Amboseli Trust for Elephants
Annual Research Report 2021

MISSION STATEMENT FOR ATE SCIENCE AND RESEARCH: *The Amboseli Elephant Research Project is the world's longest continuous elephant research programme. ATE contributes trailblazing knowledge of large mammal socioecology, provides a basis for public understanding and concern for elephants and their ecosystems, and communicates information enhancing conservation in the Amboseli ecosystem and for regional and global elephant populations.*

Introduction

As we approach 50 years of continuous research on individual elephants over their lifespan, our 2021 report provides background information for our ecosystem partners on the health and status of the Amboseli elephant population. We first thank the Maasai landowners and individuals that have enabled coexistence with elephants over the 49 years of the AERP project, as well as our ecosystem partners: the Wildlife Training and Research Institute (WRTI), the Kenya Wildlife Service (KWS), the Group Ranches and Community Conservancies, Amboseli Ecosystem Trust and Big Life Foundation. We also thank all our collaborators and donors for their sustained interest in our research results and for their support in protecting the elephants and ecosystem of the Amboseli Basin.

Of the two sets of twins born in 2020, one twin has sadly died of natural causes, while the others are thriving. A further 92 calves (42 males, 44 females, 6 unknown sex) were born in 2021. In collaboration with KWS, we now have data on the annual ranging of eight young male elephants as they started to establish independent home ranges. A further two females were added to our tracking data during the KWS Elephant Naming Event in October 2021. Tracked individuals are a small minority of the 3,840 elephants whose lives we have monitored either from birth or over the 49 years of the study, but they are important ambassadors in the face of changing landscapes. The Amboseli population continues to thrive: in 2021, there were 662 living females over the age of 9 (potentially reproductive adults) and ~300 living family males over the age of 15 (independent, mature males). Our data on reproductive dynamics and population parameters for both males and females contribute to a greater understanding of the resilience of elephants in Kenya and across Africa to the threats facing their populations.

I.   Long-Term Monitoring
A) Environmental dynamics

The rainfall year 2020-2021 was the second very wet year in a row, with over 800 mm of rain in 2019-20 and 556mm in 2020-2021 (compared to an annual average of 350mm). As may become more typical under conditions of climate change, rainfall was highly clumped, with the majority falling in only two months, February and April. This distribution is in contrast to the previous rainfall year where most fell in November and December of 2019. Conditions for grass growth were limited at the start of 2021 despite the previous year's rain, such that there may have been a delay in grass availability until late in the short rains (Nov-Dec 2020). Good rainfall in April and May was then followed by five dry months, leading to a prolonged dry period with low food availability.

We illustrate projected seasonal shifts in grass/herb biomass in response to rainfall, using a 30-day lag between rain and onset of grass production (Figure 1). It is clear that, compared to the long-term average rainfall conditions creating a bimodal biomass availability, 2021 was unusual in having a delayed start, with a late atypical peak in potential production following the long rains, preceded by a considerable dry period of low production.
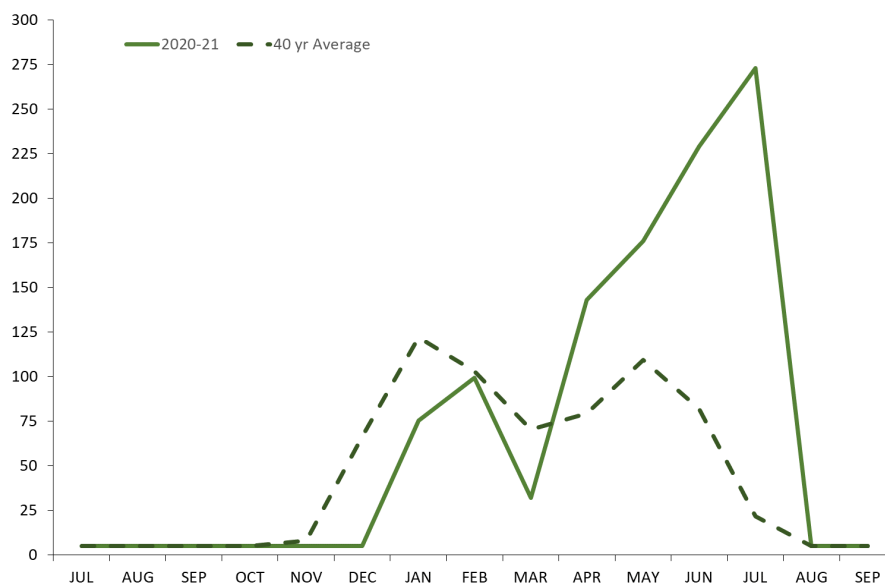
Figure 1: *Indicative biomass production from rainfall for 2020-21, compared with long-term (40+ year) average based on: (a) grass growth starting after 30 days of rainfall; and (b) a cumulative relationship between two successive months of rainfall and predicted growth. ATE long-term rainfall.*

Changing trends in rainfall have consequences for biomass production which are vitally important for understanding how climate change will affect the Amboseli elephant population and coexisting livestock and other wildlife species. Changing patterns can also illustrate why perceptions of extreme dry seasons occur even in period of apparently high rainfall. When rain and biomass production are shifted from the norm by two or three months, rangeland management can become unpredictable and difficult. Higher but more variable rainfall may make elephant movements and overlap between livestock and elephants more complex to manage.

B) Elephant ranging

Rainfall represents both food availability for elephants and releases them from proximity to reliable surface water. In Amboseli this allows elephants to disperse widely over the ecosystem without needing to return to central swamps within Amboseli National Park. In recent years, access to persistent man-made water sources has allowed a number of families and males to range shift from the central areas to previously outlying elephant zones and a number of families now permanently reside in and around Selenkay Conservancy to the north, Enduiment Wildlife Management Area to the south, and range further from Kimana in the east. Water and food availability facilitates broader elephant movements to dispersal areas like Mailua to the northwest, Kuku and Tsavo West to the east. The dispersal of elephants throughout the 8000 km^2 greater ecosystem has distributed the entire population over a wider area and reduced local densities, except at water points. Of the ~300 independent males in the Amboseli population, many are resident in these dispersal areas and return to the central park zone seasonally (especially for mating opportunities), while others, such as the younger males, roam across the entire ecosystem. More than 650 (out of 1666) known family individuals are spread across these distant landscapes.

