visibles sur des aeolianites (dunes cimentées), se situent dans une zone qui a été datée à -126 000 ans (± 8 000 ans), soit approximativement au passage du Pléistocène moyen au Pléistocène supérieur. Selon toutes probabilités, le propriétaire des empreintes était un éléphant de savane (*Loxodonta africana*). Si l'on examine ces marques conjointement à celles identifiées dans les trente-cinq autres sites présentant des traces d'éléphants sur la côte méridionale sud africaine, on peut en déduire que ces animaux étaient présents dans l'ère du Pléistocène, bien qu'on ne puisse l'étayer sur la base d'ossements retrouvés dans cette région. Une exposition didactique, en collaboration avec les gérants du parc, est attendue et pourra être enrichie des pièces fossiles originales ou de répliques créées à l'aide de données photogrammétriques.

Introduction

Through the Cape South Coast Ichnology Project, more than 350 vertebrate Pleistocene track sites have been identified along 350 km of South African coastline (Helm 2023). 'Ichnology' refers to the study of tracks and traces. Three published works have documented aspects of elephant tracks: they were shown to be potential precursors of potholes (Helm et al. 2021), the first elephant trunk drag impressions in the global record were described (Helm et al. 2022), and a possible trace fossil signature of seismic communication between elephants was reported (Helm et al. 2024). Thirty-five elephant track sites were identified, indicating the presence of regional elephants from Marine Isotope Stage MIS 11 (~400 ka) through MIS 5 (~130–80 ka) to MIS 3 (~35 ka) (Helm et al. 2022). One site, in the Robberg Nature Reserve, exhibited some of the largest Cenozoic tracks ever identified (Helm et al. 2019).

This prevalence of elephant track sites can be contrasted with the paucity of elephants in the regional body fossil record. Only two unpublished Pleistocene records from the Cape south coast are known, both from Cape Vacca: elephant bones were found in a palaeosol in the 1980s and reportedly dated to ~120 ka (Fred Orban, pers. comm., 2020), and possible elephant tusk fragments were identified in 2015 (Frikkie Orban, pers. comm., 2020). Similarly, the only localities in Eastern Cape Province from which Pleistocene elephant bones have been reported are the Klasies River 'Main Site', (Klein 1976; Avery 2019) and near Oyster Bay (Carrión et al. 2000), in both cases in Middle Stone Age layers. Evidence for a more recent widespread elephant presence in southern Africa (Carruthers et al. 2008) includes archaeological sites (Plug and Badenhorst 2001), the rock art record (e.g. Paterson 2007), and place names (Möller 2017).

This discrepancy has been attributed to the 'schlepp effect', whereby the likelihood of a carcass not being transported is related to the size of the animal, with consequent under-representation of larger animals in the body fossil record (Perkins and Daly 1968), as many southern African Pleistocene skeletal records are from archaeological sites. Similar explanations have been advanced by Parkington and Poggenpoel (1971) and Thackeray (1979), who suggested that large animals were butchered and prepared before returning to camp. Likewise, Badenhorst et al. (2021) commented on the paucity of rhinoceros remains from the Middle Stone Age (MSA), suggesting that large carcass size inhibited portability.

In contrast, the track record does not display this bias, and the tracks of large, heavy animals are identifiable with relative ease. In suitable palaeo-settings the ichnological record can thus be a more reliable guide to the presence of Pleistocene large animals in southern Africa. While the proboscidean fossil record is complex, extending back to the Paleocene (Shoshani 1998), the most plausible candidate for the Cape coastal Middle to Late Pleistocene tracks is the African savannah elephant (*Loxodonta africana*). The latest reported occurrence of earlier representatives of the *Loxodonta* genus, such as *L. atlantica*, is ~400 ka (Klein et al. 2007; Carruthers et al. 2008).

Over time we have expanded our documentation of Pleistocene vertebrate track sites, both temporally (into the Pliocene) and spatially, to South Africa's west coast and south-east coast. The latter involved exploration of the coastal portion of the Addo Elephant National Park (AENP) in the Eastern Cape Province (Fig. 1). The AENP was proclaimed in 1931 (with an initial size of just over 2,000 ha) to protect the remaining Addo elephants (Grobler and Hall-Martin 1982; Reardon 2021). The size of the Park has expanded to the current 360,000 ha, which includes the coastal Woody Cape (this section was added in 2002), making it the third largest national park in South Africa (Reardon 2021). The purpose of this field note is to describe the Pleistocene elephant tracks that have been identified in the AENP, and to discuss the potential for education and interpretation.

Geological context

The 10-km stretch of coastal cliffs (Fig. 2) in the remote Woody Cape section of the AENP comprises Pleistocene aeolianites (cemented dunes) of the Nahoon Formation of the Algoa Group (Le Roux 1989), which rise over 40 m above sea level in a stacked geological sequence draped by Holocene sands. The elephant tracks occur in the basal aeolianite unit, except for the easternmost site, as discussed below, where the tracks were found in an ex situ loose slab adjacent to the basal unit. This unit has been dated to 126 ± 8 ka, using optically stimulated luminescence (Van Tonder 2024),

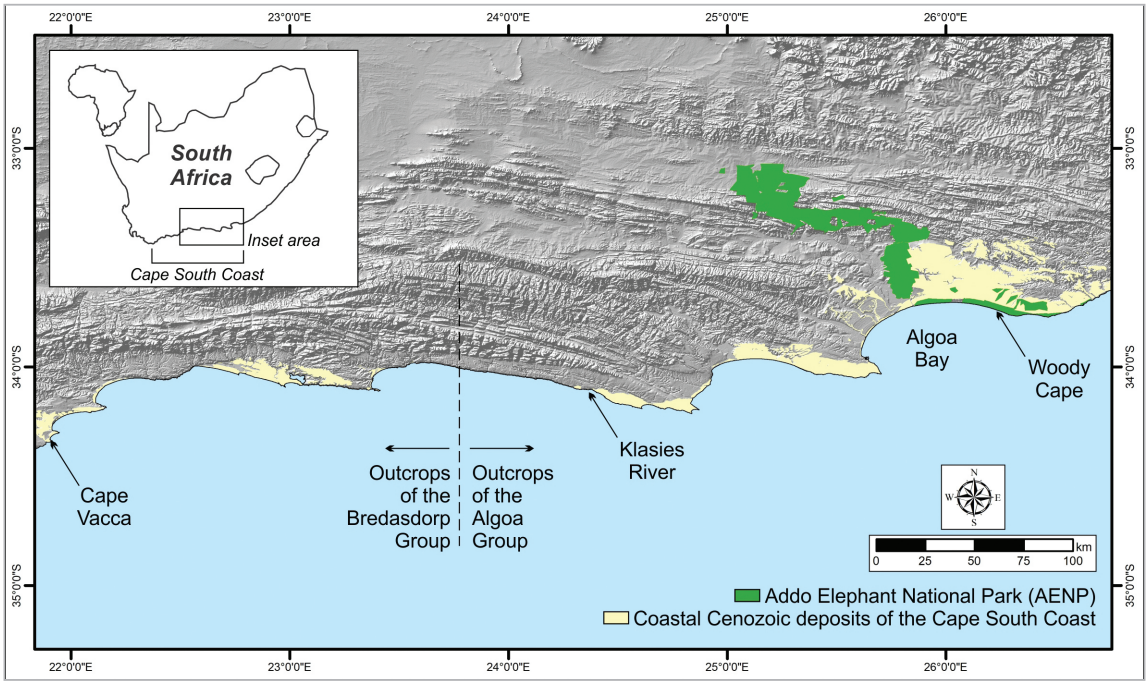

Figure 1. Map of South Africa's Cape coast, showing sites mentioned in the text.

Figure 2. The Woody Cape coastline, in the approximate area from which the sample for Optimal Stimulated Luminescence (OSL) dating was taken.

placing it approximately at the boundary between the Middle Pleistocene and the Late Pleistocene, and within MIS 5e (the last interglacial), a period with a climate and sea-level comparable to the present. The tracks would have been registered on unconsolidated dune and interdune surfaces.

The aeolianite bedding planes, including the track-bearing layers, are fairly level and laterally persistent. In places aeolianites are calcified, suggesting ancient palaeo-aquifers. Higher up in the cliffs, palaeosols predominate and contain fossilized land snails (*Achatina zebra*). Landward of the cliff tops lies the Alexandria dune field with a surface area of over 15,000 ha.

Storm surges and spring tides batter the cliffs, causing sections to collapse, exposing new track sites and destroying others. A dynamic equilibrium thus exists, and track sites are ephemeral unless they can be recovered and accessioned in suitable facilities.

Elephant tracks may be preserved in epi-relief on the original surface on which they were registered, in hypo-relief (natural casts) in the layer that filled in the tracks, or in profile. When tracks are evident in profile, distorted bedding and deformation are apparent in the underlying layers. In all cases, elephant tracks can be identified by their size. Even when viewed only in profile, a track diameter of more than 35 cm effectively excludes other large candidates such as the rhinoceros and hippopotamus, whereas tracks in the 25–35 cm range could have been registered by these animals or by juvenile elephants (Liebenberg 2000; Stuart and Stuart 2019; Van den Heever et al. 2017; Gutteridge and Liebenberg 2021).

The geology, archaeology and ichnology of the Woody Cape area form chapters in an ongoing MSc thesis by one of the authors (Van Tonder in prep.).

Methods

Track measurements included length, width and depth. Results were recorded in centimetres. The dip and strike readings were recorded on in situ surfaces. Standard field techniques were applied to understand the context of the track sites.

Photographs were taken of tracks, and photogrammetric analysis (Matthews et al. 2016) was performed. 3D models were generated with Agisoft Metashape Professional (v. 1.0.4) using an Olympus Tough model TG-6 camera (focal length 4.5 mm; resolution 4,000 x 3,000; pixel size 1.56 x 1.56 um). The final images were rendered using CloudCompare (v.2.10-beta).

Global Positioning System readings were obtained for track sites using a handheld device. Locality data were reposited with the African Centre for Coastal Palaeoscience at Nelson Mandela University, Gqeberha, to be made available to researchers upon request.

Figure 3. The westernmost elephant track; scale bar is in cm.

Results

Elephant tracks

The elephant track sites in the Woody Cape section within AENP are described here from west to east. The westernmost site contains a large, oval track 42 cm in length and 36 cm in width, (Fig. 3, see below). It is located on the ceiling of a small overhang, in an area of well-consolidated deposits that cleave readily to yield palaeosurfaces.

Two km east of here lies a 1–km stretch of coastal cliffs in which distorted bedding and elephant tracks in profile are identifiable in at least four sites (Figs. 4a-d). A typical track width of 37 cm was noted, whereas the largest track measured 50 cm in diameter and 25 cm in depth. At one of these sites, tracks were evident over an east-west distance of 10 m and in four distinct layers, separated (from top to bottom) by 20 cm, 20 cm and 22 cm. The profusion of tracks suggests trampling of surfaces by elephants, and their presence in multiple layers indicates repeated use of an area over time.

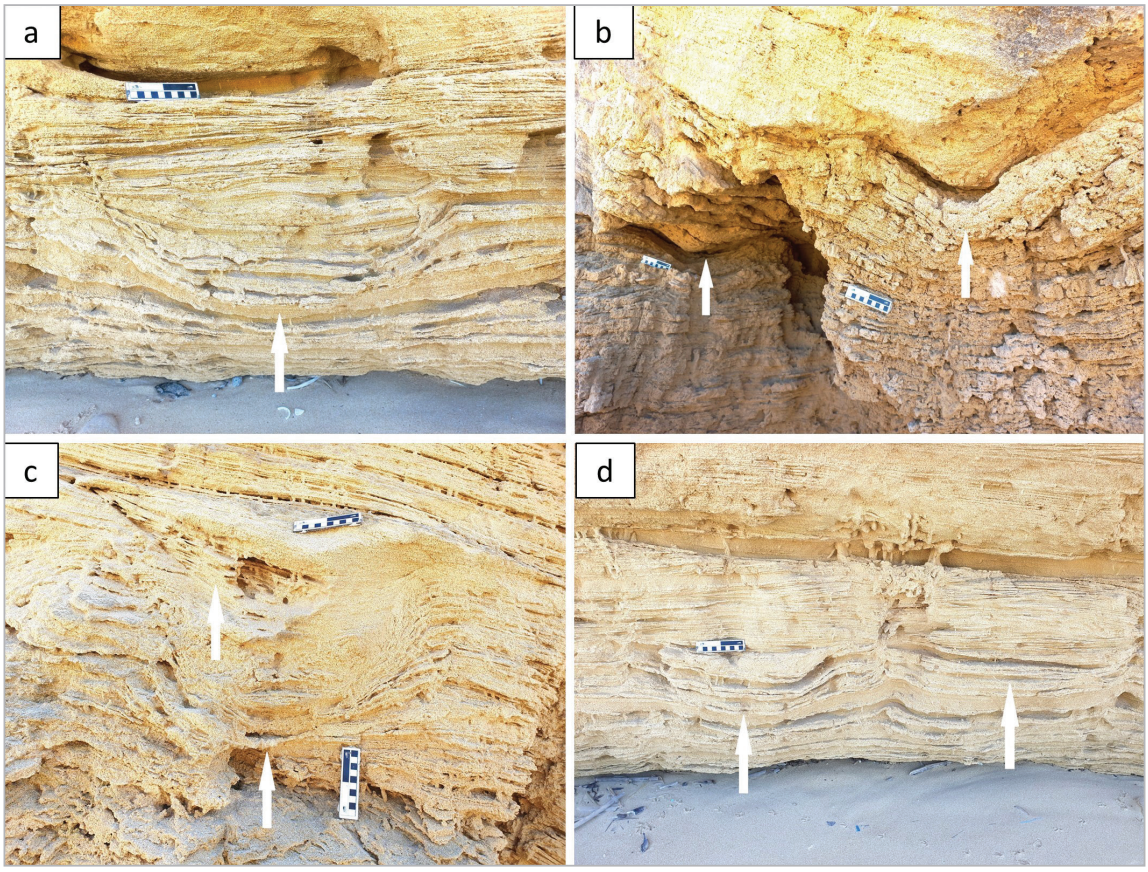

Figure. 4(a-d). Arrows indicate elephant tracks in profile; scale bars = 10 cm.

