Final report for National Geographic Society Big Cats Initiative grant

Post-civil war Rwandan nature restoration: Akagera National Park before and after the reintroduction of the African lion, an apex predator

Written and submitted on 12 August 2019 by
Adrian Treves, Ph.D.
Drew Bantlin, M.S.

with support from
Erasme Uyizeye, M.S.
Lisa C. Naughton, Ph.D.
Niwaeli Kimambo, M.S.

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Recommended citation

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Executive summary

Scientific and conservation attention has recently concentrated on apex predators -- animals conceptualized as the top of food webs -- such as African lions and leopards. However several important scientific questions remain unresolved, such as:

- Are apex predators different or do they exert ecological effects like any other predator?
- Do apex predators exert their strongest effects by killing prey or by scaring survivors?
- Are all apex predators exerting similar ecological effects or do the effects vary by species?

Our project is uniquely positioned to answer these and other important questions because we have collected data before the reintroduction of African lions to Akagera National Park, Rwanda and after it. We began in 2015 before lion release and now 36 lions roam the 1,120 km^2 park. We conduced 4.5 years of fieldwork aimed at detecting long-term changes in the ecosystem. Here we report on the medium-term effects of lion reintroduction from 2017–2019. Having before-and-after comparisons of the responses of other species such as spotted hyenas, and the typical prey of large carnivores gave us a powerful lens to draw strong inferences about the ecological effects of apex predator restoration. Our study is virtually free of confounding variables found in most other studies that used correlations or did not measure ecology before apex predators were reintroduced. We discriminate between alternative hypotheses in ecology and advance conservation efforts for national parks, for large predators, and for ecosystem restoration. We supported park management, trained and equipped Rwandan professionals, and consulted leadership at three levels from community up to national jurisdictions.

The major outcomes of this project follow:

- Research: Scientific publications relating to lions, leopards, hyenas and one analysis of 7 lion prey species are anticipated as the data are in hand and analyses complete or nearly complete (anticipated submission dates December 2019–December 2020)
- Conservation (direct): A core team member, Drew Bantlin, M.S., was employed by Akagera National Park during the study. His duties included managing anti-poaching patrols, park fence maintenance, monitoring wildlife especially lions, with trail cameras,

telemetry, and direct observations. Drew Bantlin also received training and direct experience in reintroduction of rhinoceros, an unexpected event that arose shortly after the start of our NGS-funded project. He soon took a leadership role in Akagera's rhino program and continental workshops relating to rhino conservation.

- Conservation (indirect): Our team studied large mammal ecology (1) inside and (2) outside the park and (3) interactions with humans outside the park, including social scientific survey data on coexistence with large mammals that can threaten human interests including crops, livestock, and human safety. We used all three sets of data to inform the public, managers, and decision-makers at three levels of jurisdictions (local communities, Akagera National Park, and two ministries in central government). We also trained 7 Rwandan professionals, 5 graduate students (1 Rwandan, 1 Tanzanian, 3 USA), and numerous USA undergraduates, in interdisciplinary research in field or lab.

A. Research and conservation outcomes beyond the boundaries of Akagera National Park, Rwanda

Overview

In a 41-page Appendix represents our official report to the Rwandan government and the Akagera Management Company (AMC, a partnership between the government and African Parks, Inc.). It details our findings from interdisciplinary research outside Akagera National Park and along its fenced boundary. The data include 85 interviews of village residents who either complained officially of conflicts with wildlife or lived near to an official complainant. The data also consist of a camera campaign and surveys for indirect signs of hyenas and leopards outside the park. Finally, the report presents maps of human-wildlife coexistence and conflict sites gleaned from 3 years of government records and from our own fieldwork.

The report was completed and sent to AMC in February 2019 and then Adrian Treves and Lisa Naughton communicated the report in person from July 31-August 3rd, 2019 to the manager of Akagera National Park (ANP), to the Director of the Rwandan Development board and one staff member, to the Special Guaranty Fund Acting Director and three staff members, and to 79 local community members from villages surrounding ANP with the help of Mr. Joseph Karama and a community liaison Ishimwe Fiston. The outreach and training outcomes associated with this phase of our work are described more fully in Part C.

Executive summary of 41-page report in Appendix 1.

This report concerns community relations with Akagera National Park with special emphasis on local people's interactions with wildlife and their experience with compensation. Regarding wildlife and livestock, we focused on the large carnivores, spotted hyenas and leopards, their predation on livestock and presence near and far from the boundaries of ANP. Regarding wildlife and crops, we focused on the large, frequent foragers on crops, such as hippopotamus, buffalo, baboon, and bushpig. We tried to address several research questions or test hypotheses as follow:

- Are wildlife crossing the boundary of ANP, and if so, which species and in which directions? Is there evidence of wildlife breeding outside of ANP?
- Are patterns of complaints about wildlife mirrored in patterns of verified losses?
- Do complaints, verified losses, or compensation paid vary as expected from research elsewhere? E.g., are losses higher closer to ANP? Are some individuals at higher risk due to lack of coping mechanisms or protective husbandry?
- Does the compensation program emphasize conservation goals or public welfare outcomes?