Within Amboseli National Park, elephants are still regularly seen in the main areas of high-quality water and food, although the use of the park (like that of the surrounding ecosystem) varies seasonally.
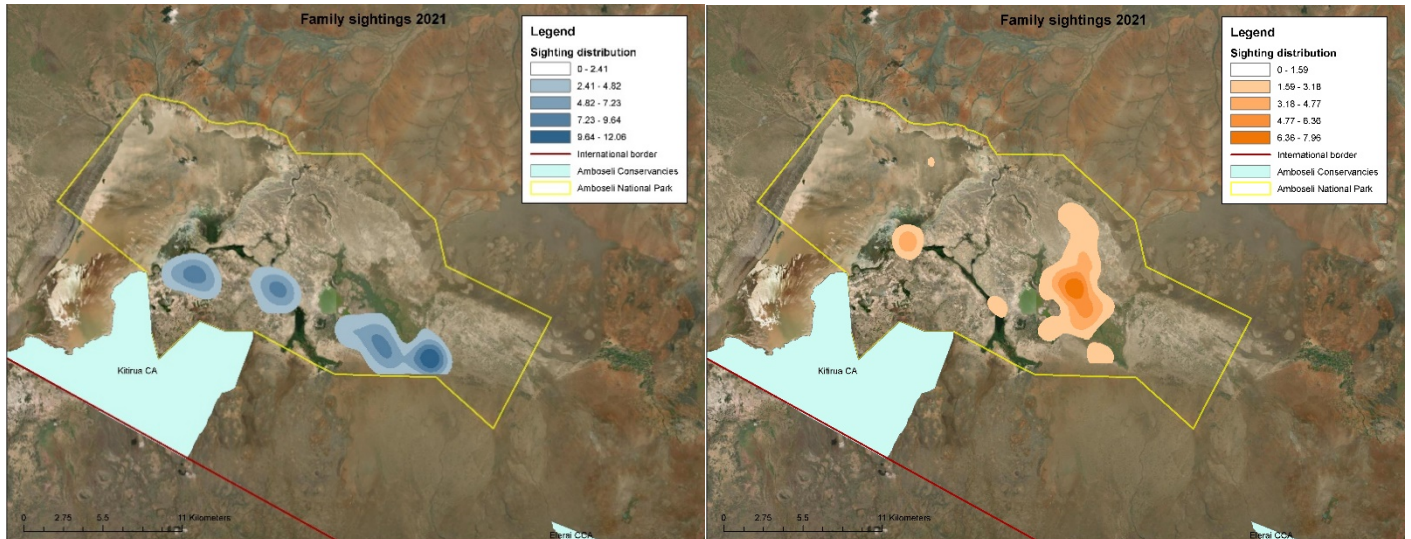
A: Wet season (Nov-Dec)   **B: Dry season (Aug-Sept)**

Figure 2: *Kernel densities of female sightings within the Amboseli protected area comparing wet and dry seasons. Females used western and southern areas in the Wet while they used a central Longinye swamps in the Dry.*

C) Elephant population dynamics

We recently produced a detailed analysis of how the Amboseli elephant population responded to droughts over the ~49 years of the AERP study (Lee et al. 2021). We summarise our findings here, and provide information of potential interest.

We explored how environmental and social adversity at birth or at the ages of first reproduction (females) or first musth (males) affected the lifespan and risk of death, as well as impacting on the ages at which these vital events occurred. Using periods of significant ecological adversity, we examined "cohort" effects for male and female elephants. Mortality spiked during severe droughts with highest mortality among calves under 2 years and females over 40 years.
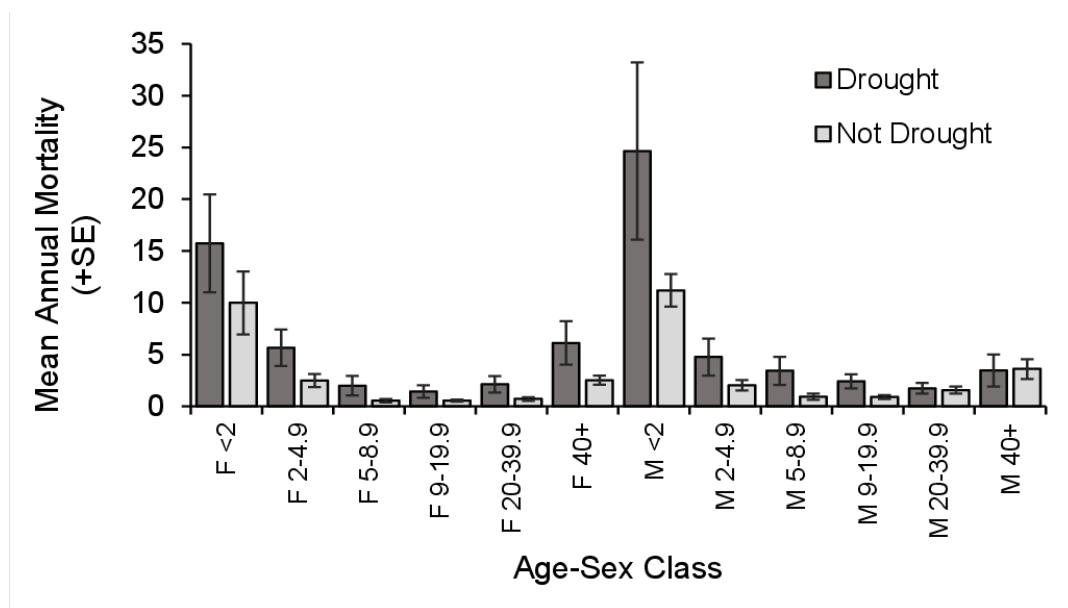

Lee et al Figure 1. *Mean (+SE) annual mortality per age-sex class (F = female, M = male; n drought = 15, n not drought = 33).*

Deaths of oldest females, the family matriarchs, resulted in social disruption via this matriarch turnover, increasing the risk of death for calves. Male calves were especially at risk. We also predicted potential impacts on resource acquisition for survivors, which we will monitor into the future.
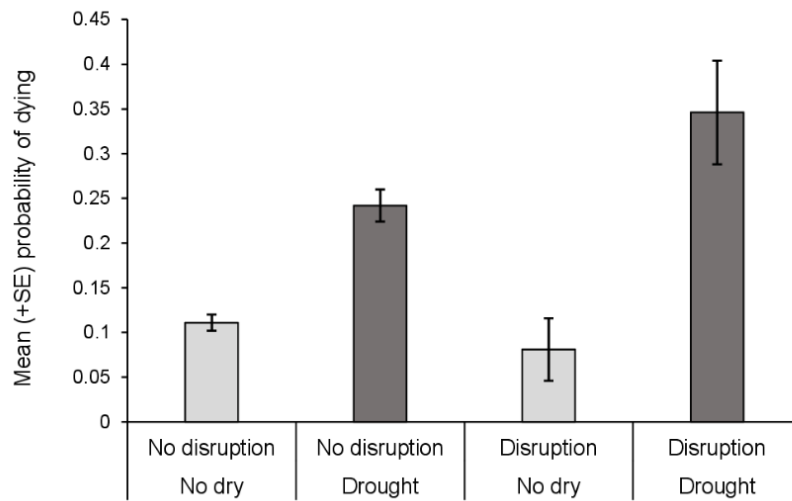
Lee et al. 2021 Figure 2. *Risk of death in the first year of life for calves experiencing drought plus disruption to the family. (Risk = proportion of death specific to context out of all deaths for age).*