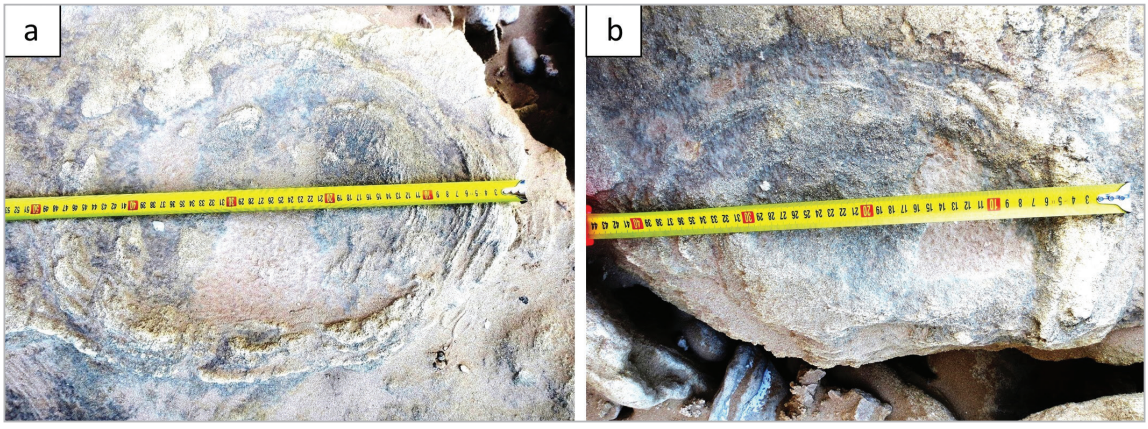

Figure. 5(a, b). Elephant tracks at the easternmost site; scale bars are in cm.

The easternmost site is situated six km further to the east. Here a loose slab contained two oval elephant tracks, respectively 50 cm and 45 cm in length (Figs. 5 (a,b) and 6). Both tracks exhibited a concentric ring-and-groove pattern, mostly in the outer portions of the tracks, which could be related either to elephant seismic communication or to the intersection of fine laminae with the tracks (Helm et al. 2024). Unfortunately, a landslide has buried the track-containing slab, which is currently not visible.

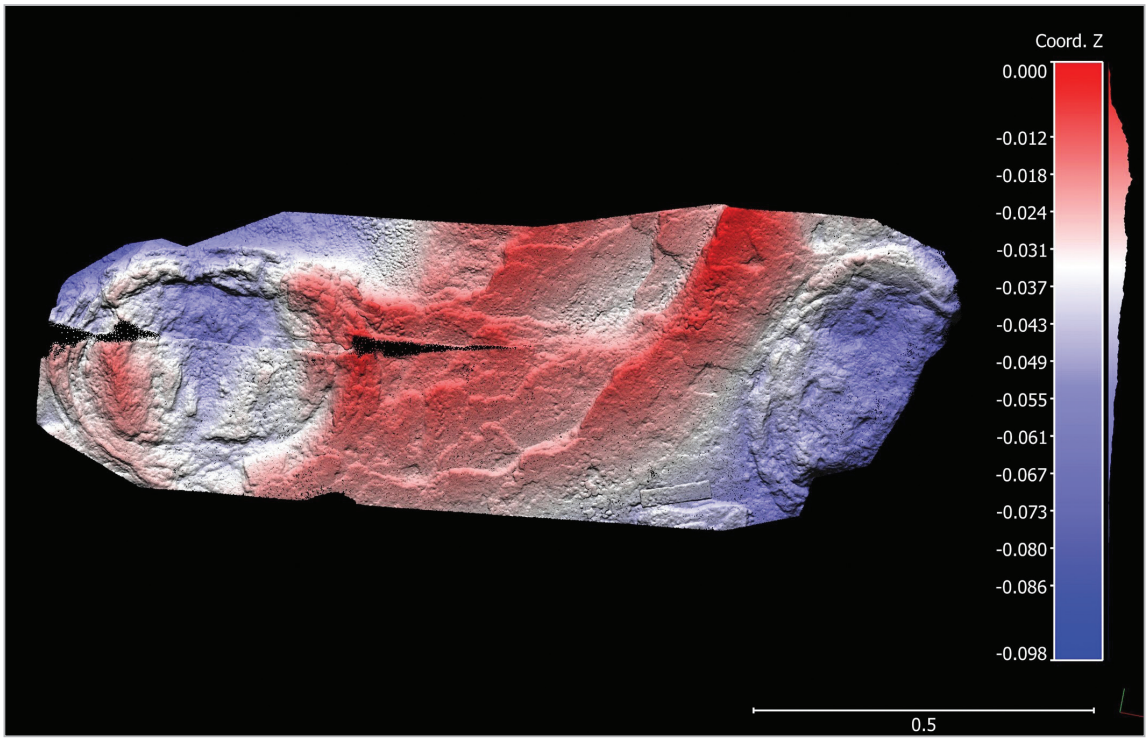

Figure 6. 3D photogrammetry model of the tracks shown in Figure 5; horizontal and vertical scales are in metres.

Other tracks

In addition to elephant tracks, traces of a sand-swimming golden mole were reported, resembling those made by the *Eremitalpa* genus, currently confined to the west coast of Namibia and South Africa. These formed the holotype for the ichnotaxon *Natatorichnus sulcatus* (Lockley et al. 2021). A trackway consistent with that of a juvenile shod hominin has also been described—this would be among the oldest known cases of humans fashioning footwear (Helm et al. 2023). Unfortunately, the loose slabs containing both the *N. sulcatus* traces and the shod-hominin trackway were destroyed in a 2023 storm surge. However, our photogrammetry data non-invasively preserve a record and can be used to make accurate replicas.

Bovid tracks of various sizes have been identified, ranging from buffalo tracks (*Syncerus antiquus* or *Syncerus caffer*) to probable duiker sp. (subfamily Cephalophinae) or grysbok (*Raphicerus melanotis*) tracks. Finally, in another 'global first', the wall of a fossilized aardvark (*Orycteropus afer*) burrow contained claw scratch marks.

Discussion

Seen in isolation, the presence of only one site in the Eastern Cape containing Pleistocene skeletal material might suggest a limited regional elephant presence. However, the complementary ichnological evidence of elephant tracks within the AENP boundary indicates that such a conclusion would be unjustified. The fossil elephant tracks that have been discovered would almost certainly have been registered by the African savannah elephant, the species that inhabits the AENP today. Expanses of sand and dunes would have formed an ideal medium for long distance seismic communication.

Considering the AENP elephant tracks in conjunction with the 35 elephant tracksites that have been identified on the Cape south coast (Helm et al. 2022), a widespread elephant presence can be inferred in both the Middle Pleistocene and Late Pleistocene, something which has hitherto not been obvious from the body fossil record in the Western Cape and Eastern Cape. Perhaps the most important consideration from the AENP perspective is that this Park, which has done so much to protect and preserve elephant survival and heritage, contains Pleistocene fossilized elephant tracks within its boundaries, as described herein. We

anticipate that visitors to the AENP might find this interesting and that it might add an extra dimension to their experience. The Main Camp has an excellent interpretive centre, opened in 2011, which includes an exhibit on dinosaurs found in the vicinity (but outside the AENP boundary) and regional geology. A wall exhibit with photographs, informing visitors of the ancient presence of African savannah elephants, could have many benefits.

Although elephant tracks have been identified in epi-relief, profile and hypo-relief, currently there are none that are suitable for recovery and exhibition. However, future discoveries can be anticipated during return visits to the Woody Cape coastline, or the eastern track-bearing slab might become re-exposed. Use of a helicopter or all-terrain vehicle to recover tracks and place them on exhibit might be of considerable visitor and media interest. An alternative is using a 3D printer to produce a 1:1 replica of the elephant track depicted in Fig. 6, using photogrammetric data. Our research team has established a good collaborative relationship with AENP management and staff, with plans in place to jointly develop such an exhibit.

Conclusions

The presence of fossilized elephant tracks in the AENP, dated to ~126 ka and probably made by the African savannah elephant, indicates an ancient elephant presence in the Park. More evidence is likely to accrue through future exploration. The recovery of tracks, or replication through photogrammetry, represent ways of preserving this evidence. The interpretive centre in the Addo Main Camp can function as a suitable venue for interpretation and education on this aspect of AENP palaeo-heritage.

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Early depictions of the first Lisbon rhinoceros in the 16th century

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Abstract

The first post-Roman rhinoceros to be seen alive in Europe reached the harbour of Lisbon, Portugal on 20 May 1515. After a fight with an elephant staged on 3 June 1515, King Dom Manuel I 'the Fortunate' decided to gift the rhino to Pope Leo X in Rome. The animal drowned when the vessel was shipwrecked in a storm off La Spezia in northern Italy at the end of January 1516. Information and a sketch reached the German city of Nuremberg, where Albrecht Dürer proceeded to make a drawing with text dated 1515, followed by a woodcut of the Lisbon Rhinoceros. Dürer's works show a characteristic twisted horn in the shoulder region, found in all later copies, which became the standard representation of the rhinoceros from 1545, in books and artworks. During the first part of the 16th century, until about 1560, there were at least 16 works which showed a rhinoceros without this Dürer-hornlet. These would have been sketches of the living animal during its short life in Europe, or possibly been derived from such portrayals. Five of such works have remained largely unknown, and are here described, discussed and illustrated. First, there is a set of similar engravings found in three separate *Cartinhas* (booklets) produced in Portugal between 1534–1544 by the printer Germão Galharde, where the animal is uniquely named "Rhinocerom", noted here in zoological context for the first time. Second, two similar figures of a rhinoceros on the cover of a pamphlet published by the Italian author Giovanni Giacomo Penni and seen in the background of a large painting by Francesco Granacci of 1515–1516, might both be based on a coloured unsigned sketch found in a volume of manuscripts held in the Library of the Vatican (Vat. lat. 2847). Third, the *Historia Senensium* by Sigismondo Tizio contains a sketch of a rhinoceros in shackles in an entry for 1515. Fourth, a rhinoceros is found among marginal drawings and manuscript annotations added to a volume of Pliny's Natural History. Finally, a book on Quadrupeds published by Michael Herr in 1546 has an independent illustration of a rhinoceros without a hornlet on the shoulders and was copied in books by Hubert de L'Espine of 1558 and Barthélemy Aneau of 1549. All examples are illustrated for future comparison.

Résumé

Le premier rhinocéros (post Antiquité) à avoir été vu vivant en Europe a atteint le port de Lisbonne (Portugal) le 20 mai 1515. Après un combat mis en scène avec un éléphant le 3 juin suivant, le roi Manuel 1er, dit « Le Fortuné », décide d'en faire cadeau au Pape Léon X à Rome. L'animal se noie fin janvier 1516, lorsque le bateau qui le transporte fait naufrage suite à une tempête au large de La Spezia, au nord de l'Italie. Un croquis et quelques informations sont alors envoyés à Nuremberg (Allemagne), à destination d'Albrecht Dürer qui s'attache à réaliser un dessin assorti d'un texte daté de 1515, puis une gravure sur bois d'après le « Rhinocéros de Lisbonne ». Les travaux de Dürer dépeignent une corne torsadée caractéristique située au niveau des épaules, détail qui ornera toutes les copies ultérieures et qui deviendra la représentation standard du rhinocéros à partir de 1545, dans les livres et les œuvres d'art. Sur la première partie du XVIe

siècle et jusqu'en 1560 environ, on retrouve au moins 16 productions de rhinocéros dépourvus de cette petite corne vue par Dürer. Il s'agit d'esquisses effectuées pendant la courte vie de l'animal en Europe, ou éventuellement de dérivés de ces portraits. Cinq de ces œuvres sont restées essentiellement inconnues et sont ici décrites, discutées et illustrées. La première est une série de gravures similaires, trouvées dans trois *Cartinhas* (brochures) différentes et produites au Portugal entre 1534 et 1544 par l'imprimeur Germão Galharde. Fait remarquable, l'animal y est appelé « Rhinocerom », nom utilisé pour la première fois dans un contexte zoologique. Ensuite, nous traitons de deux silhouettes semblables de rhinocéros, la première figurant sur la couverture d'une brochure publiée par l'auteur italien Giovanni Giacomo Penni et la deuxième à l'arrière-plan d'un imposant tableau datant de 1515–1516, réalisée par Francesco Granacci. Les deux éléments pourraient tenir leur origine d'une esquisse en couleur et non signée, provenant d'un volume de manuscrits conservé à la bibliothèque du Vatican (Vat. lat. 2847). Puis, nous abordons le croquis d'un rhinocéros enchaîné, dans une entrée de 1515 du livre *Historia Senensium* par Sigismondo Tizio. Nous trouvons également un dessin de rhinocéros ainsi que des annotations manuscrites en marge d'un tome de l'*Histoire naturelle* de Pline l'Ancien. Enfin, nous nous arrêtons sur un ouvrage traitant des quadrupèdes publié par Michael Herr en 1546, qui contient une illustration indépendante de rhinocéros dépourvu de la petite corne au niveau des épaules, et qui a été reproduite dans les livres d'Hubert de L'Espine en 1558 et de Barthélemy Aneau en 1549. Tous ces exemples sont illustrés à des fins de comparaisons.

Introduction

The first Lisbon Rhinoceros or *Ganda* lived in Europe from 20 May 1515 to January 1516 (Rookmaaker 2024: 35–37). The second rhinoceros known as the Madrid Rhinoceros or *Abada* lived in Portugal and Spain from 1577 to 1591 (Jordan Gschwend in prep). A woodcut designed by Albrecht Dürer in 1515 has brought fame to the First Lisbon Rhinoceros. Transported from Gujarat in India, the animal lived in Portugal until December 1515, when it was gifted to Pope Leo X in Rome, but drowned in transit by ship off the coast of La Spezia in northern Italy at the end of January 1516. While Dürer depicted the essential characters in the armour-plated skin and the single nasal horn, he added a small twisted hornlet on the shoulders which most rhinos do not possess. Because the woodcut was widely distributed and constantly copied for over two centuries, this representation became the default image of the rhinoceros to scientists, academics and the interested public.

The history of the life of this particular rhinoceros has been studied in detail and the story has become integrated in multiple academic and popular works. The main points together with discussions of the images of the First Lisbon Rhinoceros are carefully documented in works by Clarke (1973; 1986), Da Costa (1937), Cole (1953), Lach (1970), Rookmaaker (1973; 1998; 2024), Walter (1989; 1990), Almeida (1992), Bedini (1997), Serani (1999) and Faust (2003) among many others. For practical reasons, our references to previous illustrations of the artworks mentioned in this paper will be limited to one or two main examples, acknowledging that the work by Tim Clarke (1913–1993) culminating in his book of 1986 remains a reliable source of information.

When the rhinoceros arrived in Lisbon in 1515, some residents witnessing this creature for the first time started to write letters to their friends in other parts of Europe, and they sketched the animal's likeness. Such information of a hitherto unknown animal reached the German city of Nuremberg, where the great artist Albrecht Dürer (1471–1538) made a drawing, followed by a famous woodcut of the rhinoceros, both incorporating text about the animal's life. The unique copy of the drawing is now in the British Museum, London (Clarke 1986, pl. 1; Rookmaaker 2024, fig. 4.2). There were several consecutive states of the woodcut, discussed by Faust (2003) and illustrated in Clarke (1986, pl.2) and Rookmaaker (2024, fig. 4.3).