Methods

Our research team used interdisciplinary methods to understand human-wildlife interactions outside ANP. From May 2015–December 2018, we conducted fieldwork intermittently for a total of 22 person- months. To study wildlife and ecology, we deployed cameras within ANP and conducted behavioral observations of predators and prey in- and outside ANP. To study human dimensions, we conducted interviews with a structured questionnaire, using a priori stratified sampling based on respondents appearing in official reports and the snow-ball method to identify potential respondents who were not in official records. We supplemented the latter with efforts to map hyena dens, sites of heavy use by hyenas and hyena trap-sites. We mapped some attributes of wildlife and people around ANP.

Conclusions

Ecological studies within ANP: As ANP went from zero African lions in May 2015 to 21 lions (aged 14+ months) plus 15 cubs as of writing, we have amassed an extensive database of the reactions of the lions, of other carnivores, and of herbivore prey animals. For the present purpose, we did not find evidence of mass movements of competitors or prey outside of the park, little or no evidence for large- scale movements of any species in relation to lions, but some evidence of changes in behavior of individual carnivores and prey in response to lion reintroductions and movements. We will present these results in detailed final form under separate cover after D. Bantlin's dissertation is prepared and defended.

Camera deployments within ANP: Since 2015, we deployed cameras triggered automatically both night and day by the proximity of mammals larger than mice. We deployed the cameras in 3 separate arrays (roads in Phase 1, grids in Phase 2, and fence-line in Phase 3) but here focus on the fence-line deployments that are pertinent to our goals in this document. We detected no hyenas crossing the electric fence in the southern stretch of ANP comprising an 5 km stretch of fence-line. We detected 20 different mammal species along the fence-line, with 9 of these detected both in and outside ANP. We detected hyenas outside the fence kilometers away from ANP, but none actually crossing the fence. We detected several leopards crossing the fence in both directions although these seem to be the same young individuals. We detected leopards at two camera stations outside the fence hence outside ANP. An eye-witness reported seeing a leopard jump the fence near the main gate. We detected numerous other species inside and outside the ANP fence. Arboreal crossings by baboons and vervet monkeys are regular in either direction. Many species move in proximity to the western boundary fence, both inside and outside of the park.

Social scientific studies outside of ANP: We interviewed 85 respondents along the entire western boundary of ANP and up to 12.7 km from the park. Most respondents lacked a full understanding of verification and compensation procedures. Virtually all respondents deployed some method of protecting their property. Attitudes to compensation, to ANP, and to wildlife varied but were not strongly negative. Most respondents were inexperienced with foreign researchers and interviews but were familiar with the outreach conducted by ANP and welcomed the community liaisons. Every respondent complained of either crop or livestock damage by wild mammals. A majority complained of hyena predation on livestock plus baboon damage to crops. Buffalos and hippos are the greatest cause of human injury or death. Such incidents were relatively rare (30 of 737 total complaints from ANP records, including eight deaths (all from hippos and buffalo). None of the 85 residents we interviewed reported suffering injury or loss of a family member to wildlife. Many respondents did not file official complaints or pursue the process through to compensation. A minority reported receiving compensation, more often for livestock than crop loss. Fewer received compensation near ANP than those far from the park, contrary to our expectations. We were also surprised to learn that proximity to ANP was not associated with higher risk of wildlife losses.

Hyena ecology outside of ANP: A reproducing subpopulation of hyenas exists outside of ANP. Even though we only discovered inactive den sites, 95 verified kill sites and two cubs brought to ANP corroborate our indirect findings that hyenas reside in many rural areas and reproduce outside ANP. We describe attributes of hyena traps and recommend switching to all-metal traps, although these have not yet captured hyenas.

Mapping: We present several maps and figures to depict key spatial patterns. As in other sites where people coexist with large mammals, the spatial distribution of threats to human safety and property is highly variable, with some sites facing high rates of verified losses and others relatively low rates of verified losses. The composition of species causing verified losses also varied geographically, as is typical for other sites. A key finding was that leopards were verified in fewer villages than were hyenas, consistent with the above-mentioned differences in frequency of complaints about the two carnivores. Carnivore-related, verified losses of property occurred up to 12.7 km from ANP, corroborating the above findings about hyenas and leopards observed outside ANP. Regarding crop-raiding wildlife, baboons were the most frequently blamed for verified losses, but hippos, buffalos, and bush pigs also caused frequent losses of crops and rare threats to human safety. Although no village experienced zero verified losses to wildlife, some experienced either zero losses of livestock or zero losses of crops. We emphasize that verified losses are a subset – possibly a minority – of alleged losses, and therefore, no village experienced zero alleged losses of property.