Drought were followed by birth pulses, the first generated immediately after the drought had ended since so few females had young calves and thus most of the females in the population were available to conceive. We found another pulse of births about 5 years after a drought, suggesting that the drought "reset" oestrus among cohorts of females, creating synchronous peaks and troughs that cycled through the population.
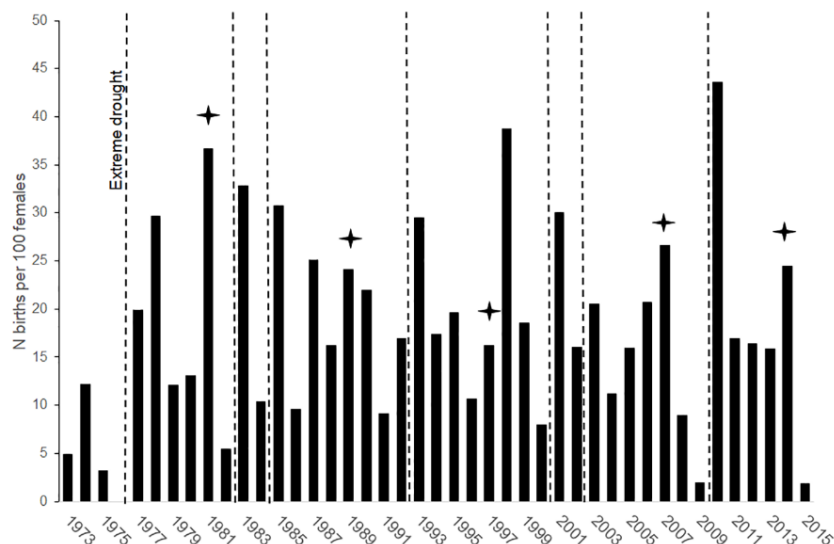
Lee et al. 2021 Figure 3. *Temporal patterning of fertility (conceptions per 100 females) by year from 1973 to 2017 with 7 extreme droughts indicated by the dotted lines. Star indicates 5-years post-drought.*

In addition to the risk of early calf death associated with matriarch turnover, risk of death at all ages was increased by 22% for elephants who lost their mothers prior to 9 years of age, even if their families remained intact.

While we predicted that survivors of high mortality and social challenges would alter life history trajectories, with later age at first reproduction and reduced age-specific fertility for females, there were no persisting early drought effects on female age at first conception. This age remained constant between 9 and 12 years (mean age = 11.96 years, SD ± 1.99, N = 560) over the years of the study. Matriarch loss around puberty accelerated reproductive onset, but only by an average of 6 months, while the loss of a mother prior to the onset of reproduction delayed the onset by about 6 months. Experience of an early life drought did not influence age-specific reproductive rates once females commenced reproduction, in part because the survivors may be able to "out-grow" any disadvantages due to stunting caused by early drought exposure.
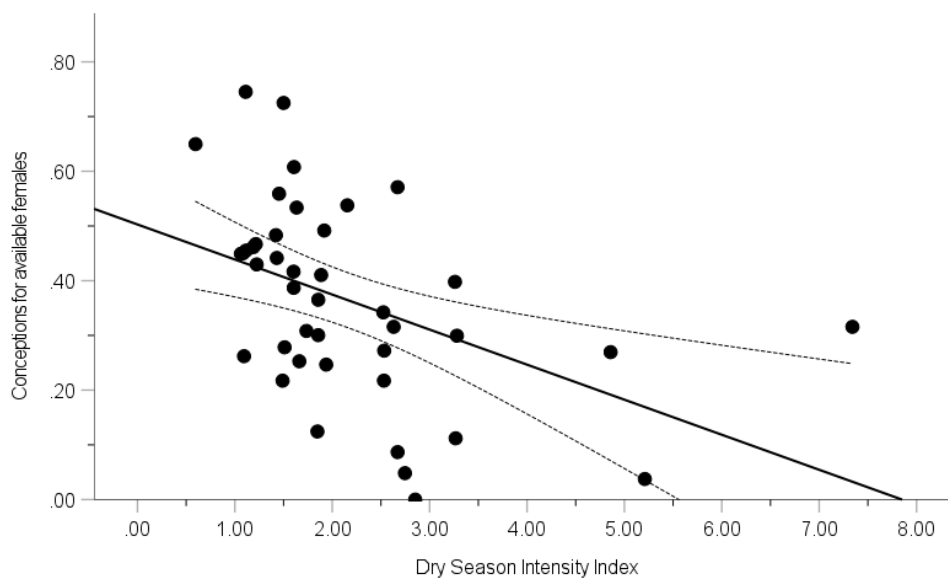
Lee et al. 2021 Figure 4. *Conceptions for available females from 1974 to 2017 in relation to Dry Season Intensity index (r = -0.452, n = 42, p = 0.003). Linear trend line with 95% CI shown.*

The key factors affecting female rates of reproduction were twofold: (a) drought or low food availability that year; and (b) whether the female was already pregnant or suckling a calf less than 12 months of age. On average, 37% of available females (9+ years, not pregnant, not in first 12 months of lactational anoestrus) conceive in any year. In the Amboseli population, female reproductive rates appear to be unrelated to the number of other females (i.e. competition which results in reproductive suppression). Thus, we have yet to find evidence of density dependence in reproductive rates.

We also predicted slow transitions to independence and late onset of potential mating or musth among males who had experience early life adversity. Contrary to our expectations again, males who survived an early drought exhibited complex consequences: male age at family independence was later with larger peer cohort size, but earlier with drought in year of independence (13.9 vs 14.6 years). We found that male age at family independence ranged from 7.42 to 19.92 years, with a median age of 14.5 years. Experiencing a drought year around the age of independence was associated with a slightly earlier departure (13.1 years ± 1.70 SD vs 13.9 years ±1.89 SD; t = 3.28, p < 0.001).

The number of male peers in the population (±2 years of target's age) was negatively associated with age at independence (t = -4.26, p <0.001): males tended to leave later when there were fewer

close age mates in the population. In addition, there was a negative association between the size of dispersing cohorts and the likelihood of those males being resighted annually within the core population, suggesting greater movement away from core habitats with large cohorts (average cohort annual resighting rate and male cohort size, rs = -0.665, p <0.01, n = 40).