Dürer's representation of the rhinoceros is immediately recognizable from the small twisted hornlet on the shoulders and is referred to as the Dürer-hornlet. It is unlikely, but not impossible, that the *Ganda* had this feature in life. Almost all copies or derivations of Dürer's woodcut show this characteristic hornlet. It is well documented that many illustrations of the rhinoceros until at least the end of the 18th century, if not much later, follow this example. This dominance

was not immediate, because as far as has been verified, the first time the Dürer Rhinoceros appeared in print was in the *Cosmographia* of Sebastian Münster (1488–1552) published in 1545 and again in 1548 in Germany (Münster 1545: dcclvii, 1548: dcclvii), followed by Goujon (1549) in Belgium. Lach (1970: 166) gave this honour to an edition of Münster's work of 1550, while Cole (1953) found the figure in Gessner (1551: 953). Given the historical popularity of the Dürer image, the absence of copies for some thirty years is remarkable.

In the text attached to the drawing, Dürer gave the animal its Indian name 'Ganda'. To complete the record, probably the first time this name was used in Western printed literature was by Garcia De Orta (1501–1568) in his *Coloquios* (De Orta 1563: 86 verso), and again by Cristóbal Acosta (1525–1594) in a similar work on medicinal herbs (Acosta 1578: 443).

i. The Lisbon Rhinoceros figured without Dürer-hornlet

There were several artworks of rhinoceros in the first half of the 16th century which were not based on Dürer. These likely depict the First Lisbon Rhinoceros, but of course other sources—like sketches or descriptions sent by travelers from Asia or even Africa—cannot be immediately excluded. The known examples up to the 1560s are reviewed here.

We have identified a total of 16 potential depictions of *Ganda*, the First Lisbon Rhinoceros of 1515. Eight of these are discussed and illustrated in this paper.

1. Hans Burgkmair (1473–1531): woodcut dated 1515, —illustrated Clarke (1986, fig. 7).
2. Anonymous: Library of the Vatican (Vat. lat. 2847), ca. 1515—discussed §iii, Fig. 4.
3. Giovanni Giacomo Penni: leaflet on rhinoceros and trade, with an engraved frontispiece, July 1515—discussed §iii, Fig. 5.
4. Francesco Granacci (1479–1543): painting "Joseph and his Brethren in Egypt" showing rhinoceros in background, 1516; discussed §iii, Fig. 6.
5. Giovanni da Udine (1487–1564) under the direction of Raffaello Sanzio da Urbino (1483–1520): Creation scene in the Loggie of the Vatican including an indistinct rhino head, 1515–1517; illustrated Clarke (1986, fig. 10).
6. Francisco de Arruda (d.1547): sculpture on the outside of the tower of Belém near Lisbon, 1517; illustrated Clarke (1986, fig. 1); Almeida (1992, figs. 11–14).
7. António de Holanda (1480–1557): Livro de Horas de Dom Manuel I (1469–1521), depiction of "The flight from Egypt" has small rhinoceros in the margin of Illum. 14, folio 98 verso, 1517; illustrated Almeida (1992, figs. 4, 5); Bedini (1997, fig. 56).
8. Sigismondo Tizio (1458–1528): *Historia Senensium*, 1516–1528; discussed §iv, Fig. 7.
9. Pliny the Elder (23–79): edition of *Historia Naturalis*, edited by Andrea Portilia in 1481, with marginalia added after 1515; discussed §v, Fig. 8.
10. António de Holanda: unfinished leaf intended for a prologue showing the arms of Infante Dom Fernando (1402-1443) of Portugal, dated 1530–1534; illustrated Almeida (1992, fig. 6).
11. Germão Galharde: ornaments of rhinoceros in three separate *Cartinhas*, produced in Lisbon 1534–1552; discussed §ii, Figs. 1–3.
12. Michael Herr (1490–1550): illustration of rhinoceros in *Gründtlicher Underricht* on quadrupeds, 1546; discussed §vi, Fig. 9.
13. Barthélemy Aneau (1505–1561): illustration of rhinoceros in animal book, 1549; discussed §vi, Fig. 10.
14. Hubert de L'Espine: rhinoceros illustrating an imaginary journey, 1558; discussed §vi, Fig. 11.
15. Pirro Ligorio (1512–1583): Rhinoceros shown in mosaic in the vestibule of the Casino of Pope Pius IV (1499–1565), dated 1560s (Bedini 1997: 190). No image found.
16. Minden church: Rhinoceros carved on a choir stall in Minden in northern Germany, probably derived from Burgkmair's woodcut, 16th century; illustrated Clarke (1974, fig. 2; 1987: 25).

ii. The Rhinocerom of Germão Galhardo

A "Rhinocerom" is illustrated in three small booklets generally known as *Cartinhas*, published in the middle of the 16th century in Lisbon by Germão Galhardo. All three are extremely rare, evidently known only from single examples. Two are preserved in the Biblioteca Pública in Évora, Portugal (BPE)

Figure 1. "Rhinocerom" illustrated on the back cover of a rare booklet *Cartinha pera ensinar* a leer, published by Germão Galharde in Lisbon in 1534. The animal is shackled on the neck and front feet. (Biblioteca Pública in Évora, Portugal, no. Res. 265–B).

Figure 2. "Rhinocerom" with a small fault in the left side of the banner with the animal's name, absent in the other two examples. Like Fig. 1, published by Germão Galharde on the back cover of a rare *Cartinha*, undated, probably 1537–1552. (Biblioteca Pública in Évora, Portugal, no. Res. 300-A).

and a third in the Biblioteca Geral (General Library) of the University of Coimbra (BGUC). All three examples are illustrated and placed in bibliographic context by Jüsten (2020).

1. "Cartinha pera ensinar a leer" (Fig. 1). Lisboa, Germão Galharde, 28 May 1534. 8vo. 64 pp. BPE Res. 265–B. Attributed to Diogo Ortiz de Vilhegas, Bishop of Viseu (1480–1544). On the final page (folio 32 verso) there are several ornaments, including prominently a figure of a "Rhinocerom" (95 x 80 mm). Further information on this *Cartinha* in Proença and Anselmo (1923: 33); Anselmo (1926: 171, no. 600); Jüsten (2020, vol. 1: 115, vol. 2: 490).
2. ["Cartinha pera ensinar a leer"] (Fig. 2). Lisboa, Germão Galharde. 8vo. 64 pp. BPE Res. 300–A. No author found. Jüsten proposes a date range of 1537–1552. Rossi (2015) reproduces all pages in facsimile, transcribes the text and provides background information. Again, on the final page (folio B XVI verso) there is a prominent figure of a "Rhinocerom". Further information in Proença and Anselmo (1923: 34); Anselmo (1926: 171, no. 601); Jüsten (2020, vol. 1: 168–169, vol. 2: 506).
3. "Incipit officium angeli custodis, regni civitatis vel, loci secundum usum, cisterciensis ordinis" (Fig. 3). [Lisboa], [Germão Galharde], [1544]. 16 pp., 8vo. BGUC R–4–5. No author found. Probably dated 1544. The figure of the "Rhinocerom" is found on folio 8 verso. Further information in Proença and Anselmo (1923: 165); Anselmo (1926: 190, no. 671); Jüsten (2020, vol. 1: 208, vol. 2: 506, 521).

These three *Cartinhas* were published by Germão Galharde, also known as Germain Gaillard or Germanum Galhardum, a French printer who had settled in Lisbon. Various works from his press appeared from 1519 to the time of his death in 1565 (Jüsten 2020). The first example (BPE RES 265–B)

Figure 3. "Rhinocerom" illustrated in a *Cartinha*, like Fig. 2, but without the fault in the banner. From the back cover of *Incipit officium angeli custodis*, attributed to the press of Germão Galharde in 1544. (Biblioteca Geral de Universidade de Coimbra, no. R-4-5).
Courtesy: General Library of the University of Coimbra © BGUC.

includes the date 28 May 1534, while the second example (BPE RES 300–A) seems to be later, and the third (BGUC R–4–5) dates to 1544.

The images of the rhinoceros in the three booklets are very similar. The animal is depicted in full lateral view, facing left, showing a large nasal horn, and shackles running from the neck to the front feet. There are differences in the banner holding the title, the placement on the page, also in the length and shape of the horn, the position of the ears, and the indication of the skin folds. There is no evidence of who was responsible for the engraving or why it was inserted. None of these three *Cartinhas* contain any text relating to the rhinoceros or even animals in general. The name "Rhinocerom" given to the animal is novel and unique, not found elsewhere in the printed literature.

iii. Drawing of rhinoceros in a Vatican manuscript

Inserted in a volume of various texts in the Biblioteca Apostolica Vaticana (Vat. lat. 2847), there is a drawing of a rhinoceros (Fig. 4). The volume, which is available in digital format, also includes ten drawings of trees (mainly *Quercus*?). As far as can be ascertained, there is no textual reference to the rhinoceros in this volume, hence it is unclear why the drawing was inserted here. Hermann Walter (1994, fig. 5) was the first to notice its significance. It is without title and unsigned, but it clearly shows an animal in captivity with shackles around the front feet, in lateral view facing right with one good horn on the nose.

There is an unmistakable similarity of this drawing with the engraved frontispiece of a booklet by Penni dated 1515 (Fig. 5) and the animal painted by Granacci in 1516 (Fig. 6). The shape of the head, the long

Figure 4. Rhinoceros with shackles around the front feet. From an undated manuscript (16th century) in the Biblioteca Apostolica Vaticana (Vat. lat. 2847_0390, folio 190r).

neck, the piece of skin below the ears extending downwards, and the length of the shackles are all particular to these images.

Giovanni Giacomo Penni wrote a poem published in a pamphlet of 1515, which is only known from a single copy (*Institución Columbina*, Sevilla, Spain), bought in Rome by Fernando Colombo (1488–1539). It was examined and explained by De Matos (1960) and in more detail by Serani (2006), who includes a full transcript of the Italian text together with a translation into Spanish. Penni's poem is largely about the spice trade from India and only partly about the rhinoceros which was transported from India to Lisbon. The leaflet of four pages was printed by Étienne Guillery, who worked in Rome 1506–1524: "Impresso in Roma: in casa de mastro Stephano Guilireti a di tredici de luio, 1515", or on 13 July 1515. This date, remarkably, is just 54 days after the arrival of the rhinoceros on the River Tagus in Lisbon, but the poem has no reference to the battle with an elephant on 3 June 1515. Penni, probably a Florentine physician visiting Rome, must have seen a letter with the historical details, together with the original drawing crudely copied on the front of the leaflet.

Figure 5. Rhinoceros from the frontispiece of *Forma & natura & costumi de lo Rinocerothe* by Giovanni Giacomo Penni dated 1515. (Institución Columbina, Sevilla, sign. 6–3–29 (29)).

Figure 6. Detail of painting by Francesco Granacci, “Joseph and his Brethren in Egypt” (Giuseppe presenta il padre e i fratelli al Faraone). Oil on canvas, 1516. (Uffizi Gallery, Florence, inv. 2152–1890).

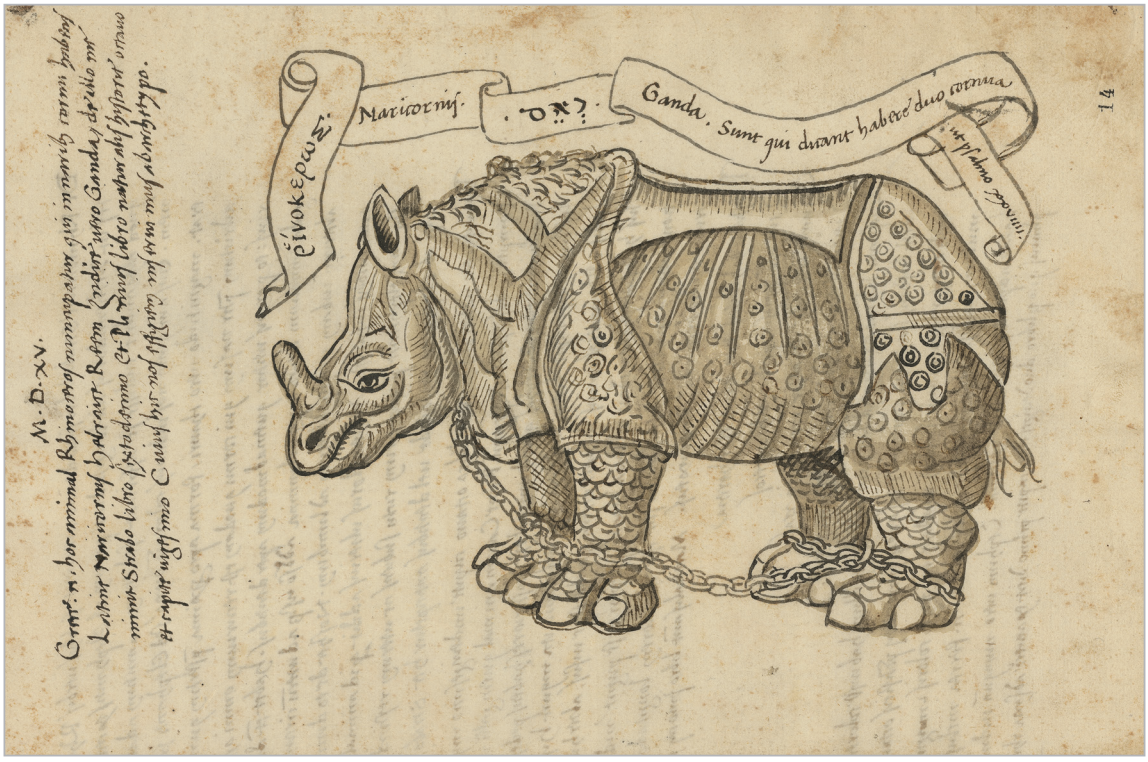

Figure 7. Ganda, rhinoceros, shackled to neck and hind feet. Illustration in the 1515 entry of the manuscript *Historia Senensium* of Sigismondo Tizio. (Biblioteca Apostolica Vaticana, Codex Chigi G.II.38_fa_0014r).