B. Research and conservation outcomes within Akagera National Park

Overview

The following document represents our preliminary report on wildlife research within Akagera National Park. We are still analyzing and preparing them for publication in peer-reviewed journals. As such, the narrative that follows is preliminary and relates to different data sources piecemeal without being fully integrated. The data and results can be summarized as follows:

I. Lions: Reintroduction has been a clear success with 36 lions now in the park from two reintroduction efforts of 7 and 2 individuals, respectively. Hence 30 cubs were born and 2 lioness and 1 male died, as of writing. Moreover lions have extended their spatial distribution throughout the park (Figs. B.1 and B.2) without crossing the electric fence or lake boundaries of it. Many lions are GPS-collared and these and other observations indicate they are behaving normally.

II. Spotted hyenas and leopards: The park has abundant hyenas and leopards if not being saturated with them. After several years of one type of camera campaign using occupancy grids throughout the park and new abundance estimation methods, we expect to estimate the population sizes of both large carnivores within the park. We paced paired cameras along roads to identify individual leopards by their unique spot patterns. We identified 20 unique individuals (13F, 7M)) in the southern quarter-third of the park (Fig. B.3.a-b). We did not identify individual spotted hyenas (Fig. B.4.a-b).

III. A second type of camera campaign oriented to measuring behavioral changes in 10 species after lion reintroduction has produced manuscripts on leopards, hyenas and one on 8 species of lion prey (Figs. B.3–12). Preliminary analyses indicate that hyenas did not respond to mesopredator suppression but instead seem to have been attracted to lions, perhaps as sources of scavenged kills or to challenge the lions for the apex predator position. Preliminary results for leopards suggest a different pattern with some short- to medium-term changes to behavior that suggest avoidance of lions but no long-term range shifts or other dramatic effects. Preliminary results for prey of lions suggest a complex mosaic of behavioral changes from slight to major changes, including both increases in anti-predator behavior. However, not uncommonly, we detected ambiguous responses that might reflect a shift to a multi-predator environment from the prior single-predator environment for those species in which adults faced spotted hyena predation but were largely invulnerable to leopard predation and now face both lions and hyenas (e.g., zebras). Smaller prey species seem to have heightened anti-predator behavior perhaps reflecting a shift in the niche of leopards to smaller prey to reduce competition with lions (e.g., waterbuck) although this remains speculative until we complete analyses.

IV. The third type of camera campaign along several km of fence-line with cameras oriented to detect wildlife inside and outside the fence line has provided insights into crossings (see Part A) and the occurrence of leopards and hyenas on both sides of the fence.

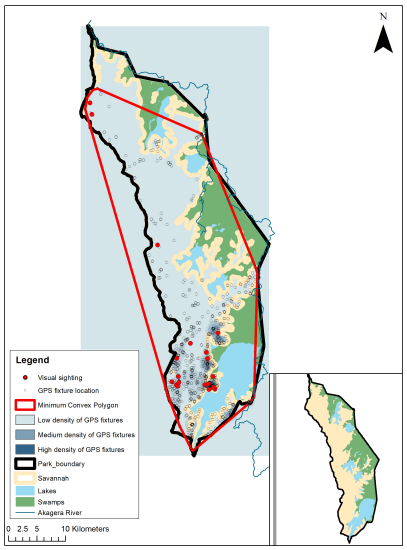
V. The fourth and final type of camera campaign was oriented to understanding rhino behavior after reintroduction and the behavior of other wildlife near the rhino release site. Drew Bantlin, in his capacity as rhino reintroduction monitor, has confirmed that a

special fence to keep rhinos enclosed but allow other wildlife to pass freely into and out of the large reintroduction area seems to be functioning as expected because lions and other large wildlife (but not rhinos) have crossed the filter successfully.

The many maps that follow depict the raw data from the above data collection campaigns

Figure B.1.a-d. Home range maps of main groups of lions before 2018 in Akagera National Park (ANP), Rwanda.

Locations of six collared lions: 2 two-male coalitions from the 2015 reintroduction ("Old Males" panel a),and the 2017 introduction ("New Males" panel b) respectively, and two females from the 2015 reintroduction ("Sisters" panel c). Collars record a GPS location (fixture of fix) thrice daily. We mapped all points using ArcGIS around which we fitted minimum convex polygons (MCP) to estimate the area of home ranges. The New Males' MCP (panel b) includes a few, brief ventures north, but they typically ranged in the south, away from the Old Males (panel a), so we include panel d for New Males in their more typical southern range. We also used monthly visual sightings to assess health and condition by either opportunistic or VHF telemetry by vehicle or on foot from the most recent GPS fix.