Mean age at first musth was 29.3 ± .377 SE (range 16.4 – 38 years, n = 440 with 211 known events). Early drought had no effect on age at first musth again because (a) the small proportion of males who survive to musth age have out-grown size constraints of early adversity and (b) because survivors represent a different group of more successful males: half of males die before the age of first musth, but for those that survived beyond a minimum age of first independence (10+), their median age at death was 39.3 (95% CI 36.0 – 42.5, n = 571).
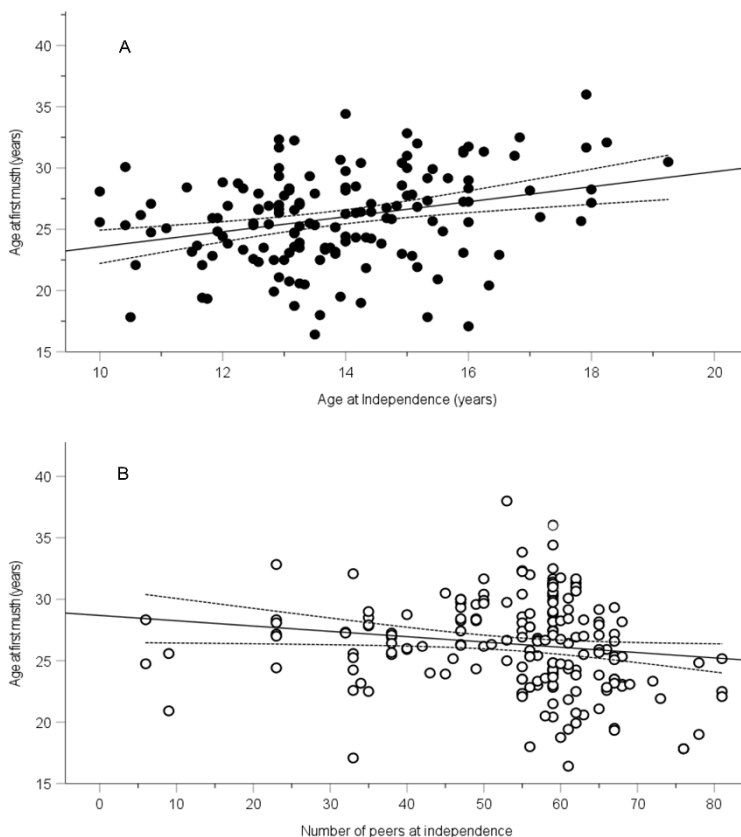

The median number of musth-age competitors was 26 (range 11-47). We found that males who left families late were also those experiencing a later first musth (Fig. 5A), while larger peer cohorts were associated with younger ages at first musth (Fig. 5B). In *post hoc* comparisons for only known-aged musth males, the number of musth age competitors was also associated with a later age at first musth (r_s = 0.196, p = 0.004, n = 211); the effect was, however, small and constrained since relatively few well known males have yet reached musth age in the most recent larger birth cohorts.

Male reproductive onset was weakly associated with the number of peers (negative) and age at independence (positive).

Lee et al. 2021 Figure 5. *The association between age at first musth with: (A) the age at independence from the family (n = 151); and (B) with the number of peers at mean independence age (14) (n = 192). Linear trend lines with 95% CI shown.*

One interesting feature of the unpredictable but frequent droughts is that the population structure is dynamic, which has consequences for individual survival and reproduction. This is illustrated below showing dynamic cohort effects over time due to pulses of births and deaths.
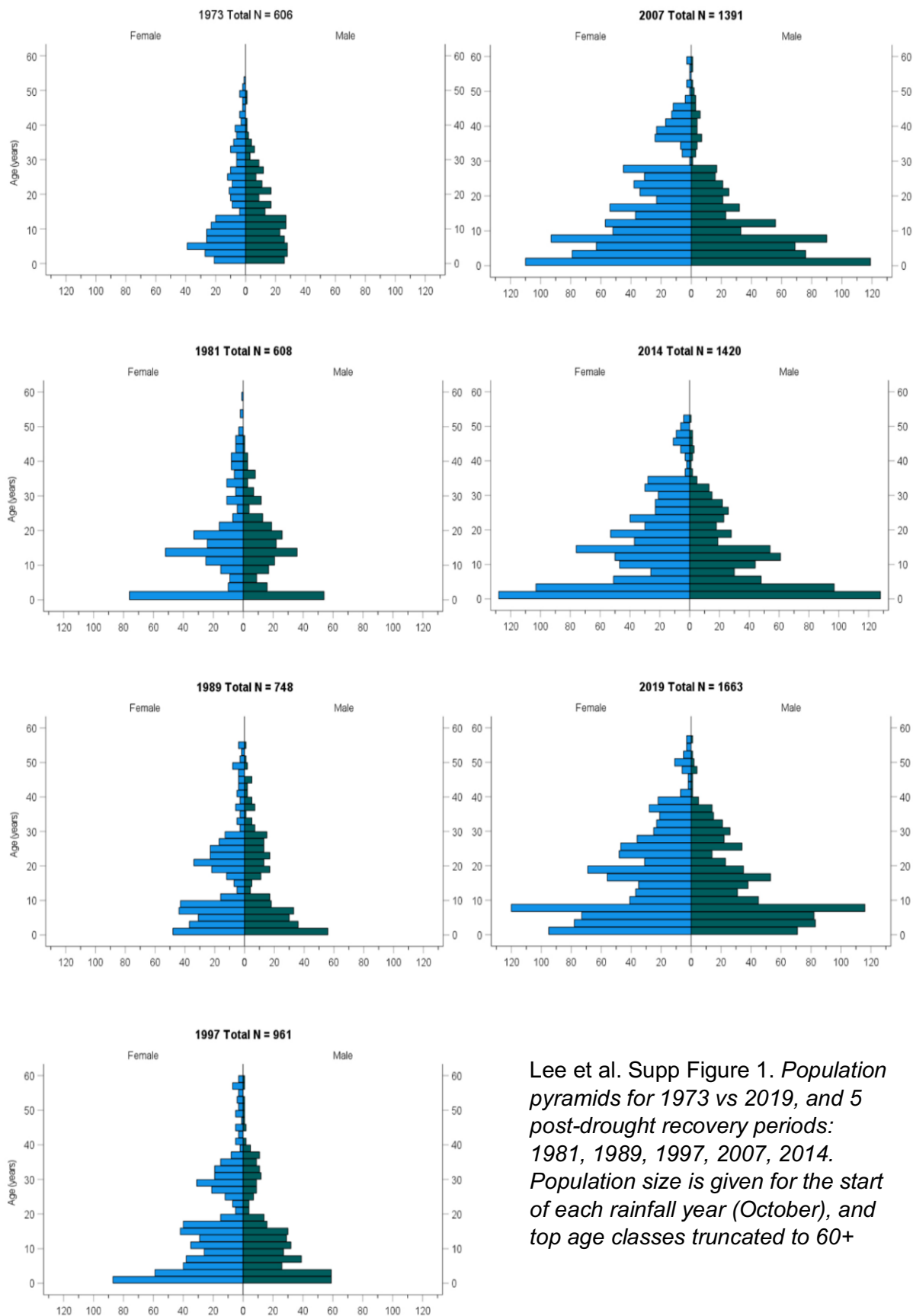
Lee et al. Supp Figure 1. *Population pyramids for 1973 vs 2019, and 5 post-drought recovery periods: 1981, 1989, 1997, 2007, 2014. Population size is given for the start of each rainfall year (October), and top age classes truncated to 60+*