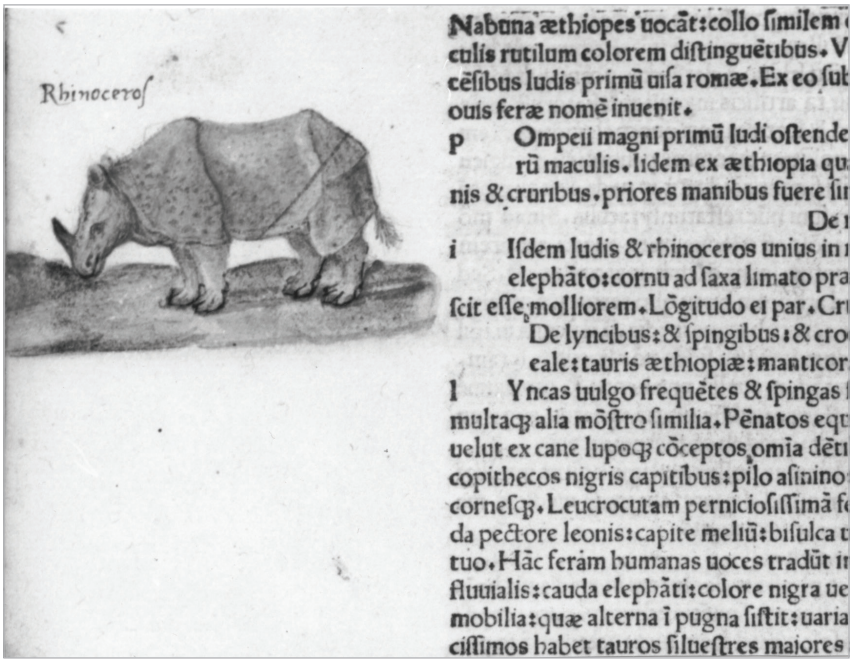

Figure 8. Rhinoceros painted in the margin of a page of a 1481 edition of the *Historia Naturalis* by Pliny, which was added in the period 1515 to 1526. (Biblioteca Palatina di Parma, Inc.Pal. 1158).

Francesco Granacci (1469–1543) painted "Joseph and his Brethren in Egypt" as part of a series in 1516 (Uffizi Gallery, Florence). Given the subject, the inclusion of a rhinoceros with its keeper in the background might be a reference to the extreme rarity of this exotic animal (Rookmaaker 2024: 37, fig. 4.5).

The drawing in the Vatican is of such quality that it seems unlikely that it was a copy taken from Penni or from Granacci. While it might be based on an unknown precursor sent from Lisbon, it is equally possible that it was in fact this precursor. The letter which must have explained the significance of the animal is still unknown.

iv. A depiction obtained by Sigismondo Tizio in Siena

Sigismondo Tizio or Ticci (1458–1528) was a scholar who lived and worked in Siena, Italy, from 1482. He wrote a comprehensive history of the town, the *Historia Senensium* (History of the Sienese), which remained unpublished until recently (Garfagnini 1992). The manuscript contains an entry for the year 1515 with an account of the rhinoceros (Biblioteca Apostolica Vaticana, Codex Chigi G.II.38, folio 14r). Tizio must have been particularly fascinated with this animal when news about its journey and death were discussed.

Tizio's notes are illustrated with a drawing showing the animal in lateral view facing left, with a single nasal horn of good size, and shackles extending from his neck to the hind (not front) feet (Fig. 7). The animal is named in four languages "Rhinoceros [in Greek]. Naricornis. Reem [in Hebrew]. Ganda. Sunt qui dicant habere duo cornua ut psalmo XXVIIII" ('there are those that say it has two horns from Psalm 29'). First discussed by Walter (1989: 273, fig. 10) and more extensively by Monson (2004), Tizio's Latin text starts with a detailed and accurate account of the history of the Lisbon Rhinoceros from arrival in Portugal to its death in the shipwreck in 1516, including some of the important dates. Tizio must have composed this section between 1516 and 1528. Although there is no indication about the provenance or the artist of the drawing, it could have been obtained in the same period. Walter (1989) and Monson (2004) correctly suggest that this was an early image of the Lisbon Rhinoceros, which differs from the other known examples. There is no dorsal horn as found in Dürer's woodcut, but there appears to be a slight prominence in the hairy pattern in the shoulder region.

Figure 9. The "Hellfantsmeister" or Rhinoceros illustrated in the *Gründtlicher Underricht* by Michael Herr of 1546 (folio size, p. lxi). Note the long nasal horn and the absence of a hornlet on the shoulder. (Staatsbibliothek zu Berlin, 4" Lk 3585<a>).

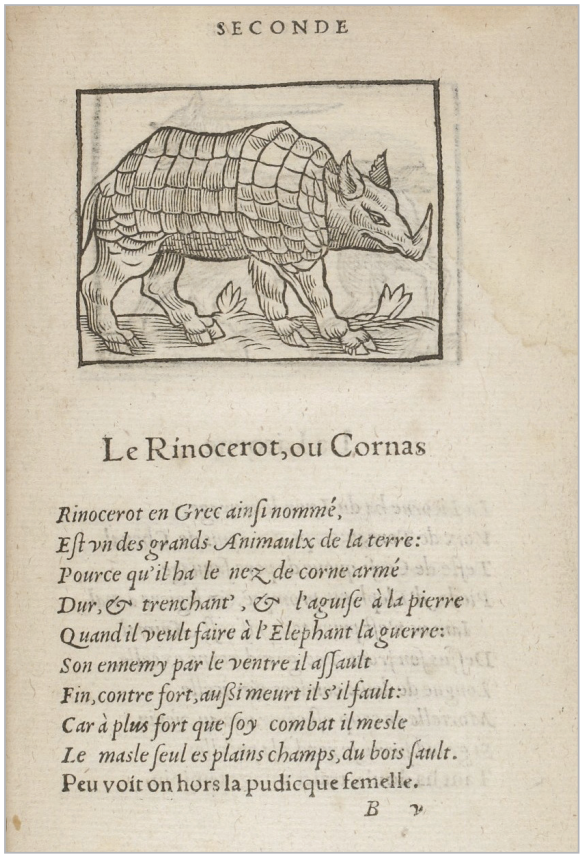

Figure 10. "Le Rinocerot, ou Cornas" published in the 1549 edition of the *Décades* by Barthélemy Aneau. This resembles the figure of the rhinoceros published by Herr in 1546. (Bibliothèque nationale de France, RES–YE–3468 (1)).

v. The Parma copy of Historia Naturalis by Pliny

The text of the *Historia Naturalis* (Natural History) by Pliny the Elder or Gaius Plinius Secundus (23–79) was often reprinted and annotated. A copy of an edition printed at Parma in 1481 by Andrea Portilia, once in the library of Carlo II, Duke of Parma (1799–1883), has a large number of added marginal illustrations, including a rhinoceros. Hermann Walter (1989, fig. 1; 1990) examined this unique example in the Biblioteca Palatina di Parma. He suggests that the annotations and drawings were added by unknown persons working in Rome and date from the period 1490 to 1526.

There is one drawing of a "Rhinoceros" (folio 67 verso) showing a lateral view of the animal with one sizeable nasal horn, while noting the absence of a dorsal horn (Fig. 8). Walter (1989: 270, 1990: 212) suggests that the image must have been added after 1515, styled after the drawing sent by Valentim Fernandes of Moravia from Lisbon, which circulated in Italy at the time (Da Costa 1937). The animal does not show any chains around the neck or the feet.

vi. The book by Michael Herr and two contemporary copies

The rhinoceros was still rarely illustrated in printed books of the 16th century. Starting with Münster (1545), the animal was usually modelled after the woodcut by Dürer, with the characteristic Dürer-hornlet on the shoulders. A rhinoceros without this second hornlet is found in the *Gründtlicher Underricht* on quadrupeds by Michael Herr (1490–1550), known as a translator

Figure 11. The "Rinocerot" included in the account of an imaginary journey by Hubert de L'Espine, published in 1558. Size 50 x 30 mm. (Bibliothèque nationale de France, RESP-O2-2292).

with extensive classical knowledge living is Strasbourg, France (Nissen 1978, vol.2: 62, pl. XI; Walter 1996, fig. 5). Published in 1546 in German (Herr 1546: lxi recto), the image shows an animal from the side, facing left, with a long horn, scales all over the body, feet with two hooves (unless the third hoof is obscured) and a solid tail (Fig. 9). There is no known precursor, nor any indication which might provide a clue about the origin of the drawing. Herr called the animal "Hellfantsmeister" (Master of Elephants), also known as "Rhinoceros."

The rhinoceros of Herr was copied as "Le Rinocerot, ou [or] Cornas" by Barthélemy Aneau (1505–1561) in a smaller reversed version (Aneau 1549, without page number). This book went through several editions for about a century, all with the same figure (Fig. 10). Again, there is no information about the origin of the animal.

Another copy, but very crude and disfigured, is found in a rare volume written by Hubert de L'Espine, said to be from Avignon on the title page. Published in 1558, this recounts an imaginary journey, which was illustrated by 21 vignettes. The "Rinocerot" faces to the right, has a large horn on the nose but lacks the one on the shoulder (Hubert 1558: 88 verso). The author places the animal in the gardens of the Castle of Morgon in the land of Cadosse, none of which are retrievable (Fig. 11).

The absence of a Dürer-hornlet in this period is remarkable. Although an unknown drawing of the First Lisbon Rhinoceros is not the most likely source, other potential precursors remain elusive.

Acknowledgements

We dedicate this short paper to Hermann Walter (b. 1934), who retired from the University of Mannheim, where he specialized in Roman Grammar and Mythographie. He came across rhinoceros' depictions in the course of his original research in Italian libraries, museums and buildings. These were the subject of a small number of incisive papers, which deserve to be better known. Walter and KR corresponded for several years in the 1990s and 2000s, exchanging ideas and information on rhinoceros iconography. Through his intensive and informed research, the iconography of the rhinoceros has made some great leaps helping to build a better understanding of the historical events.

In our search of early Ganda images, we were greatly assisted by the specialists and librarians in Portugal: Helga Maria Jüsten, bibliographic researcher in Lisbon; Zélia Parreira, Director, Biblioteca Pública de Évora; and Maria de Fátima Bogalho, General Library of the University of Coimbra. We thank Annemarie Jordan Gschwend for reading an early draft and providing information on her forthcoming paper. Many of the older books, drawings and manuscripts can now be consulted online, thanks to the invaluable efforts of the world's museums and libraries to digitize their holdings. We are grateful to these institutions who have allowed us to reproduce the artwork in their care.

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FIELD NOTES

Asian rhinoceros species in early China: unravelling Si (兕) and Xi (犀) in historical Chinese records

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Introduction

As elsewhere in the world, the history of rhinoceroses in China is one of progressive extinction, and wild rhinos no longer exist in China, having been exterminated due to the cultural value placed on their horns (Martin 2017). However, Si (兕) and Xi (犀) were two animals commonly mentioned in Chinese historical records prior to 221 BCE and appear to have been widely distributed in China from the 17th to the 11th century BCE. Xi refers to rhinoceroses in general. The character of Xi is used as the modern Chinese word for rhinoceros, although it is unclear which species of rhinoceros was being referred to over 2000 years ago. As for Si, it is also uncertain which specific animal it refers to. This field note sheds light on the different meanings of the terms Si and Xi from the Shang dynasty (1600–1046 BCE) to the Tang dynasty (618–907 CE), a period that spans more than three thousand years (Table 1). It suggests that Si refers to the one-horned Javan rhinoceros (*Rhinoceros sondaicus*), and Xi refers to the Asian two-horned rhinoceros *Dicerorhinus sumatrensis*, also known as Sumatran rhinoceros, corresponding to the two species known to be present in China in historical times (Rookmaaker 2006).

Table 1. Timeline of ancient Chinese dynasties referred to in this field note.

Dynasty	Staging of dynasties		Dynastic time period
Shang dynasty			ca. 1600–1046 BCE
Zhou dynasty	Western Zhou dynasty		1046–771 BCE
	Eastern Zhou dynasty	Spring and Autumn period	770–476 BCE
		The Warring States period	476–221 BCE
Han dynasty	Western Han dynasty		202 BCE–8 CE
	Eastern Han dynasty		25–220 CE
Jin dynasty	Western Jin dynasty		266–317 CE
	Eastern Jin dynasty		317–420 CE
Tang dynasty			618–907 CE

Si and Xi in literary sources

The term Si refers to a type of animal widely found in unearthed antiquities and surviving literature from the pre-Qin period (before 221 BCE) in ancient China. During earlier periods, Si had been a commonly seen animal in central and southern China, as evidenced by references in various poems in the collection known as *Shijing* (Book of Songs) from the Western Zhou period (1046–771 BCE), where it is mentioned in poems such as *On an Auspicious Day* and *Why Are the Plants Not Yellow?* (Mao Heng et al. 1999). The poem *On an Auspicious Day* records King Zhou's hunting of Si, aligning with unearthed antiquities such as divination inscriptions from the Zhou dynasty (1046–256 BCE) which mention hunting Si. Records of Si are also abundant in the oracle bones of the Shang dynasty (ca. 1600–1046 BCE), as discussed below. This evidence suggests that Si was widely distributed in China from the Shang dynasty to the Western Zhou dynasty.

Today and in contemporary literature, there is no animal named Si, and there are several theories about what Si refers to historically. While some Chinese authorities consider that Si refers to *R. unicornis* (Wang 2011), other Western sinologists maintain that it refers to a species of water buffalo (Lefeuvre 1991). To complicate matters further, some traditional Chinese texts use Si as the name for *R. sondaicus* (Sun 1982).

The *Shanhaijing* (Classics of Mountains and Seas), an ancient geography book compiled during the late Warring States (5th century to 221 BCE) and western Han dynasty (206 BCE–220 CE) periods, records that "The Si is located to the east of Emperor Shun's tomb, south of the Xiang River. Its appearance is like that of a cow, dark blue, with a single horn". Following this passage, the book also mentions Xi, noting that "in the north-west, there are Xi, resembling cattle but black" (Yuan 1980). These descriptions make it clear that Si and Xi had similar forms, both resembling cattle and being black in colour. Guo's (267–324 CE) commentary on the *Shanhaijing* (Classic of Mountains and Sea) describes the Xi and Si mentioned in the section *Prayers for Crossing Mountains* as follows:

> "The Xi resembles a water buffalo. It has a pig's head, stiff legs resembling those of an elephant, three hooves, a large belly, and is black. It has three horns: one on top, one on the forehead, and one on the nose. The one on the nose is small and does not fall off; it serves to eat. It likes to eat thorns and often spews blood from its mouth. The Si also resembles a water buffalo, is bluish-green, and weighs a thousand jin (千斤), equivalent to 500 kg", (Yuan 1980).

Apart from the number of horns, the pre-Qin literature also records differences in the hardness of the skin between Xi and Si. The Zhou people often used the skins of Xi and Si as armour. The *ZhouLi* (The Rites of Zhou), compiled between 1046–771 BCE, describes "the armour of the Han people" as follows: "Xi armour consists of seven sections, Si armour consists of six sections, and combined armour consists of five sections. Xi armour has a lifespan of a hundred years, Si armour has a lifespan of two hundred years and combined, the armour has a lifespan of three hundred years" (Yang 2004).

The pre-Qin era is seen by the Chinese as "like childhood for humanity". Books of the time are full of legends, and care is required to interpret their contents. In Guo's annotation, the Xi has three hooves, indicating that it belongs to the odd-toed ungulate order, but it is transformed into a three-horned animal. Its body is massive, like that of a cow, while the presence of horns, although a characteristic feature of Rhinocerotidae, could also refer to Bovidae.