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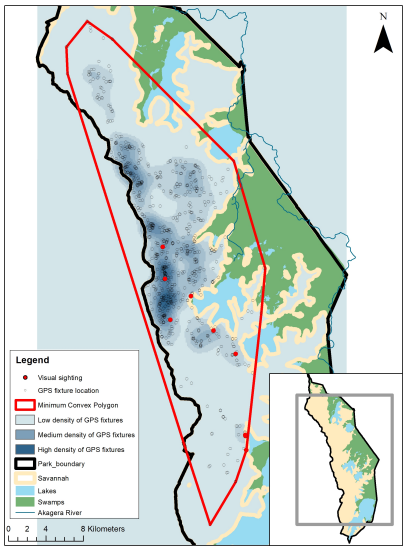

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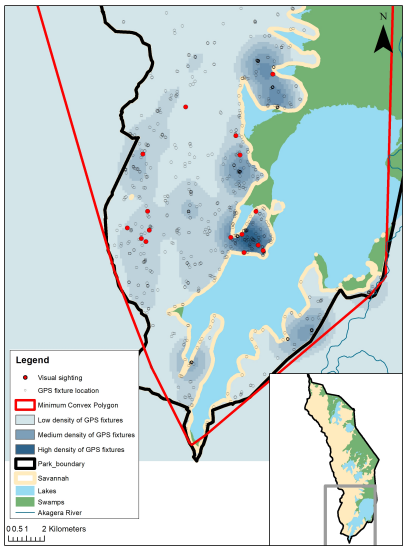

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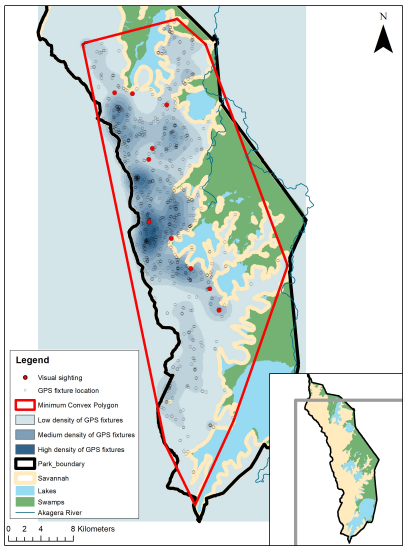
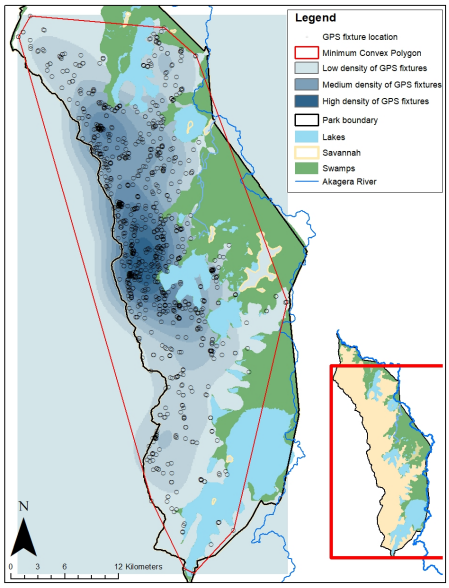


d

Figure B.2.a-d. Home range maps of main groups of lions 2018–2019.

Symbology and methods as in Fig. B.1. Because of unequal use of the home range, we also used a kernel density analysis to produce a 'heat' map of frequency of use within the MCP. We calculated use from thrice daily GPS fixes, not from direct observation. Lion movements between fixes might have extended into areas not shown by the MCP or 'heat' map.



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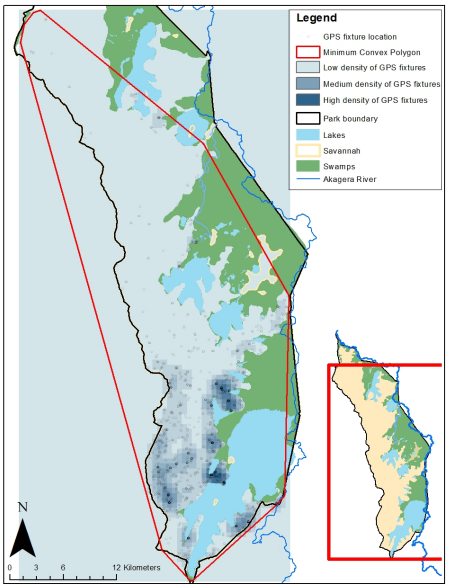

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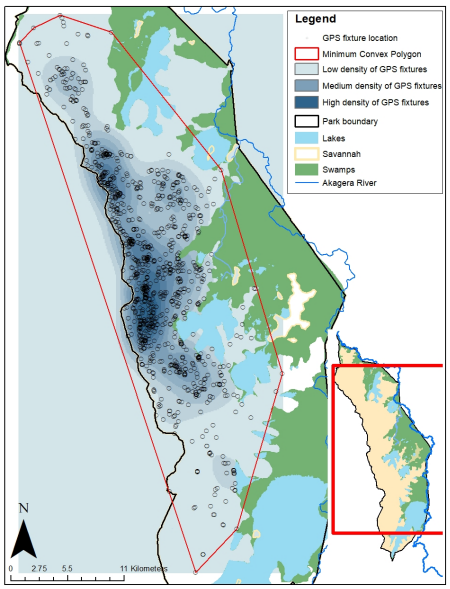