II) Elephant social dynamics: Ongoing studies

Elephant sociality remains key to early survival, to longevity and to reproductive rates. We thus continue to focus on questions of social behaviour and dynamics. Our monitoring is based on sightings of known individuals with known family histories. We are currently exploring the associations between individuals within and between families, based on over 56,000 sightings and censuses from 1972-2021. We aim for 100% annual re-sightings for females in ~65 families although there are some families that we see less often. In 2021, there were 3 families who were not seen: one is a Tanzanian immigrant family that may have returned south, and the other two recently lost matriarchs, which tends to make families unstable and fragment. For the majority of families, we obtain up to 9 sightings per month, with a median in 2021 of 6 sightings per month (total N =169 sightings of Family Units).
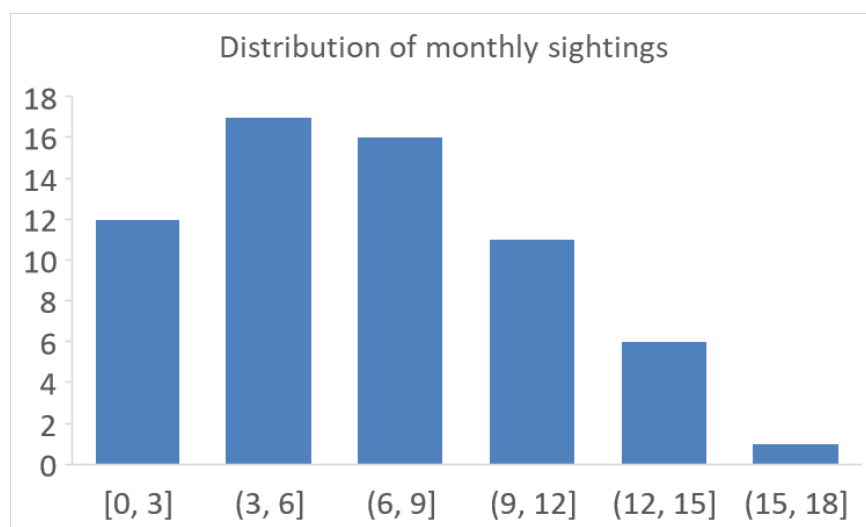

Figure 3. *Monthly sightings of 63 Family Units over 2021, ranging from 0 to 18 in any month.*

This monitoring work is key to three major aims with both theoretical and conservation implications: (1) defining family stability and dynamics over the very long term; (2) assessing the benefits of grouping for elephant females; (3) describing mechanisms of leadership within families. All of these questions are ongoing work.

The average group size for 2021 was 25 individuals, which is fairly typical for Amboseli elephants. Maximum group size was 140 in March 2021, reflecting the timing of grass growth supporting aggregations. Large groups persisted into the normally drier months of May-July, again, reflecting the later peak in grass availability.
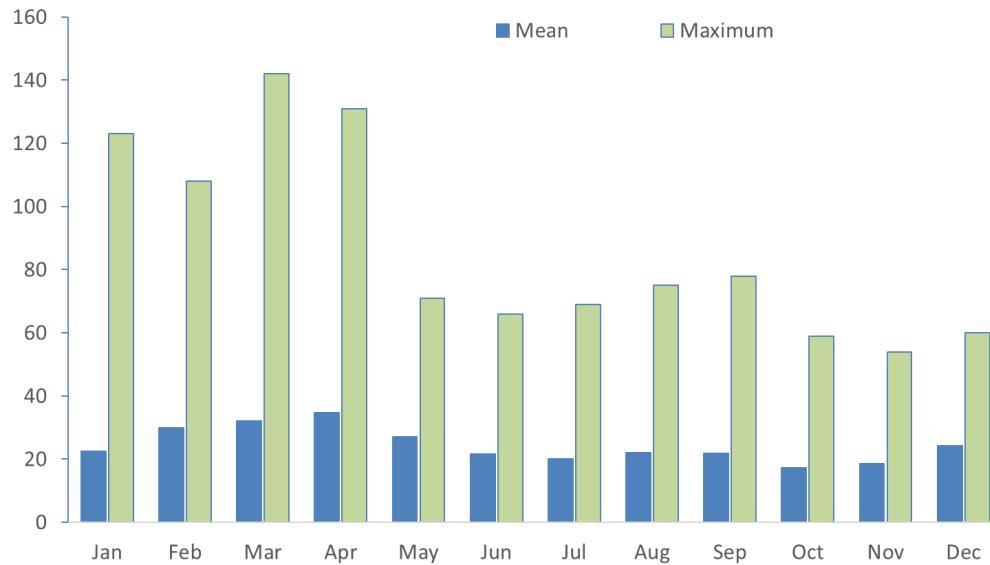
Figure 4: *Mean and maximum group sizes for family units in 2021 by month.*

In another joint project with external partners started in 2021, we are using historical data to examine the associations (social networks) between our known males, in relation to known life history events such as independence and musth. Male sociality is an important consideration for understanding population stability, recovery and resilience; males across Africa are threatened by hunting, poaching and conflicts and place larger pressure on the human-elephant interface than risk-averse females. An understanding of their sociality can help predict vulnerability and responses to risks, and craft better conservation plans. This study into male association dynamics is linked to ATE's ongoing study on male dispersal (see **III, A** below) as well as potentially to the genetics of population connectivity. Even as the size of male cohorts has grown over time, we have achieved an 87% annual re-sighting of 405 well known independent adult males (median = 8.8 sightings per year between 1974-2020; maximum sightings for any male = 556 over 30 years, among 802 independent males known from 1972-2020). Some males (n = 20) are known to have dispersed from the population after ~15 years of age and were therefore "lost" to further monitoring, and a few known males (n = 29) have been re-sighted after periods of 5 to 8 years away from the population. A small proportion (6.7% n=124) of our known males have dispersed, died or returned unrecognized and are scored as "fate unknown".

III)   Collaborations and Dissemination

A) Overview of collaborative research

We are currently in the process of developing collaborations with WRTI scientists to gain insight into the genetics of the Amboseli families and in particular, population connectivity between Amboseli, Tanzania and Tsavo. We are also working with Professor Robert Chira and Nairobi university colleagues to finalise the MSc study by WRTI's Peter Kimani on how elephant diets can be assessed from environmental DNA (e-DNA) extracted from dung. This collaborative study, due for completion in 2022, should be able to chart how elephants exploit the different vegetation types in the ecosystem as well as pressures on vegetation from drought, grazing and wildlife in this region, and the role of elephant consumption on species of conservation concern (sandalwood, *Santalum spp.* and invasive species e.g. *Opuntia*).