Possible confusion with cattle is evidenced in other historical texts. The *Erya*, the first surviving Chinese dictionary, the most of whose glosses must reasonably date from the 3rd century BCE, notes that "the Si resemble cattle" (Guo 1999). However, Guo's subsequent annotations on the *Erya* explicitly state that Si has "one horn, greenish in colour". He adds: "The weight of the horn is about 500 kg" (Guo and Bing 1999), greatly exaggerating the weight of the horn.

The *Shuowen Jiezi*, a dictionary-like collection of various Chinese character glyphs drawn by Xu Shen during the Eastern Han dynasty (ca. 100 CE), describes Xi as "a type of cattle from the southern borders, one horn on the nose, one horn on the top of the head, resembling a pig." (Ding Fubao 2014).

Wang Yun's (1784–1854) interpretation of this passage includes the observation that: "the rhinoceros lives beyond China's south-western border" (Ding 2014). The vagueness and inaccuracies of descriptions of rhinos from northern China imply that—during the

Eastern Han period (25 BCE–220 CE) there was already a noticeable decline in the numbers of rhinoceroses in northern areas and they were no longer commonly seen within the Eastern Han dynasty borders. In addition to this factor, frequent wars during the Eastern Jin period| (317–420 CE) disrupted the dissemination of knowledge and information. Similarly, the very brief references to Si in Guo's (2nd–3rd century CE) annotations on the *Shanhaijing*' suggest that Si was already in decline in the area during the Eastern Jin period. From the pre-Qin period to the Eastern Jin period, due to the increasing scarcity of tangible references, records related to Si gradually became blurred and distorted by history.

Evidence from oracle bone scripts

Oracle bone script is the oldest attested form of written Chinese, dating to the late 2nd millennium BCE. Inscriptions were made by carving characters into oracle bones. The character Si in the oracle bone script is a pictograph representing the form of an animal, and apparently with a single horn (Fig. 1). Lefeuvre (1991) pointed out that the inscription on the base of a bronze vessel from the Shang dynasty, now preserved in the Academia Sinica, representing a side view of a cow, resembles the Si character in oracle bone script (Fig. 2). This viewpoint makes it appear that the cow has a single horn, and Lefeuvre uses this feature to suggest that the character Si refers to a wild *Bubalus mephistopheles*, an extinct Pleistocene-era buffalo species, rather than a rhinoceros. This assertion is incorrect. During the Shang dynasty, the characters representing buffalo in oracle bone script depicted the frontal form of the cow's head, as well as representing the side profile of the animal. This glyph, 牽 (qian), is still preserved in Qin (221–207 BCE) bamboo slips (Fig. 3).

Figure 1. Si in oracle bone script.
© Li Xueqin (Ed). *Origin of Characters* (Li 2013, p 852).

Figure 2. (Above) Inscription on a Shang dynasty bronze square *Ding*.
© Jean A. Lefeuvre (Lefeuvre 1991, p 155);
(Below) https://openmuseum.tw/muse/curation/3e4e9550d8e75d9a37431a52098b724f#curation-viewer-infobox-3870).

Figure 3. The Chinese character "牽" (qian).
© Li Xueqin (Ed).
(Ziyuan, Tianjin Ancient Books Publishing House, 2013 edition, page 72.)

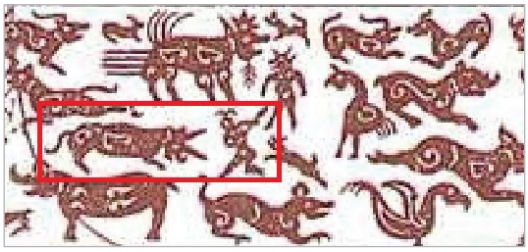

Figure 4. Person hunting a cow with a spear on a spring and autumn period Dou with hunting patterns.
© Palace Museum, Beijing

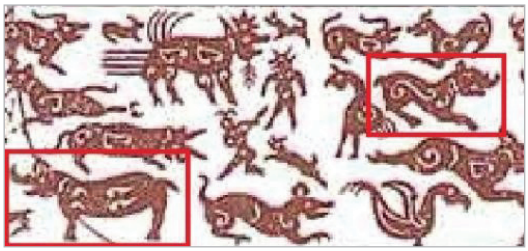

Figure 5. Two-horned rhinoceros on a spring and autumn period Dou with hunting patterns.
© Palace Museum, Beijing

Figure 5 shows a phono-semantic compound character, with 宀 (Mi) as the radical and 牛 (*niu*; this Chinese character means cow) as the phonetic component. The upper component 宀 resembles the rope used to lead cattle, while the lower component resembles the inscription found on the Shang dynasty bronze vessel, depicting the profile view of a cow.

Excavated antiquities differentiate distinctly between images of cows and other bovines and those of rhinoceroses. The hunting pattern engraved on a Spring and Autumn period (770–476 BCE) *Dou* (豆) (an ancient Chinese bronze vessel used to hold offerings) depicts a person hunting a cow with a spear, showing the cow with double horns and a robust body with a long tail (Fig. 4). Beneath this cow, an animal is depicted with a body similar in shape to a cow but with a shorter tail, double horns on its nose; with the front horn longer than the rear horn (Fig. 5) that closely resembles the description of two-horned rhinoceros (Xi) in the *Shuowen Jiezi*.

Si goblets in the Book of Songs

An argument against the identification of Si as cattle is suggested by references to *si gong* (兕觥), wine goblets made from the horns of a rhinoceros, in the Book of Songs, which contains some of the earliest known references to Si. There are four references to *si gong*, as shown in Table 2.

Table 2. Occurrences of the phrase *si gong* (兕觥), translated as 'Si goblet', in the Book of Songs (Source: *Thirteen Classics Annotation and Commentary on the Book of Songs*. (Ed). Li 1993, published by Peking University Press).

Title	Section	Poetic text
Juan Er	*Guofeng: Zhou Nan*	I fill the Si goblet, to prevent eternal sorrow. Climbing that rocky path, my horse tires, my servant falls ill, what can I do?
Seventh Month	*Guofeng: Bin Feng*	In September, the frost is solemn; in October, we cleanse the field. Friends gather for a feast, saying, "slay the lamb" as we ascend to the public hall. We raise the Si goblet, wishing for boundless longevity!
Sang Hu	*Xiaoya*	Filling the Si goblet, the fine wine seems soft. Seeking blessings, without arrogance, they come in multitude.
Silk Garments	*Song*	From the hall to the ancestral shrine, from the sheep to the cattle, with the dainty cups and the Si goblets.

The *Song* (Hymns) are poems for sacrificial rites, while the *Xiaoya* (minor odes) are poems written for and read by aristocrats. *Juan Er* and *Seventh Month* belong to the *Guofeng* (Airs from the States, i.e. folk songs). *Juan Er* depicts a man from an affluent family who travels with horses and servants, while *Seventh Month* depicts a lavish feast for distinguished guests, similar to the ambiance described in the *Silk Garments* of the *Song*. Poetic texts imply that drinking vessels made from Si horns are regarded as luxury utensils, used by nobility and affluent families on formal banqueting occasions. This makes it unlikely that *si gong* refers to humble drinking vessels made of cow horns. Cow horns were very common in those times (as well as now), while rhinoceros horns were incredibly valuable.

Historical references make it clear that rhinoceroses were highly prized animals and that rhino horn was regarded as a precious material. For example,

Figure 6. Si horn wine vessel made of bronze from the late Shang dynasty, ShanXi Province. © Shanxi Museum

Zhanguoce (The Strategies of the Warring States), a book mostly about the mixed wars of the states during ca. 476–221 BCE, notes "They sent envoys with a hundred chariots, presenting the astonishing chicken-horned rhinoceros and the luminous jade *bi* (an ancient Chinese jade ornament which is round in shape with a whole in the centre of the circle) to the King of Qin" (Liu 1983). This reference, where rhino horn is listed alongside the prized treasure of luminous jade, shows that it was valuable and used as a tribute during the Eastern Zhou dynasty. The Eastern Zhou dynasty was the later phase of the Zhou dynasty, which covered the period from 770 BCE to 221 BCE. Moreover, rhino horn was considered to possess mystical and medicinal properties. For example, the *Shennong Bencao Jing* (The Holy Husbandman's Classic on Roots and Herbs), a book on folk medicine prior to 221 BCE, states: "Rhinoceros horn governs against the sting or bite of a hundred venomous insects, evil spirits, [and] obstructed vital energy, and the effects of poison from hooks, bites, stings, and venomous snakes, preventing confusion or sleepiness. Long-term use lightens the body" (Shang 2007).

Although cattle horns were easy to process, they lacked precious and mystical attributes, thus did not highlight the status of the user and were unsuitable for use on formal occasions, in contrast to the dignified nature of Si goblets. People of the pre-Qin period chose luxurious materials for ritual vessels and craftsmen spared no time or effort. Rhinoceros horns were more difficult to craft into wine vessels, than buffalo horns, but their precious attributes and mystical aura made them a far more desirable choice of material for goblets. The symbolic importance of rhino horn in ancient China is also indicated by the choice of precious materials such as bronze to make replica horn goblets for use on ceremonial occasions (Figs. 6 and 7).

These two bronzes (Figs. 6 and 7) are known to Chinese experts in antiquities as *si gong* (drinking vessels made from rhinoceros horn). At first, *si gong* were made directly from rhinoceros' horn. When ancient Chinese craftsmen mastered the art of casting objects in bronze, they enlarged and distorted the si gong to enhance its mystical and solemn character, as it was used in the context of sacred rituals for gods and ancestors.

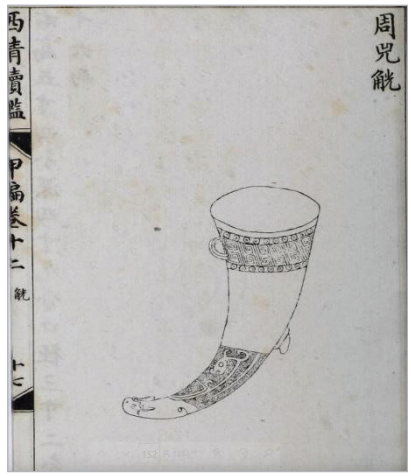

Figure 7. A Si horn drinking goblet made of bronze in the Zhou dynasty (1046–256 BCE). © Wang Jie (Ed). Compilation of antiquities collected by the Qing Royal Family (Wang 1793, chapter 12, p 17).

The stone Si in Xianling

By the time of the Tang dynasty (618–907 CE), the cold climate in the Central Plains made it difficult for rhinoceroses to survive, and from the early to middle Tang period, rhinoceroses entered China through diplomatic channels. The *Old Book of Tang*, a book documenting the history of the Tang dynasty, records: "In the early years of the Zhenguan era (627–649 CE), envoys were sent to present tame [captive] rhinoceroses" (Liu 1975). our references to *si gong*, as shown in Table 2.

Although rhinoceros sightings were rare at that time, rhinoceroses can still be seen in ancient literature and artifacts. In the ninth year of the Zhenguan era (635 CE), Emperor Liyuan of Tang passed away. Outside the divine gate of Xianling (The tomb of Emperor Li Yuan of the Tang Dynasty), leading to the mausoleum where he was buried, pairs of stone tigers and rhinoceroses stood guard, as well as a stone Buddha housed in a niche outside the east divine gate.

The placement of tigers and rhinos together harks back to earlier descriptions from the literature of the Qin and Han dynasties, where Si and tiger are referred to together as 'fierce beasts'. For example, in the *Book of Discussions*, compiled in 50–59 CE, it is stated that: "When one dies, the form decays. Even though tigers and Si are fierce and brave, they cannot return to life" (Huang 1990). Similarly, in the *Salt and Iron Debate*, a book completed in 81 BCE, it is stated: "Tigers and Si can capture bears and tigers, subdue other animals because their claws and teeth are sharp, and they can grasp easily" (Wang 1992). Both passages explicitly describe tigers and Si as fierce and formidable beasts. This suggests that the rhinoceroses outside the divine gate of Xianling were intended to represent Si, and placed together with stone tigers to guard the mausoleum, symbolizing their fierce and resolute nature.

The stone Si from Xianling is on display at the Xi'an Beilin Museum (Fig. 6). The statue is of single-horned rhinoceros, with three toes on its feet, folds on its neck, shoulders, waist, and legs, and skin resembling armour. The stone rhinoceros had lain on its side on the ground, with severe weathering on the right, while its left side protected from the elements remained intact, showing neat scale patterns and irregular rings on its hide (Zhu 2023).

As shown in the illustration, the nasal horn of the stone rhinoceros is shown as a lump-like growth. Female Javan rhinos do not have horns, but some of these individuals grow a lump an inch or two high at the tip of their snouts. This lump on the nose of the stone rhinoceros in Xianling is a typical feature of female Javan rhinoceroses. Therefore, it can be inferred that the stone rhinoceros in Xianling was modelled from a female Javan rhinoceros, *R. sondaicus*. Therefore, the stone rhinoceros in the ancestral tomb of Emperor Liyuan of Tang should be referred to as Si.

Figure 8. Tang dynasty–Xianling Stone Rhinoceros.
© Shaanxi, Xi'an Beilin Museum

Conclusion

In summary, based on pre-Qin literature and unearthed antiquities, the term Si, which commonly appeared, refers to the *R. sondaicus*. It was not until the early 19th century, driven by the continuous development of biological classification, that *R. sondaicus* was identified as a separate species. The historical traces of referring to the single-horned rhinoceros as Si could still be observed in the early years of the Tang dynasty, and the stone rhinoceros dedicated to Emperor Liyuan at Xianling should be called the Xianling Stone Si. Another Asian rhinoceros commonly found in classical Chinese literature at that time—the two-horned *Dicerorhinus sumatrensis*—was referred to as Xi.

R. sondaicus and the *R. unicornis* are both one-horned rhinoceroses and have skin like thick armour. In the early days of China, when observation and species classification were not well developed, they were probably regarded as the same species, called Si. Some Chinese scholars believe that *R. unicornis* was historically present in southwestern China (Lan 1992), but there is no fossil evidence to support this view. Perhaps, with the development of Chinese archaeology and the expansion of the scope of ancient species identification, we will make new discoveries about the relationship between the *R. unicornis* and Si.

It is hoped that this field note will act as a catalyst, especially for Chinese scholars wanting to learn more about the rhino in classical Chinese literature and art, and that it will generate further discussion and research on the presence of rhino species occurring in China historically.