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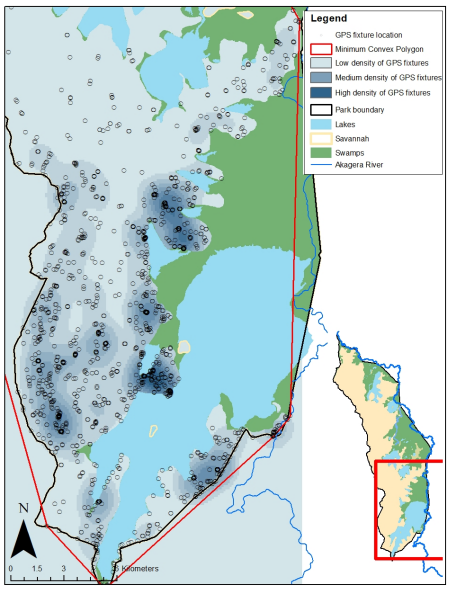
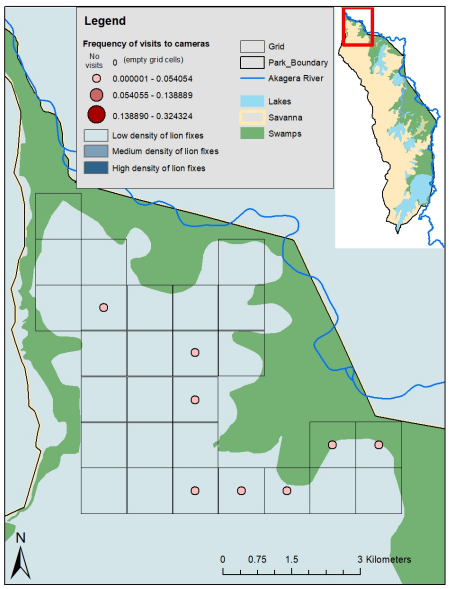


d

Figure B.3.a-b. Frequency of visits by leopards to cameras in grids in relation to lion use.

We deployed remotely activated cameras throughout the park in grid patterns, with grid cells of 1 square kilometer. We deployed cameras in four grids 13 February 2018-25 March 2018 for grid 1, 11 April 2018-20 May 2018 for grid 2, 30 May 2018-6 July 2018 for grid 3, and 27 October 2018-7 December 2018 for grid 4. We left cameras in place for five to six weeks without maintenance or disturbance from humans. Grid 4 was not adjacent tor grid 3, but further north. We separated leopard and hyena photos for independent analyses. Based on date and time stamps on the photos, we estimated the number of independent visits to camera sites. We defined visits by recording the time interval between every successive photo of leopards (panels a and b) or hyenas (panels c and d) and plotting those intervals on a histogram. We used the first major gap ≥5 min in the histogram as a threshold. We defined sequential photos with an interval less than the threshold as a single visit and all sequential photos with a greater interval than the threshold, as occurring in two different visits. We divided the number of visits at each camera by the number of days it was deployed and active at that site as visits/camera day. For each grid cell, the frequency of visits is indicated by shaded circles (darker, larger circles indicate a higher frequency, absence of a circle indicates zero visits). Because the southern grids were non-overlapping, we indicate the extent of each grid with white lines. We super-imposed lion heat' maps as in Figs. B.1 and B.2, but only for those dates that each grid was active and trimmed to the area covered by the grid. Our intent is to show patterns of leopard or hyena frequency of visits in relation to high or low use by lions.

Leopard visits in the North grid (panel a): The highest frequency of visits to any camera in the grid was 0.05 visits/camera day, with no obvious pattern of detection and many zeroes. Leopard visits in the 3 South grids (panel b): The highest frequency of visits to any camera in these grids was 0.32 visits/camera day. Visits were spread across the grids, with the cells with highest frequencies being found close to the western boundary or along the lakes.



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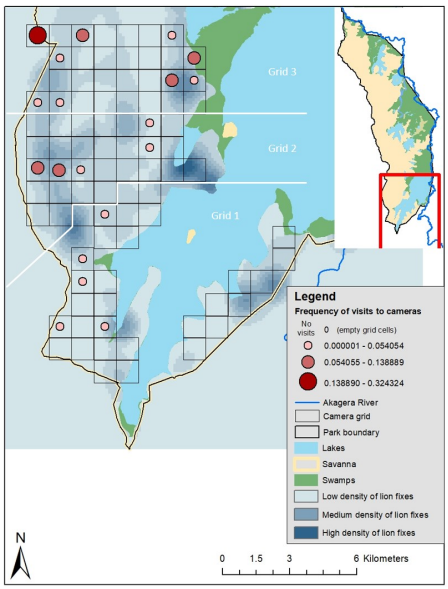
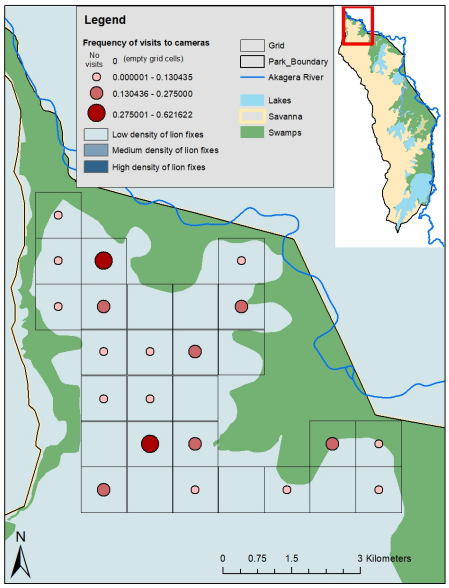


b

Figure B.4.a-b. Frequency of visits by spotted hyenas to cameras in grids in relation to lion use.