In further collaboration with KWS and WRTI, our study on how young male elephants use social and ranging strategies to buffer against anthropogenic risks, has now finally deployed all eight collars on young males who have recently dispersed from their families. The ATE collaring project is managed by ATE's Senior Research Scientist, Dr Vicki Fishlock. The males have travelled widely over the ecosystem (**Figures 5-7**), although they have all returned at times to the central core of the protected area. These males show both the range across which elephants travel, and the variety of strategies they use to move across varying risk gradients within the landscape. We are tracking companion choices for all males in this cohort, to determine who these young males learn new social and ecological strategies from. By mapping these choices onto previous social experience, examining our records of who their families associated with while they were growing up, we can gain insights into how males expand their range and companion choices as they become independent, and more likely to test the human-elephant interface. Mapping work is managed by our GIS and media manager, Tal Manor.

The importance of corridors and connectivity between Amboseli and Tsavo West are illustrated in detail by the 2021 home ranges of the eight young males.

Peet (PA, eastern family) and Lenku's (TC, eastern family) home ranges show the greatest eastern movement clearly connecting the Amboseli and Tsavo elephant populations. Jaeger's (JB, eastern family) range also shows clear Tsavo connections.
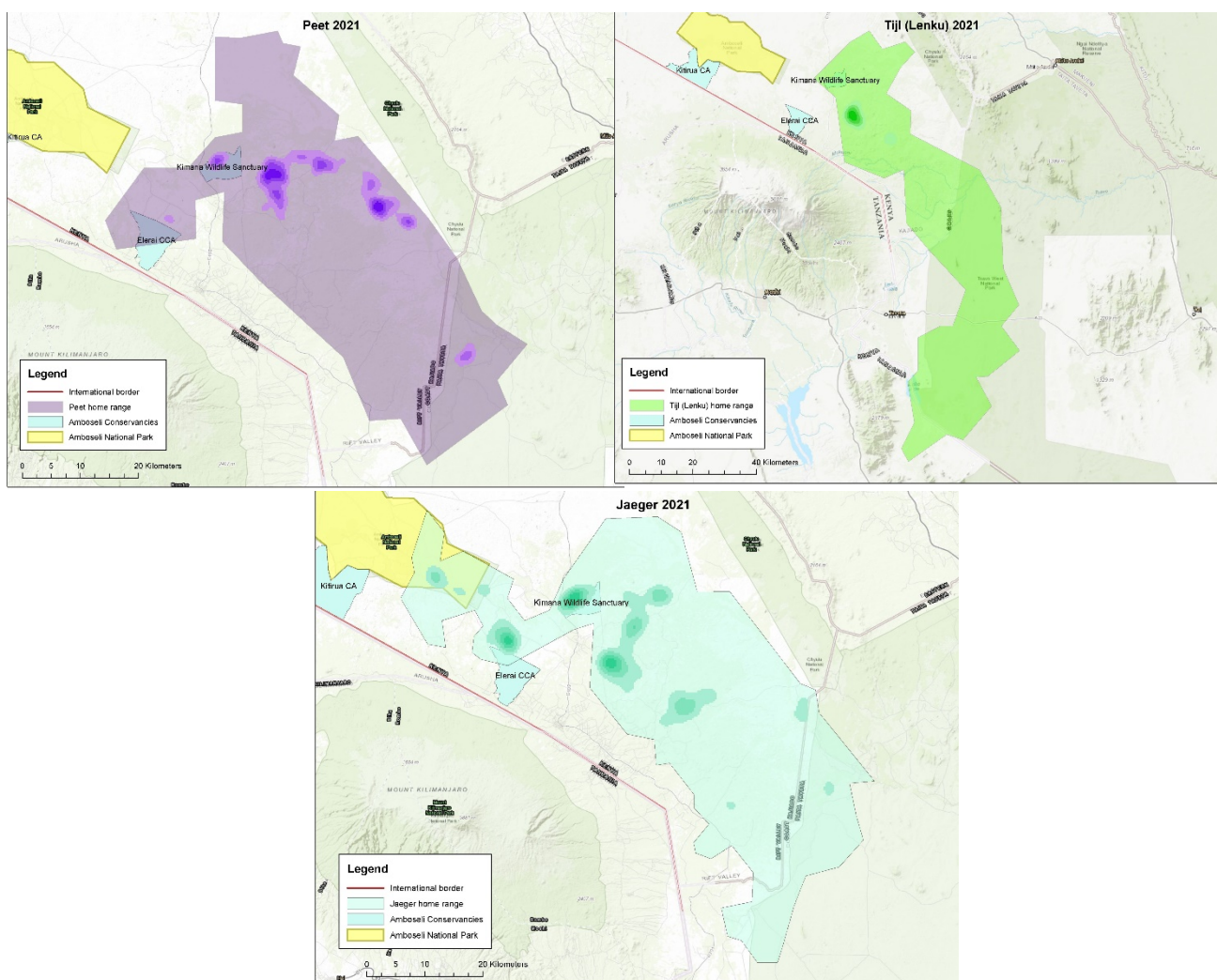

Figure 5. *Kernel densities showing annual home range for collared young males ranging east: Peet, Lenku and Jaeger*