Appendix 1

Ancient Chinese texts quoted in the paper

Ancient Chinese Texts
《爾雅・釋獸》：“兕，似牛。”
《山海經・海內南經》：“兕在舜葬東，湘水南，其裝如牛，蒼黑，一角。”
《山海經》：“犀似水牛。豬頭，痺腳，腳似象，有三蹄，大腹，黑色。三角：一在頂上，一在額上，一在鼻上；在鼻上者，小而不墮，食角也。好噉棘，口中常灑血沫。兕亦似水牛，青色，一角重三千斤。”
《說文解字》：“犀，南徼外牛，一角在鼻，一角在頂，似豕。從牛，屃聲。”
《說文句讀》：“徼猶塞也。東北謂之塞，西南謂之徼。”
《爾雅注疏》：“一角，青色，重千斤。”
《韓詩外傳》：“太公使南宮適至義渠，得駭雞犀，以獻紂”
《戰國策・楚策》：“遣使車百乘，獻雞駭之犀、夜光之璧於秦王。”
《犀鉤序》：“世稱雞駭之犀，聞之父常侍曰：犀之美者有光，雞見影而驚，故曰駭雞。”
《神農本草經》：“主百毒蟲注，邪鬼，障氣殺鉤吻鴆羽蛇毒，除不迷或厭寐。久服輕身。”
《說文解字》：“鰓，角中骨也。”
《周禮注疏・冬官・考工記》：“函人為甲，犀甲七屬，兕甲六屬，合甲五屬。犀甲壽百年，兕甲壽二百年，合甲壽三百年。”
《舊唐書》：“貞觀初，遣使貢馴犀。”
《馴犀》：“馴犀生處南方熱，秋無白露冬無雪。一入上林三四年，又逢今歲苦寒月。飲冰臥霰苦蜷跼，角骨凍傷鱗甲蹜。馴犀死，蠻兒啼，向闕再拜顏色低。”
《論語》：“虎兕出于柙，龟玉毁于椟中，是谁之过与？”
《論衡・論死》：“如死，其形腐朽，雖虎兕勇悍，不能復化。”
《鹽鐵論》：“虎兕所以能執熊羆、服群獸者，爪牙利而攫便也。”

Appendix 2

List of phrases referring Si goblets in the Book of Songs

Title	Section	Poetry Lines
卷耳	國風・周南	我姑酌彼兕觥，維以不永傷 陟彼砠矣，我馬瘏矣，我僕痛矣，云何籲矣。
七月	國風・豳風	九月肅霜，十月滌場。朋酒斯饗，曰殺羔羊，躋彼公堂。稱彼兕觥：萬壽無疆！
桑扈	小雅	兕觥其觩，旨酒思柔。彼交匪敖，萬福來求。
絲衣	周頌	自堂徂基，自羊徂牛，鼐鼎及鼒，兕觥其觩。

Acknowledgements

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Has horn length in an Eastern black rhino population (*Diceros bicornis michaeli*) decreased over time?

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Introduction

To provide information on long-term changes in rhino morphology, an evaluation of the extensive Rhino Resource Center online repository of rhino images was made using image-based analyses (Wilson et al. 2022).

That study looked at, to what extent data on rhino morphology can be quantified from image repositories, with emphasis on horn sizes, and whether this has changed over time. All measurements were performed using Fiji for ImageJ (Schindelin et al. 2012). Horn length was defined as the distance from the tip to the base of the horn parallel to the long axis of the horn. Given the absence of a scale bar, all measurements were made in arbitrary units.

The authors' measurements reported a small but significant decline in relative horn lengths over time in all (rhino) species. However, the validity of this and other conclusions made by the authors was challenged (Ferreira et al. 2024). One criticism was that the images were from multiple sites and did not consider potential differences within species (subspecies) differences.

However, the questions raised 'has the length of the horns of black rhinos decreased with time?' and if so, 'why?' are pertinent. This paper, with data from a single fully enclosed reserve populated with Eastern black rhino (*Diceros bicornis michaeli*) over a 33-year period, contributes to the discussion.

Methodology

A rudimentary system for measuring rhino horns from photographs (Patton 2021) was used to provide horn length data from profile photographs of Eastern black rhinos from a wild but fenced population, taken at intervals over 33 years.

The photographs available for measurement were right-side profiles of six mature adult females with the longest horns in the years 1989, 2006, 2017 and the 2020s. This sampling of the six largest did not account for whether none or one or more of the same females appeared in more than one sampling year. The ages of the females in each sample year were also not considered. All photos were standardized so that the distance between the center of the base of the rear horn and the lowest point of the jaw was the same.

Results

The results in Table 1 show a small reduction between the measurements of both the front and rear horn photographs of 1989 and each of the other three years. There was a significant reduction in front horn lengths between the 2006 and 2020 calculations, but not in rear horn lengths. In all but one of the 24 photographs, the front horn was longer than the rear, as would usually be expected in Eastern black rhinos. (Twelve are shown in Fig. 1 below).

An analysis of variance (ANOVA) did not show significant differences between the rear horns over the years. Figure 2 shows an ANOVA for the front horns only, across the 24 data points, with a significant year effect ($p = 0.00743$). When one outlier front horn was excluded, there was still a significant year effect ($p = 0.0214$).

Discussion

The results, although from a small sample, suggest that horn length may be declining in this population. This ‘suggestion’ would need to be validated from a much larger sample. However, it raises the question ‘what may be the cause of the decline’? This, in turn,

Table 1 Mean of the six measurements of the length of the longest-horned female Eastern black rhino horns in each sampling year. The measurements are in cm from head size-standardized side profile rhino photographs printed on paper.

Year	Front	Rear
1989	4.27	2.73
2006	3.74	2.53
2017	3.24	2.39
2020s	3.33	2.56

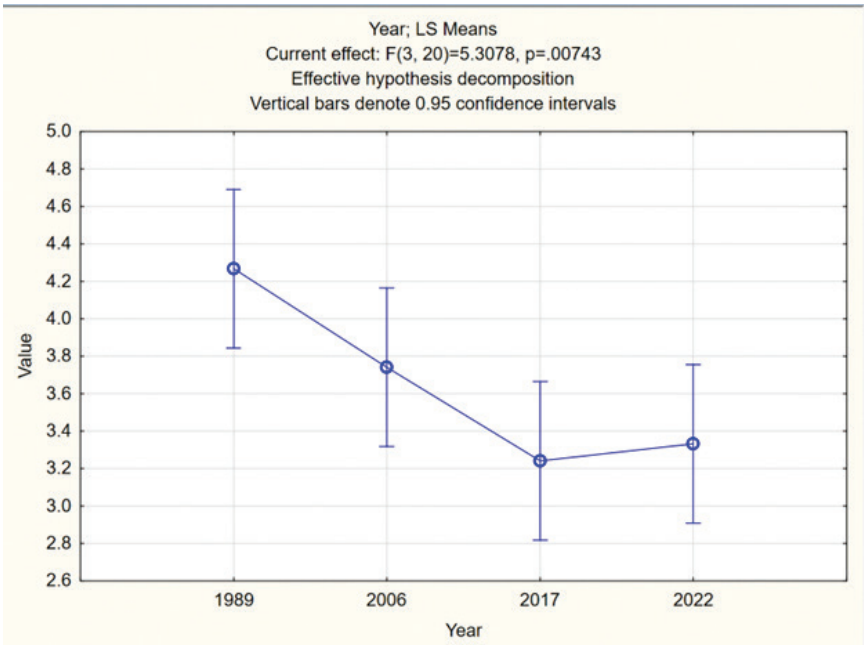


Figure 2. The ANOVA for the front horns of six female Eastern black rhinos

raises the question of 'what affects horn growth and length attained in black rhino'?

One possibility is that it is a heritable trait. It could be postulated that long-horned female rhinos will produce females that will have long horns. There is a paucity of research on this. However, there are some limited data for comparison that can be obtained from available photographs, as mentioned above.

Figure 1 shows the right profile photographs of six adult females with long horns alongside right profile photos of their offspring, all of which are also long-horned when mature. Although only a small sample was analyzed for this study, it suggests that horn length could be a heritable trait; this can only be confirmed by genetic testing. Should this be the case, then the decline in horn length could be due, in whole or part, to the unnatural death of selected long-horned females, reducing the potential for passing on the trait.

However, another possibility of reduction in horn length could be due to a change in nutrition. There were a few black rhinos in the population that suffered from split or broken horns (6% of adults and subadults out of the total population). The author considered this to possibly be a sign of poor nutrition. An unpublished vegetation study carried out in 2006 showed a lack of grade-one food sources for black rhinos, particularly a lack of *Acacia drepanolobium*. This was not unexpected, as a programme to remove up to a third of the population was planned in 2006 due to acknowledged overpopulation. Despite the

(a)

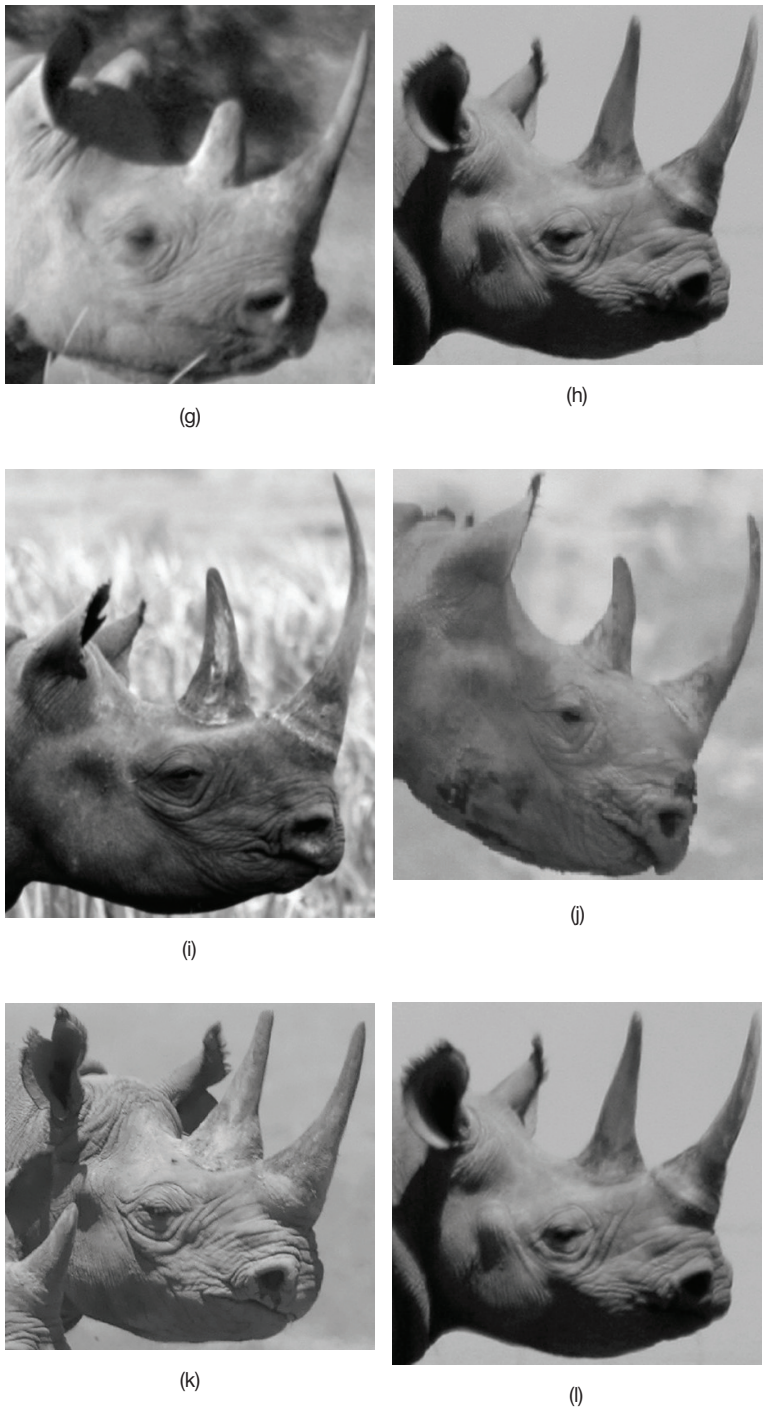
(b)

(c)

(d)

(e)

(f)



(g) (h) (i) (j) (k) (l)

Figure 1. Six long-horned adult females (left: a, c, e, g, i, k) and their female, now adult, calves (right: b, d, f, h, j, l)

translocation (in February 2007) and a second smaller translocation (12 individuals in early 2012), and some losses due to poaching, the acacia did not recover significantly.

Other causes for a rhino horn not meeting its true potential length include the extent of horn rubbing and abrasiveness of the available substrate and the length of time that the horn may have had to develop (depending on the age of the rhino).

To date, there has been no published research on factors that affect rhino horn size. A limiting factor of this study is the small sample size; however, as most black rhino protected areas have collected photographs for individual rhino identification over many years for monitoring purposes, an analysis of factors affecting rhino horn characteristics can easily be extended.

Conclusions

It is clear that there are gaps in published research into the reasons for the variation in rhino horn length. With significant advances in rhino genetic techniques and analysis and the potential availability of source material from translocations, ear notching, dehorning and other interventions, opportunities exist for research studies. Furthermore, research on the ecological carrying capacity and whether or not the nutritional needs of black rhinos are being met in intensive protection zones and sanctuaries in Kenya is recommended for future study.

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BOOK REVIEWS

The Rhinoceros of South Asia

LC (Kees) Rookmaaker, with contributions by Joachim K Bautze and Kelly Enright

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Eloquently written with a wealth of absorbing detail about Asian rhinos (*Rhinoceros unicornis, Rhinoceros sondaicus* and *Dicerorhinus sumatrensis*), and outstanding illustrations, this is a magnificent encyclopedic publication. The book describes the three rhinoceros species that existed in South Asia and their historical distribution. Most chapters cover *R. unicornis* (the author uses the Latin names), which had by far the most extensive range in South Asia. Kees Rookmaaker, a retired historian of zoology, has specialized in finding and compiling rhino records throughout his career. This book is the culmination of Rookmaaker's study of more than 40 years, collating archaeology, Indology, art history, palaeontology, geology, conservation and zoological research. It provides an incredible synthesis of data.

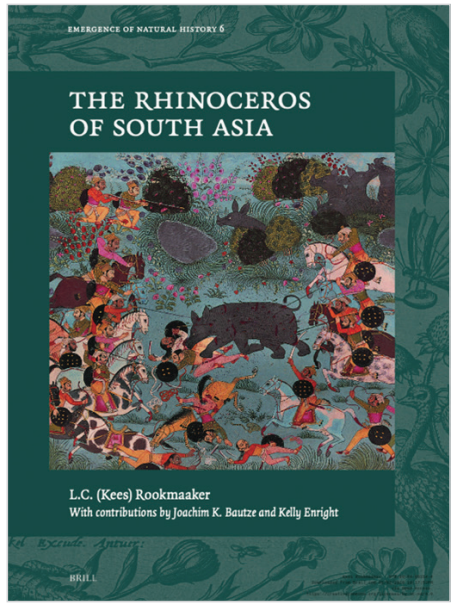

Figure 1. Front cover

The publication is available open access (free to the public) on the Internet, which will help researchers immensely for further study and those interested in rhinos around the world. The hard copy, a collector's item, can be obtained from the publisher's Brill (details at end). The text is supported by over 700 illustrations that show the importance of rhinos in the scientific and cultural fabric of South Asia, and beyond. There are 38 rhino distribution maps for the different parts of South Asia where they were found. All locality records are researched up to the map coordinates.