Methods and symbology as in Fig. B.3. Hyena visits in the North grid (panel a): The highest frequency of visits to any camera in the grid was 0.35 visits/camera day, with detection spread evenly across the grids and very few zeroes. Hyena visits in the 3 South grids (panel b): The highest frequency of visits to any camera in these grids was 0.62 visits/camera day. There were very few visits to grid 1 but for the eastern boundary. Visits in grids 2 and 3 were most frequent towards the western boundary.



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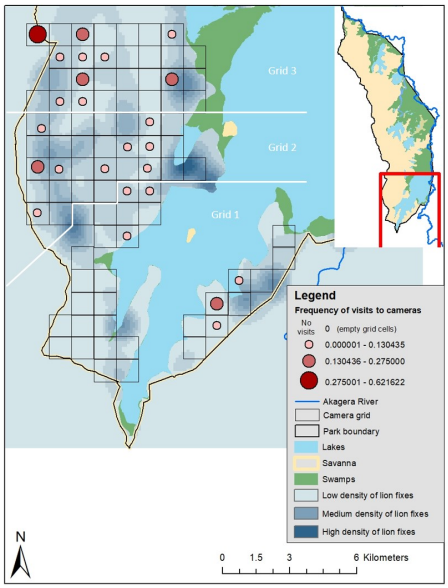
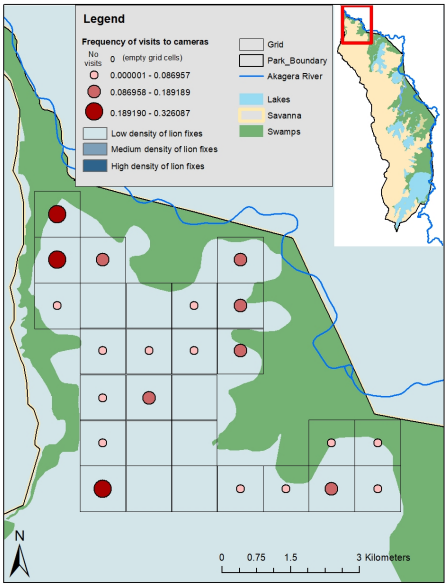


b

Figure B.5–12. Frequency of visits by 8 species of lion prey to cameras in grids in relation to lion use

Methods and symbology as in Fig. B.3. The 7 species depicted are Cape buffalo (*Syncerus caffer*), elephant (*Loxodonta Africana*), Masai giraffe (*Giraffa camelopardalis tippelskirchi*), impala (*Aepyceros melampus*), topi (*Damaliscus korrigum*), Defassa waterbuck (*Kobus ellipsiprymnus*), warthog (*Phacochoerus africanus*) and Plains zebra (*Equus quagga*).

Fig. B.5.a-b. Buffalo visits in the North grid, panel a: The highest frequency of visits to any camera in the grid was 0.33 visits/camera day. Visits were most frequent along the swamps. Buffalo visits in the 3 South grids, panel b: The highest frequency of visits to any camera in these grids was 0.22 visits/camera day. Visits were most frequent towards the park's western boundary, where there are plentiful waterholes during the season we deployed cameras.



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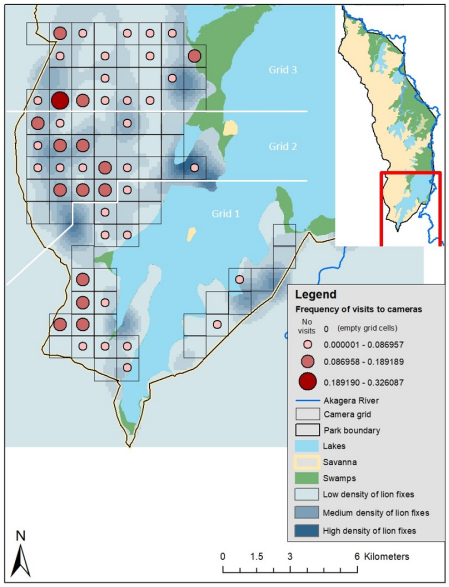