For the males collared in 2019, their ranges are now showing more consistent use of specific areas. Pakwach (in contrast to his younger cousin Peet, also from the Eastern PA family) uses areas north to Selenkay. Garango (from the central GB family) now splits his time between the north and the western bushlands, including areas as far as the Mombasa Road (in 2022 he has already travelled to Kibwezi, and then returned to the Park). Esposito (a central EA family male) has also moved to the north and west.
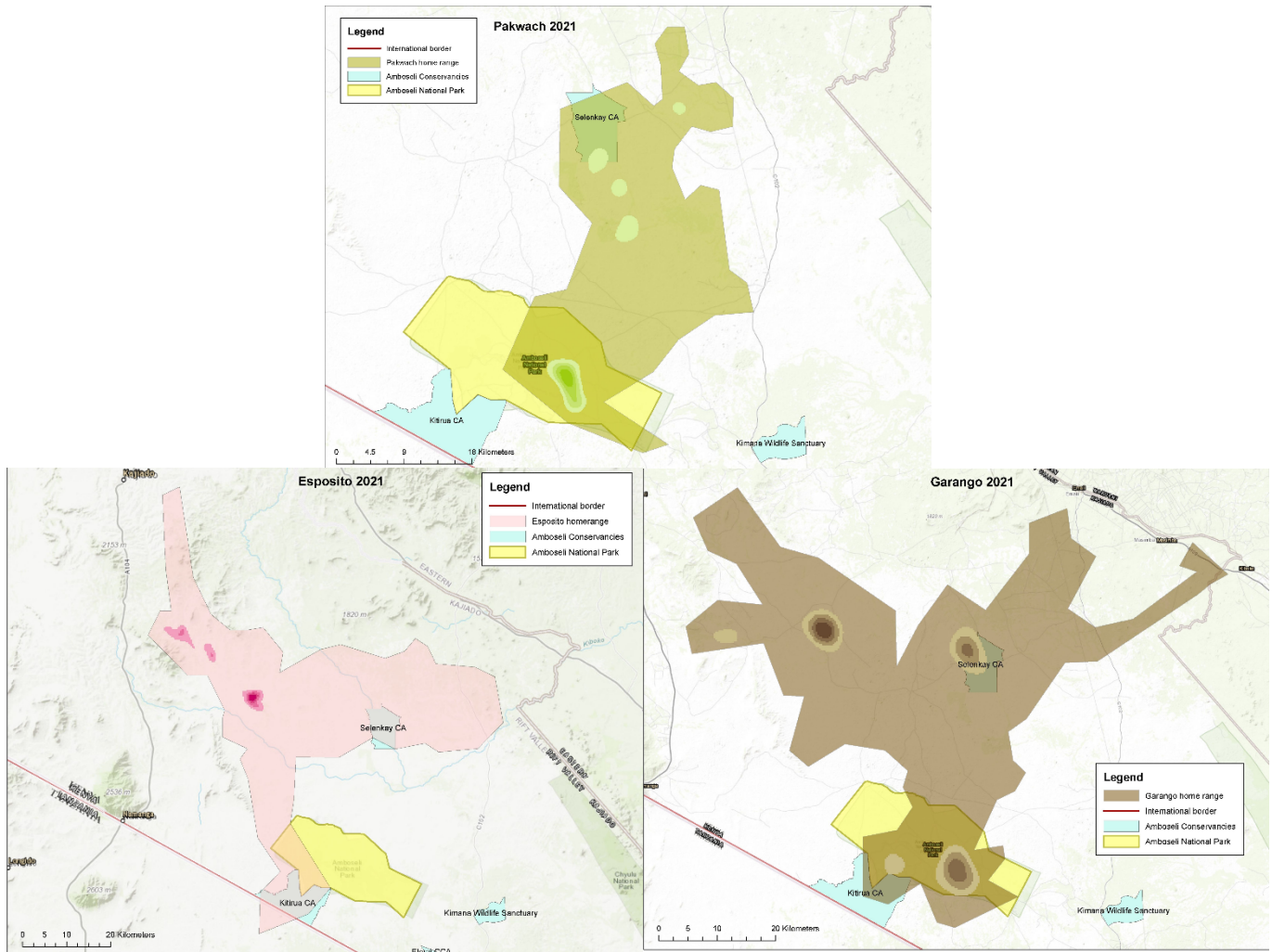

Figure 6: *Kernel densities of annual home ranges for three males ranging north: Pakwach, Esposito and Garango.*

Jameson (JA family, southwestern) and Ibadan (IA/IC family, west central) are found using areas far into Tanzania, although Jameson has also started moving north.
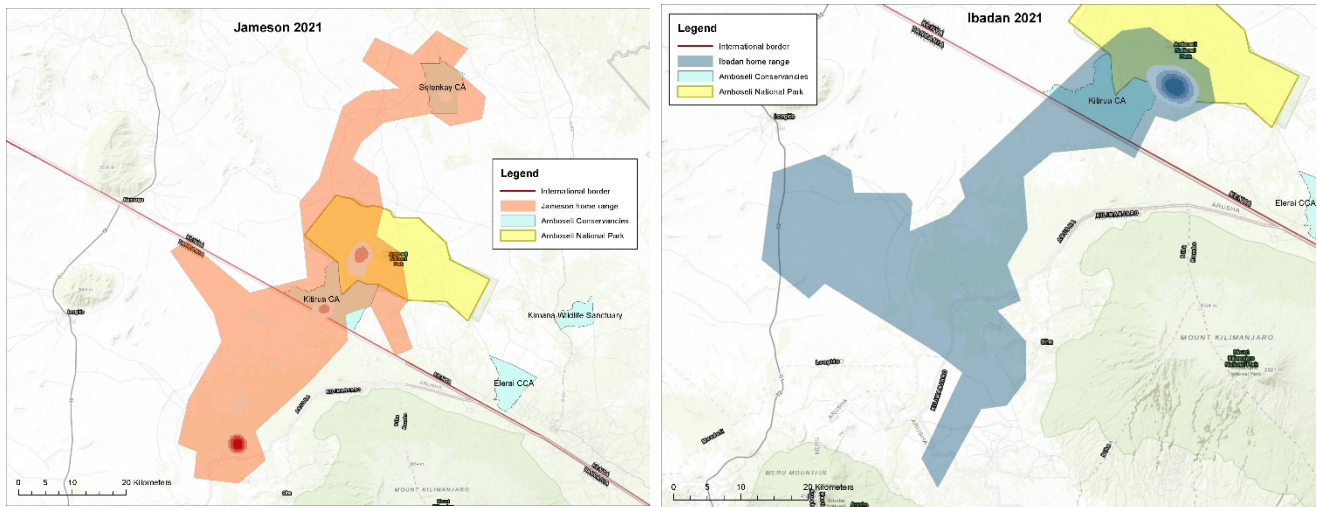

Figure 7: *Kernel densities of annual home ranges for males crossing the border to Tanzania: Jameson, Ibadan.*

The key features of the movements of these young males are that some regularly cross the international boundary between Kenya and Tanzania, that all males include large amounts of semi- or unprotected areas in their ranges, and that linkages allowing free movement and unimpeded foraging between habitats and elephant "populations" appear to be vital to the success of the Amboseli elephant males. Their future survival and success are predicated on these movements over hundreds of square kilometres being sustained.

B) Dissemination

Our research findings have been successfully published in a number of peer-reviewed journals. We aim to continue to disseminate our findings widely so that unique knowledge from these individuals will continue to act as a baseline for understanding elephant behaviour in general, communication and cognition, responses to landscapes and climate change as well as enabling comparative models of population dynamics across Africa. Our collaborators, drawing on our data and knowledge, have also contributed to our current list of publications.

2022
Shannon, G., Cordes, L. S., Slotow, R., Moss, C., & McComb, K. (2022). Social disruption impairs predatory threat assessment in African elephants. *Animals*, *12*(4), 495. (open access https://doi.org/10.3390/ani12040495)
Wiśniewska, M., Puga-Gonzalez, I., Lee, P., Moss, C., Russell, G., Garnier, S., & Sueur, C. (2022). Simulated poaching affects global connectivity and efficiency in social networks of African savanna elephants—An exemplar of how human disturbance impacts group-living species. PLOS Computational Biology, 18(1), e1009792.

2021
Brakes, P., Carroll, E.L., Dall, S.R., Keith, S.A., McGregor, P.K., Mesnick, S.L., Noad, M.J., Rendell, L., Robbins, M.M., Rutz, C. and Thornton, A. (2021). A deepening understanding of animal culture suggests lessons for conservation. Proceedings of the Royal Society B, 288(1949), p.20202718.
Campbell-Staton, S.C., Arnold, B.J., Gonçalves, D., Granli, P., Poole, J., Long, R.A. and Pringle, R.M., 2021. Ivory poaching and the rapid evolution of tusklessness in African elephants. Science, 374(6566), pp.483-487.