There are 82 datasets—with dates and locations—that include records of rhinos encountered and information about those people who recorded them, some hitherto unknown, with their life dates. There are 75 tables, some with important estimates of the status of rhinos. The first and last rhino recordings are given where they occurred across South Asia, the first time these have been compiled. The book is divided into 47 'Rhino Regions' with chapters moving from west to east. At the end is a detailed bibliography of 3,081 items and a comprehensive index.

The abundant illustrations with informative captions are fascinating and occasionally gruesome—these are part of history, and the author does not shy away from their inclusion. Instead, Rookmaaker comments that accurate records of a dead rhino provide a means of learning and 'for it to have some significance through some form of utilization'. A specimen can be examined

and measured scientifically and can provide an accurate locality and date. Some past observers confused the three species, and thus whether they were sympatric or allopatric in certain areas. Identification was easier when rhinos were killed or captured, but even then, the description of the species was often not clearly recorded. The author has been careful to note the occasional erroneous historical records or if there were inadequate data and the need for continuous investigation where possible.

Rookmaaker has scrutinized the literature on Asia's rhinos since his first academic paper was published in 1973 when he was just finishing secondary school, unravelling the story of Clara the Dutch rhinoceros (*R. unicornis*), who came to Holland and toured the European continent between 1741 and 1758. Since then, he has been intrigued by rhinos in the historical literature. This book is a labour of love, and combines academic precision with a clear writing style, presenting many absorbing anecdotes and stories.

British citizens living in South Asia described encounters with rhinos, sometimes hunts with Maharajas, and meeting rural people who told them of their experiences with rhinos. Many local hunters used pit traps and spears to kill rhinos for their meat and other body parts, mainly their skin and, of course, their horns, which were in demand for export to China. In some moving accounts by British colonials, involving the rescue or capture of rhinos, a common finding was how quickly these wild creatures habituated to captive life, often being ridden upon and following their keepers meekly. People who described rhinos in art or literature generally either captured them for private menageries and public zoos or killed them as trophies and for museums. They were perceived as dangerous beasts to hunt (Fig. 2).

In Rookmaaker's clear introduction, he laments that the history of natural science is not a well-studied field, despite the need to combine the humanities with science for effective conservation. Chapter 2 written by historian Kelly Enright 'Reading Rhinos through the Lens of Human-Animal Studies' prepares the reader for the text to come. She explains that the value of history is immense in helping guide our current actions and future plans, based on understanding varied cultural perspectives. She remarks that more

Figure 2. Artistic rendering of a rhinoceros attacking an elephant bearing Victor Reginald Brooke (1873–1914) on 12 February 1909 in the Manas jungle, Assam (Rookmaaker, *The Rhinoceros of South Asia*, Fig. 40.3).

people in India and Nepal today are aware of the allure of rhinos and respect them as treasures that must be guarded with as much care as museum artworks—albeit as living animals.

While the focus of the book is mostly on *R. unicornis* there is something new on every page, depending on what people find interesting. Part 1 (chapters 3–45) is about *R. unicornis* (the greater-one horned or Indian rhino). This rhino species is the only one endemic to South Asia that occurred in India, Bangladesh, Bhutan, Nepal, Pakistan, and Afghanistan, but disappeared from much of its range before the 19th century. With successful conservation approaches and anti-poaching measures *R. unicornis* has been recovering well in protected areas in northern and north-east India and southern Nepal. The species flourishes in the rich grassy floodplains of the Himalayan rivers, mainly in India's states of Assam and West Bengal, and in the southern provinces of Nepal.

Chapters 3–14 cover *R. unicornis* taxonomy and nomenclature; captivity, especially in Oudh (Lucknow

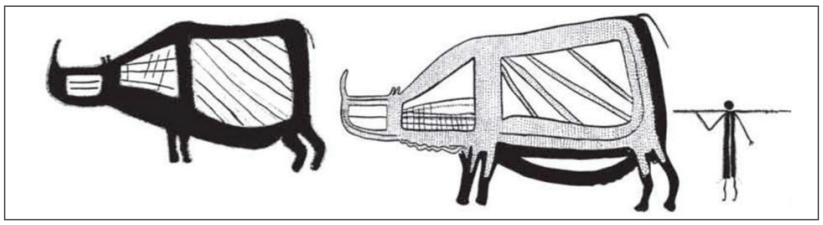

Figure 3. Erwin Neumayer surveyed prehistoric drawings (from the Mesolithic period 12,000-4000 years ago) in shelters and caves in the central part of India, providing for the book those depicting rhinos (tracing by Neumayer; Rookmaaker, *The Rhinoceros of South Asia*, Fig. 9.3).

Figure 4. All Mughal emperors from Babur to Humayan, Akbar, Jahangir, Shah Jahan and Aurangzeb hunted or kept rhinos in the 16th and 17th centuries. This painting by Willem Schellinks shows a hunting scene with Shah Jahan, circa 1665, with a rhino-elephant fight faintly in the background (Museum of Orientalists, Doha, Qatar; Rookmaaker, *The Rhinoceros of South Asia*, Fig 11.13).

Figure 5. Mahout and hunter on an elephant are surprised by a rhinoceros. A mural within the Badal Mahal, Palace of Bundi. Rajasthan. This is one example of a long series of depictions of rhinos on the walls of the palaces in Rajasthan, here for the first time made public; height: 56 cm (photographed by Joachim Bautze; Rookmaaker, *The Rhinoceros of South Asia*, Fig. 15.2).

Figure 6. King Tribhuvan of Nepal posing with a rhino after a hunt. Taken by Kiran Man Chitrakar, 1920s or 1930s. This is one of a series of photographs that have never been published before (private collection, reprint not allowed; Rookmaaker, *The Rhinoceros of South Asia*, Fig. 24.19).

Figure 7. Elephants hauling a dead *R. unicornis* in hill country. Watercolour by Sita Ram. The rhino was shot by the party of Hastings at Maharajpur in the Rajmahal Hills, Bihar, on 14 December 1820 (British Library; Rookmaaker, *The Rhinoceros of South Asia*, Fig. 29.1).

Figure 8. The Maharaja of Cooch Behar invited high-ranking officials and friends to take part in his annual shoots in West Bengal and Assam from 1871 to 1907, including women. Here in 1896, the Maharaja, in the bow tie and his son Rajev, are seen with Daisy of Pless next to her husband, the Prince of Pless. (This photo is from a private collection; Rookmaaker, *The Rhinoceros of South Asia*, Fig. 32.22).

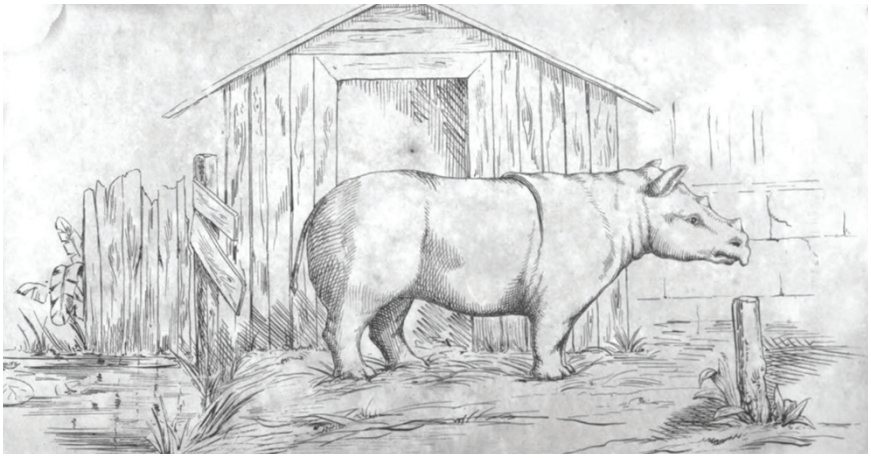

Figure 9. Begum was a famous two-horned hairy rhinoceros captured in Chittagong (Eastern part of Bangladesh) in 1867 by Captain Frederick Henry Hood, who made this drawing in his compound. This female rhino, *D. sumatrensis lasiotis*, lived in the London Zoo until 1900, setting a captive longevity record (Rookmaaker, *The Rhinoceros of South Asia*, Fig. 54.12).

and Baroda); fossil records; rock art in central India (Fig. 3); rhino records in Harappan settlements (an Indus Valley civilization that flourished from 2600 to 1900 BC in southern Pakistan); rhinos recorded in the Mughal period (from the start of the 16th century for two centuries) (Fig. 4); rhinos and their products exported from India east and west; historical records of rhinos in Afghanistan, Pakistan, Punjab and Gujarat.

Chapter 15 entitled 'A Pictorial survey of rhinos in the art of Rajasthan' was researched and written by Joachim Bautze. There are over 70 illustrations in this chapter alone, most showing rhinos encountering people, elephants, tigers and other rhinos. Many are photographed from wall paintings in some of Rajasthan's old palaces showing intricate, artistic details. These give clear evidence that their range once extended into Rajasthan (Fig. 5). Chapters 16–19 continue with historical records eastwards into Uttar Pradesh, including Dudhwa National Park (NP), where rhinos are nowadays protected.

Nepal follows (chapters 20–27), again with historical records of rhinos and those who encountered them (Fig. 6), including a chapter on members of the British royal family visiting Nepal. Rookmaaker also writes about the successful protection of rhinos in Shuklaphanta NP, Bardia NP, and Chitwan NP.

The following seven chapters return to India, from the state of Bihar (Fig. 7) to Cooch Behar (Fig. 8) in the state of West Bengal today and describe the growing numbers of rhinos in Gorumara NP and Jaldapara NP. Bhutan's rhino records (chapter 35) and then 10 chapters on the rhinos recorded in north-east India, including Fitzwilliam Thomas Pollok and his writings in the 19th century, are thoroughly described. The state of Assam is famous for its rhinos, nowadays well protected from poaching in Manas NP, Orang NP, Pabitora Wildlife Sanctuary and Kaziranga NP, which Rookmaaker covers in depth.

Part 2 (chapters 46–52) is about *R. sondaicus* (the lesser one-horned or Javan rhino). This species was found in South Asia's Bangladesh (Sunderbans) and India (West Bengal). Chapters cover taxonomy and nomenclature; captivity; historical records in Odisha (Orissa), the Sundarbans, North Bengal and Assam. The book describes their gradual local extinction in these regions. Today extremely few exist in the world, in merely one protected area in Java, Indonesia.

Part 3 (chapters 53–64) is about *D. sumatrensis* (the hairy or Sumatran rhino). This species was also found in South Asia's Bangladesh (Chittagong) and the north-east states of India (from Mizoram to Nagaland) and in West Bengal/Assam. Chapters cover taxonomy and nomenclature; captivity; and historical records in Chittagong and areas further north-east towards the Myanmar border. As for *R. sondaicus*, the book records the gradual local extinction of *D. sumatrensis* in South Asia, which remarkably had to be pieced together from just 26 reports from 1862 onwards. Today extremely few *D. sumatrensis* are known to survive in the world,

Figure 10. This is a previously unknown photograph of a young *R. sondaicus inermis* captured in the Sundarbans and kept in the premises of a well-known animal dealer, William Rutledge in Calcutta. Photo taken by Captain William George Stretton on 1 December 1875 (private collection; Rookmaaker, *The Rhinoceros of South Asia*, Fig. 48.9).

Figure 11. In 1876, Philip L. Sclater published one of the best illustrated papers about the rhinos exhibited at London Zoo highlighting their unique rhino collection. This Javan rhino is the subspecies *R. sondaicus sondaicus*. The plates were engraved after watercolours by the animal artist Joseph Wolf (Zoological Society of London; Rookmaaker, *The Rhinoceros of South Asia*, Fig. 46.1, and also *R. unicornis*: Fig. 3.1, and *D. sumatrensis*: Figs. 53.1, 53.2).

and are restricted to Sumatra, Indonesia.

Rookmaaker's earlier findings on the number and details of Asian rhinos in captivity historically, especially the most numerous, *R. unicornis*, but also *D. sumatrensis* (Fig. 9) and *R. sondaicus* (Figs. 10 and 11) are greatly augmented. For *R. sondaicus* Rookmaaker has revised his 1998 figure of 22 specimens in captivity to 39 clear identifications, still a very small number, and gives interesting information about them, with 19 recorded in captivity in India and Bangladesh, the last one in 1905.

An epilogue (chapters 65–67) summarizes

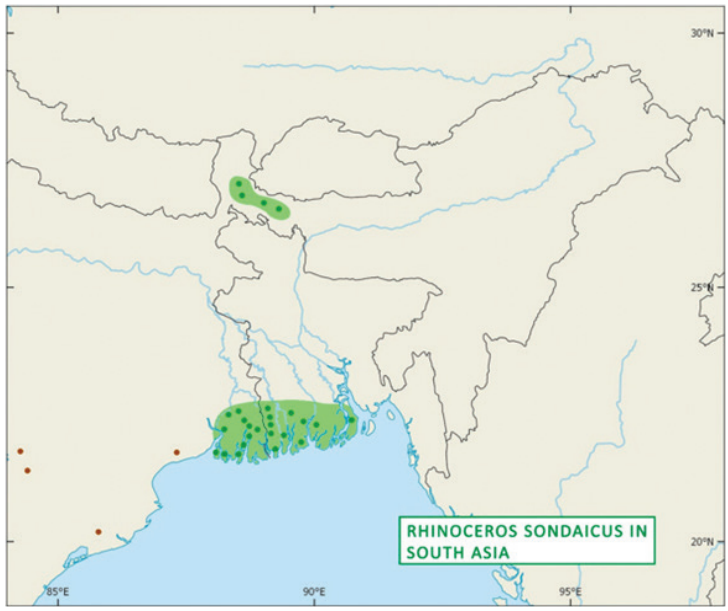

Figure 12. This map shows the historical distribution of *Rhinoceros sondaicus inermis* in South Asia. (Map design by Ajay Karthick and Richard Kees, © Kees Rookmaaker (Rookmaaker, *The Rhinoceros of South Asia*, Fig. 66.37).

Rookmaaker's main findings, with his updated historical distribution maps (Fig. 12) for each of the three species in South Asia. A map also shows the proto-historical distribution of *R. unicornis* from 11,700 years ago. Many factors led to the massive decline in rhinos in most of South Asia, including the spread of human settlement, hunting, and cultivation. The book provides the data to explore the processes leading to the local extinction of two of the three species, even in areas where human interference might not have been the most significant factor.