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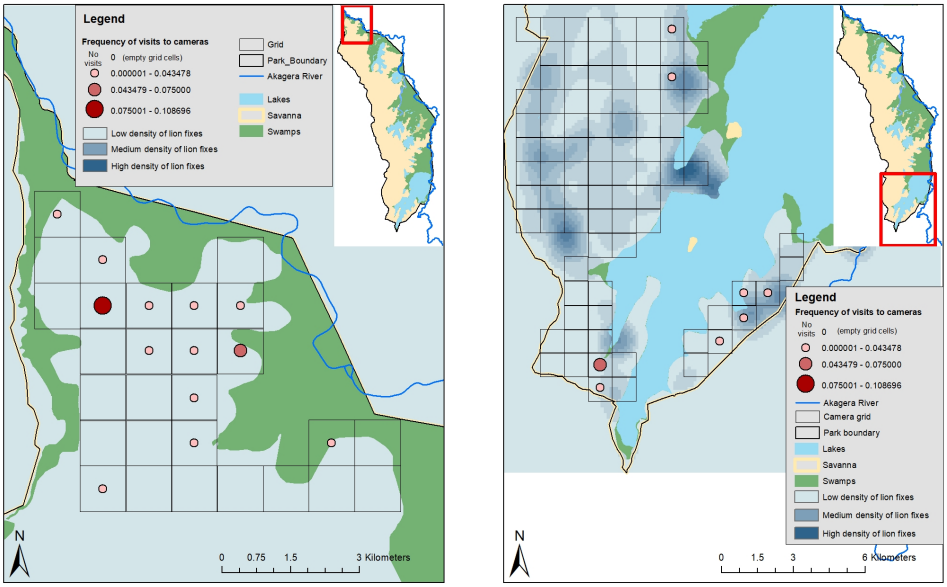
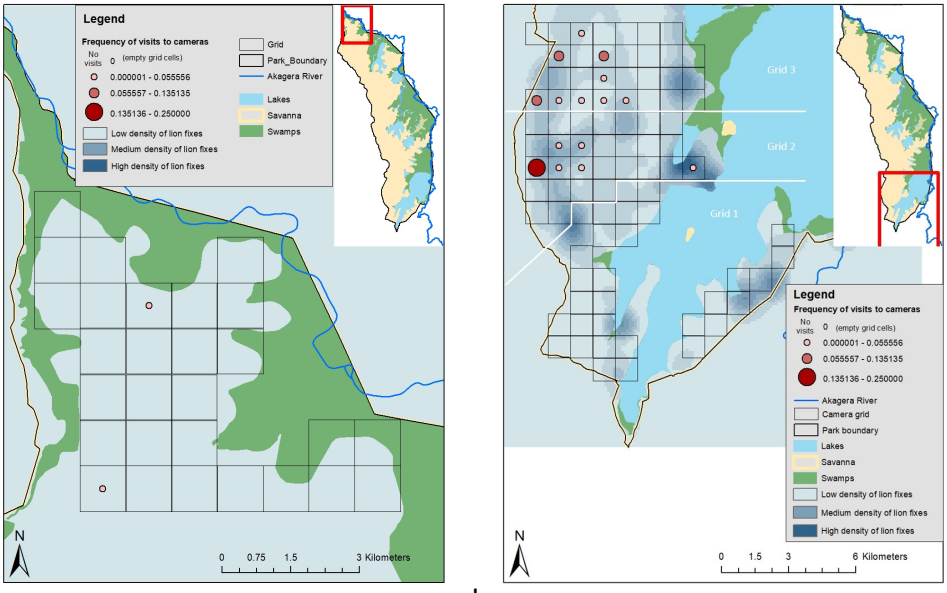
Fig. B.6.a-b. Elephant visits in the North grid, panel a: The highest frequency of visits to any camera in the grid was 0.11 visits/camera day. Elephant visits were most common near the swamps. visits in the 3 South grids, panel b: The highest frequency of visits to any camera in these grids was 0.08 visits/camera day. All visits occurred near the lakes.