Hartmann, W. L., Fishlock, V., & Leslie, A. (2021). First guidelines and suggested best protocol for surveying African elephants (*Loxodonta africana*) using a drone. Koedoe, 63(1), 1-9.

Hedwig, D., Poole, J., & Granli, P. (2021). Does Social Complexity Drive Vocal Complexity? Insights from the Two African Elephant Species. Animals, 11(11), 3071.

Lee, P. C., Moss, C. J., Njiraini, N., Poole, J. H., Sayialel, K., & Fishlock, V. L. (2021). Cohort consequences of drought and family disruption for male and female African elephants. Behavioral Ecology. https://doi.org/10.1093/beheco/arab148

Poole, J., & Granli, P. (2021). The Elephant Ethogram: a library of African elephant behaviour. Pachyderm, 62, 105-111.

2020

Bates, Lucy. (2020). Cognitive abilities in elephants. The Cambridge handbook of evolutionary perspectives on human behavior. Cambridge University Press, Cambridge. pp14-22.

Lee, P. C., & Lindsay, W. K. (2020). A "halfway house" for improving captive welfare. *Animal Sentience*, *5*(28), 14.

Moss, C., Fishlock, V., & Lee, P. (2019-20). Twinning in the Amboseli elephant population. Pachyderm, 60, 118-119.

Schlossberg, S., Chase, M. J., Gobush, K. S., Wasser, S. K., & Lindsay, K. (2020). State-space models reveal a continuing elephant poaching problem in most of Africa. *Scientific reports*, *10*(1), 1-9.

Webber, C. E., & Lee, P. C. (2020). Play in elephants: Wellbeing, welfare or distraction? Animals, 10(2), 305.

IV)   Activities with Stakeholders and Communities
A) Stakeholder engagement

ATE continues to play an active role as technical advisors to the Amboseli Ecosystem Trust (AET), and especially to KWS and Big Life Foundation who are the principal agencies managing the human-wildlife interface. ATE community research officer, Moses Saruni, has been helping AET to work with Group Ranch Planning Committees as they design strategies for monitoring of stocking and grazing regimes.

Protocols to deal with serious incidents occurring between people and elephants from the Human Wildlife Coexistence Committee are still pending approval from KWS Senior Management. These protocols are vital as part of the effort to prevent retaliatory attacks, which result in further injuries and fatalities to humans and wildlife. We continue to work with Big Life to harmonise elephant mortality data for KWS, to identify elephants that have been treated for injuries or illness and where possible provide follow up information on treatment outcomes to KWS vet teams. ATE worked with KWS vets on 24 occasions, of which 4 were deaths, and 14 were treatments for injured elephants. Our team also participates in ecosystem counts and other monitoring activities as and when requested by KWS.

Training, sensitisation and filming

ATE provides training in elephant behaviour, biology, growth, ageing and sexing to our collaborators within the ecosystem and for range country biologists and conservation managers from Africa and Asia. While the Covid-19 pandemic brought our traditional group-based training to a halt, we have future events planned with Tanzania rangers and Big Life Foundation rangers.

We engaged in over 25 online, written and face to face interviews or events with educators and media communicators over the year. We also participated in the Magical Kenya Tembo Naming Festival, during which two collars were fitted to female elephants. One female was named Naborr by Kajiado Governor Joseph ole Lenku.

Cabinet Secretary Najib Balala, with KWS Director, Brig.(Rtd) John Waweru *and Dr Cynthia Moss at the collaring event.*

Supporting Government of Kenya authorised film-makers

- BBC filmmakers for series "Dynasties" (ongoing from 2020)
- "Queens" series (Wildstar)

B) Consolation Scheme

Our consolation scheme, which addresses the loss of cattle, sheep/goats, and donkeys as a result of interactions with elephants outside the protected area of Amboseli National Park, was called on to support 29 events of livestock loss (20 cows, and 9 sheep/goats) in 2021. This number was almost 3 times that of 2020 (12 total), possibly due to the late start of the short rains and high overlap between elephants and livestock in the southern bushlands. Our programme, which is not designed to be compensation but rather an expression of regret for loss, remains important to sustaining tolerance of elephants among Maasai pastoralists even when they experience livestock losses caused by elephants.
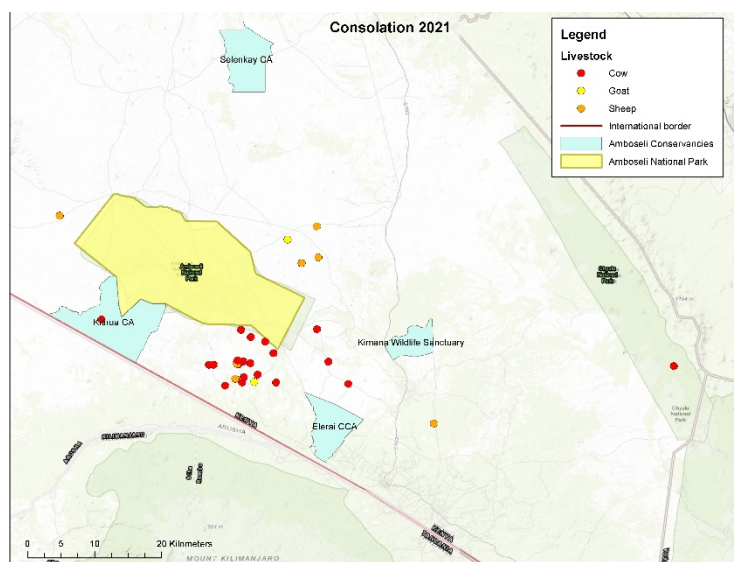

Figure 8. *Location map of consolation events for 2021.*

The killing of livestock by elephants appears to be rare elsewhere in Africa, although more common where Maa-speaking people herd livestock. Outside of reports from Mkomazi, there are no documented reports from elsewhere in Tanzania, nor from Botswana or Uganda. Livestock killing by elephants may be a learned or cultural behaviour illustrating their long-term response to human-elephant interactions such as spearing.

C) Scholarships

ATE fosters livelihood development among young men and women through funding scholarships for primary, secondary and university students from the Group Ranches surrounding Amboseli National Park. In the calendar 2021 ending, we sponsored 21 students in total. (We had 16 girls and 5 boys). The pandemic changed the Kenya school calendar bringing the year 2021 to a close in March 2022. Two of our girls who have been doing their Masters in Mathematics and Education respectively have successfully finished their studies and we look forward to seeing them succeed in their future endeavours. ATE's scholarships build capacity and develop livelihoods in many areas of learning and professional training for young community members who share their lives with elephants, and our ecosystem partners.

Mrs Sylvi Nyambura (ATE) presenting a laptop to two of our university students, Isaac Letunka and Daniel Tajeu, who are doing degrees of Bachelor of Science (Wildlife Management).

Cynthia Moss, Director
Phyllis Lee, Director of Science
March 2022