Rookmaaker comments near the end of his tome that he 'spent many happy hours chasing rhinos on the pages of the great books of the past and present in many shapes and forms'. His publication is indeed another great book, packed with nuggets of information. He points out that in retirement it was an enquiry he could 'pursue more vigorously', combining the many records from fossil remains, rock paintings, drawings, photographs, trophies and writings. These can inspire further study and data compilation about rhinos historically, as is the author's hope.

Kees Rookmaaker's masterly book, *The Rhinoceros of South Asia*, is the culmination of a life's work reconstructing the historical distribution of *R. unicornis*, *D. sumatrensis* and *R. sondaicus* resulting in new maps showing the extent of their occurrences. Thousands of sources were used to study the interactions between humans and the three rhinoceros species that were found in South Asia. While most of the material focuses on *R. unicornis*, there is important new information included for *D. sumatrensis* and *R. sondaicus*. I cannot recommend Rookmaaker's new book highly enough, for rhino researchers, those interested in art and history, and of course conservation, in South Asia, and indeed all enthusiasts wishing to increase their knowledge about the three ancient rhino species of Asia.

Rookmaaker, Kees (LC) 2024. The Rhinoceros of South Asia. Brill, Leiden, The Netherlands.
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TRIBUTES

Diane Skinner

Former Programme Officer of IUCN SSC African Elephant Specialist Group, and conservationist who bound hearts and minds

Born: 8 December 1980
Died: 10 August 2022

Tribute with reflections by Holly Dublin, Tom Milliken, Nicholas Dyer

email: holly.dublin@gmail.com

"Diane will be remembered by many, as during her years on Earth she touched many lives and made this a better world for people, animals, and the environment".

***Jane Goodall, PhD, DBE**; Founder of the Jane Goodall Institute/UN Messenger of Peace*

Africa's conservation community lost one of its leading figures, Diane Skinner, the Executive Director of the Painted Wolf Foundation, who succumbed to cancer on 10 August 2022. Although only 41, Diane leaves behind a stellar legacy of global efforts to conserve not only African elephants and rhinos, but also wild dogs, chimpanzees, pangolins and other charismatic fauna in Africa.

Through a long body of work addressing international policy, community conservation, and NGO interventions, Diane continually navigated the delicate, ever-fraught balance of human-wildlife conflict; always striving for win-win solutions to safeguard endangered species and also benefit local communities.

A proud Zimbabwean, Diane graduated summa cum laude from Denison University in Granville, Ohio, USA, and commenced her career in conservation starting with the Jane Goodall Institute in Washington, DC in the early 2000s. Diane worked for the JGI for six years. Following this, Diane undertook her Masters in Society and Development at the University of Sussex, in England, achieving a distinction. After completing her MSc, she joined the IUCN SSC African Elephant Specialist Group as a Programme Officer in Nairobi from 2008 to 2014, which included her role on the editorial board of *Pachyderm* (Issues 46–55).

Dr Holly Dublin, the Chairperson of the AfESG for over two decades, warmly recollects their friendship and time working together:

> *"From 2008 to 2014, Diane's constant companionship was a central feature of my professional life and for the years after, my personal*

life as well. We recognized from the start that we shared several key characteristics. We were non-conformist, unconventional, and often constructively mischievous, filled with our own ideas on novel ways to tackle the problems we encountered in our work together. Whether it was purely operational matters or the 'wicked problems' inherent in conserving elephants in Africa, we always stepped up to the challenge together.

Although Diane secured the much-flaunted job of being the Programme Officer for one of the most prestigious and high-profile IUCN SSC Specialist Groups, it was not what she expected. While most people assumed that Diane spent endless time in the field getting to know the world of elephant conservation from the bottom up, that was not her role. Her job was to support the members of the AfESG to do their work, not to be a practicing technical player herself.

By the time she left the post, she had become one of the most ele-savvy people around. She carried out her position with aplomb, rigour and without a hint of the ego and arrogance so often seen in elephant conservation circles. Diane was highly knowledgeable, always pragmatic, and hugely effective. Above all, she was a diplomat, and with a disarming smile, sharp intellect, and ironic wit, she won over anyone and everyone that came her way. A West African minister warmly referred to her as 'la dame au grand sourire'. Diane always left an indelible mark!

Diane and I travelled extensively together to places near and far, gaining vast experience of the cultures and sensitivities of people in China, Europe, and Africa. Diane's innate ability to absorb everything around her and synthesize it into deep understanding to inform subsequent actions was unparalleled. What she learned in one place, she applied in another, learning profound lessons from the issues that divided our membership and those that united them.

But there was another far less serious side to Diane, and I loved (and miss) that even more. How could I forget the time we were preparing for a CITES Standing Committee meeting, we booked our own Airbnb for the duration of a conference, and on many nights, we hosted pizza parties or had potlatches with friends and colleagues, creating some of my most lasting memories… and some of the best relationships anyone could ever have with delegation members of the Parties to CITES.

In fact, I have endless memories of our time together in the AfESG, always wanting to have an even broader and deeper reach using all of our knowledge of elephants and the wider implications to ensure a greater impact for African conservation. One of our most deeply shared passions was our belief that for conservation to be successful in Africa, it had to be led by African people, [done] with African people and for African people.

After leaving AfESG, Diane became central to the group that developed a new methodology called 'Local Communities: First Line of Defence", commonly known as FLoD. This cutting-edge approach worked with local communities to document how they lived with wildlife, what it meant to them, and what they felt were critical actions toward delivering a larger vision for conservation and development.

For me, Diane's ability to work with all people, regardless of their differences and perspectives, was the greatest contribution she made not only to elephant conservation but also to successful conservation efforts across Africa… and always with a smile.'

In 2014, Diane left IUCN to return to her beloved Zimbabwe to become an independent consultant working for species such as elephants, rhinos, and pangolins and developing strategies to improve coexistence with local communities.

In her work, Diane advocated collaborative approaches to conservation working in a multidisciplinary way. As a passionate advocate for increasing African conservation capacity, especially for women, she volunteered her time to mentor and train young Africans and became a conservationist in residence at the African Leadership University (ALU) School of Wildlife Conservation. She volunteered to serve on several boards, including the Zimbabwean Chapter of the Society for Conservation Biology.

In 2018, Diane became the founder of the Painted Wolf Foundation (PWF), an organization that she evolved to bring best practice conservation interventions to wild dogs across Africa. In 2020/21,

as Executive Director of the PWF, she analyzed the status of wild dog conservation across Africa and produced the seminal report 'Securing the Future of the Painted Wolf'. The report provides an intelligent and workable strategy to remove wild dogs from the edge of extinction and is a lasting and impactful legacy for the species.

The Painted Wolf Foundation and the ALU School of Wildlife Conservation have established the Diane Skinner Award for the 'Unsung Hero in Conservation'. This award celebrates people like Diane, who work selflessly for conservation and focus on wildlife and not themselves. The inaugural winner in 2023 was Norah Njiraini of the Amboseli Trust for Elephants for her dedicated work to the savannah elephant.

This year, PWF and ALU created the Diane Skinner Conservation MBA Scholarship for African Women to help build a future generation of African conservation leaders. The winner of the Award for 2024 will be announced in early 2025.

Those who knew Diane remember her as a warm and resilient person with contagious enthusiasm for the natural world. Her loss is deeply felt by the conservation community; however, her legacy will continue to inspire future conservationists. Colleagues describe her as someone who did not waste energy on self-promotion or seeking recognition but who used her keen intellect to find solutions and her gentle charm to push them through.

Sadly, Diane leaves behind countless friends, a loving family, her husband, Nicholas Dyer and her much loved dog, Snowy.

ACKNOWLEDGING OUR REVIEWERS

We thank our reviewers for their valuable time and detailed feedback, improving the quality of the work we publish; for Vol. 64/2023 and Vol. 65/2024.

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Aim and scope

Pachyderm publishes papers and notes concerning all aspects of African elephants, African rhinos and Asian rhinos with a focus on the conservation and management of these species in the wild. At the same time, the journal is a platform for disseminating information concerning the activities of the African Elephant, the African Rhino, and the Asian Rhino Specialist Groups of the IUCN Species Survival Commission. Currently, *Pachyderm* is published online once a year and is 'Platinum Open access' (for all readers free access to published scientific works; with no publication fees for the authors to publish). All research, management, and history papers are peer-reviewed.

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All manuscripts should be submitted online at: http://Pachydermjournal.org & https://pachydermjournal.org/index.php/pachyderm/about/submissions.

If there are any questions or concerns regarding the submission process, kindly send an email to: afesg@iucn.org and/or pachydermeditor@gmail.com. We are also contactable by post:

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Manuscripts are accepted in both English and French. Where possible, the abstract should be provided in both languages, whether submitted in English or French.

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Papers may be reports of original biology research or they may focus more on the socio-economic aspects of conservation, including market surveys. Each Research and Management paper is subject to peer review, the reviewers who are assigned have expertise in the specialist subject/s related to your paper. This process is "blind" with both author(s) and reviewer(s) anonymous to each other unless otherwise agreed.

Papers should not exceed 6,000 words (the word count is inclusive of all parts of the manuscript, including the title page, abstract, references, table and figure legends). Papers should be structured as follows: 1a) Title, 1b) Names, addresses and emails of authors, 2) The Abstract must not exceed 250 words (informative in style, outlining information from the Introduction, Methodology, Results, Discussion); 3) additional key words (if any, not appearing in the title, maximum six); 4) Introduction; 5) Methodology; 6) Results; 7) Discussion; 8) Conclusions; if appropriate; 9) Acknowledgements (optional, brief); 10) References should be included only when essential and quoted in the text (maximum of 25); 11) Tables; 12) Figure and photo captions; 13) Figures and photos. (Tables, figures and images should be inserted in the text in the relevant section).

Should your paper exceed 7,500 words, an article processing contribution (APC) fee may be requested by the Editorial Board.

Field notes

The journal welcomes notes from the field. They may contain figures and tables but should be a maximum of 3,000 words, including references.

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Reviews, which are unbiased reviews of all the existing knowledge on a specific topic, are welcomed. Length should be a maximum of 6,000 words, including references.

Book reviews

Pachyderm invites reviews of newly published books, which can be up to 1,500 words. Kindly liaise with the editor before submission.

Letters to the editor

Letters should be addressed to the relevant Specialist Group Chair/ or Editor and should be a maximum of 1,500 words. Letters are welcome that comment on articles published in *Pachyderm* or on any other issue relating to elephant and rhino conservation in the wild.

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Submissions may be prepared using any word processing software but must be submitted in .doc or .docx format. Submissions should be set in 12pt Times New Roman font, left-aligned, and with double-spacing. Submissions in PDF format are not acceptable.

Tables, figures, images and maps

Preferably provide figures and maps in their original form, and data in Table format; (Excel files are not accepted), maps as EPS and images should be submitted in the highest quality possible, such as TIF (minimum 300 dpi), or JPEG (minimum 300 dpi). Indicate clearly the author or source of figures, maps and photographs. Colour is acceptable. We shorten figure to 'Fig. x' within the text, and 'Figure x.' in full in the caption.

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The title should contain as many of the key words as possible but should not be more than 25 words long. Follow with the name(s) of the author(s) with institutional affiliation, postal and email address of the corresponding author, to whom proofs and editorial comments will be sent.

Journal conventions

Nomenclature

Use common names of animals and plants, giving scientific names in italics on first mention. Generally, refer to animals in the plural form (i.e. rhinos, elephants). We do not capitalise elephant, black rhino, white rhino and greater one-horned rhino. We do capitalise Javan and Sumatran rhino.

Spelling

Use British spelling, following the latest edition of the Oxford Advanced Learners Dictionary using 'z' instead of 's' in words like 'recognize', 'organization', 'immobilized'; but 'analyse', 'paralyse', a full list can be obtained from the Managing Editor: https://elt.oup.com/catalogue/items/global/dictionaries/oxford-advanced-learners-dictionary/?cc=global&selLanguage=en

Numbers

Use the International System of Units for measurement (m, km, kg, ha, h) with a space between the numeral and the unit of measurement. Give measurements in figures, for example 12 mm, 1 km, 3 ha, except at the beginning of a sentence; in which case write out the full number, e.g Forty-two black rhinos were born in 2023.

Spell out numbers under 10 if not a unit of measurement unless the number is part of a series containing numbers 10 or over, for example: 14 adult males, 23 adult females and 3 juveniles or there were nine people watching the group of 65 elephants.

In the text, use a comma as the separator for figures four digits or more: 1,750 and 11,750. The separator will be a full stop in French papers.

Hyphen, en dash and em dash

The hyphen (narrow) is used to separate compound words:

Long-term

Seventy-two

Decision-making systems

The en-dash (wider) is used to separate a range of numbers:

South Africa's Kruger National Park is home to 7,000–8,300 rhinos as of 2016.

Overall, all of the elephants had smaller annual home ranges (~450–1,750 km^2).

The en-dash is also used to indicate relationships, for example:

Human–elephant conflicts

North–South divide

The en-dash is used to indicate distance, example:

The headwaters of the Chobe River–Victoria Falls is a distance of 136.3 km.

The em-dash (even wider) is to enclose a phrase within a sentence and provides greater emphasis than parentheses:

Our core values—integrity, collaboration, adaptability, sound decision-making and commitment—are at the heart of everything we do.

The presence of the new species—that scientists suspected existed—was confirmed last week.

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A DOI should be provided where available and especially for digital sources, in the format "doi:prefix/suffix" and hyperlinked to "https://doi.org/prefix/suffix". Whenever both a URL and DOI are available for a source, the DOI is preferred, and the URL may be omitted. The preferred format is: doi:10.1000/182

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Article in a journal or periodical

Barnes RFW, Barnes KI, Alers MPT, Blom A. 1991. Man determines the distribution of elephants in the rainforests of north-eastern Gabon. *African Journal of Ecology* 29 (1): 54–63.

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Common abbreviations that can be abbreviated without further explanation in your manuscript

Other abbreviations should be defined at the first mention in the article and then only the abbreviation used thereafter, e.g.

SSC	Species Survival Commission
AZA	Association of Zoos and Aquariums
AfESG	African Elephant Specialist Group
AfRSG	African Rhino Specialist Group
AsRSG	Asian Rhino Specialist Group
CITES	Convention on International Trade in Endangered Species (of Wild Fauna and Flora)
CMS	Convention on Migratory Species
DEFRA	Department for Environment, Food and Rural Affairs
EAZA	European Association of Zoos and Aquaria
ETIS	Elephant Trade Information System
IUCN	International Union for the Conservation of Nature
IRF	International Rhino Foundation
KAZA-TFCA	Kavango–Zambezi Transfrontier Conservation Area
MIKE	Monitoring the Illegal Killing of Elephants
RRC	Rhino Resource Center
SRI	Save the Rhino International
USFWS	US Fish and Wildlife Service
WAZA	World Association of Zoos and Aquariums
WCS	World Conservation Society
ZSL	Zoological Society of London