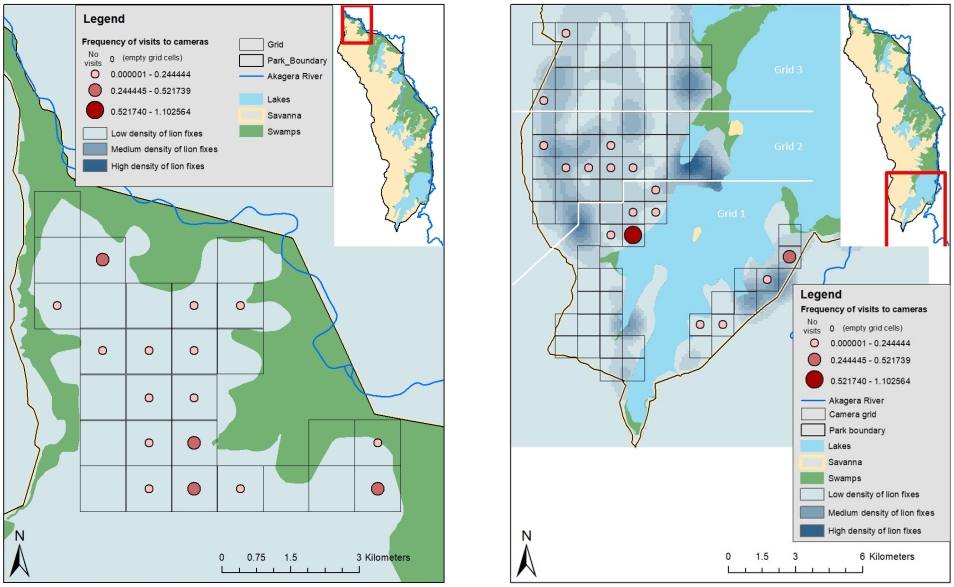
a b

Fig. B.7.a-b. Giraffe visits in the North grid, panel a: The highest frequency of visits to any camera in the grid was 0.06 visits/camera day. Only two cameras detected giraffes while active. Giraffe visits in the 3 South grids, panel b: The highest frequency of visits to any camera in these grids was 0.25 visits/camera day. Visits were most frequent along the smore open western areas of ANP whereas grid 1 had no giraffe visits.



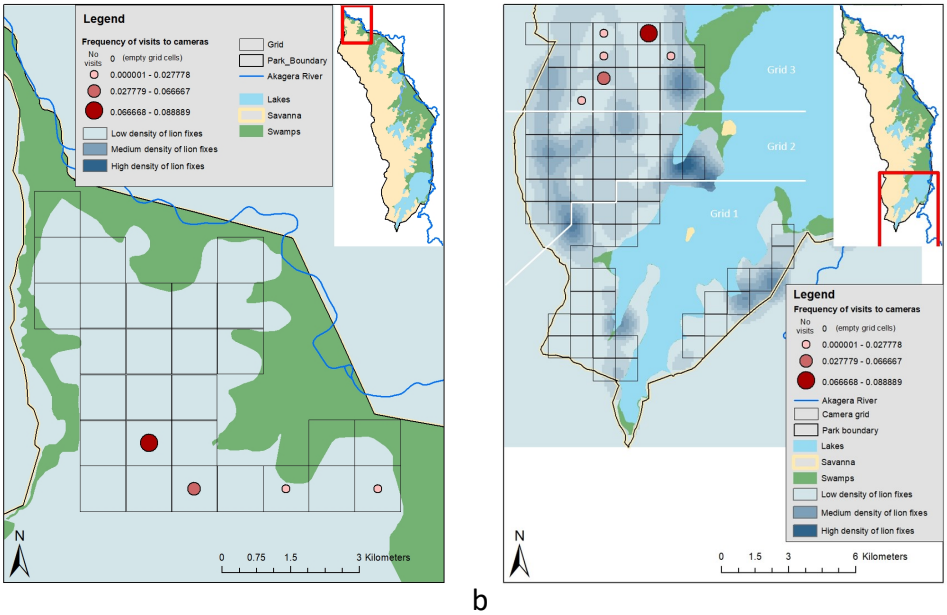
a b

Fig. B.8.a-b. Impala visits in the North grid, panel a: The highest frequency of visits to any camera in the grid was 0.52 visits/camera day. Visits were widely distributed. Impala visits in the 3 South grids, panel b: The highest frequency of visits to any camera in these grids was 1.10 visits/camera day. Visits were most frequent on the eastern lake margins.



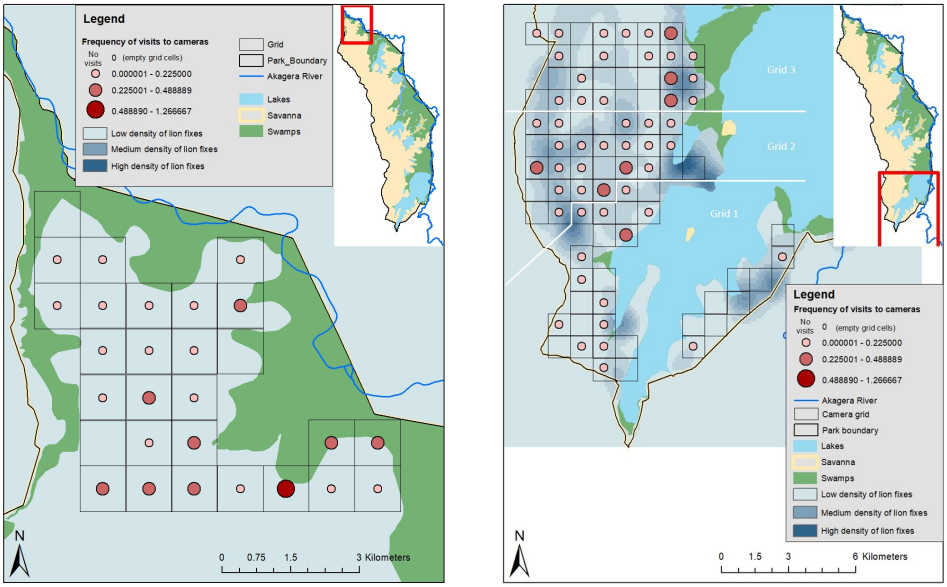
a b

Fig. B.9.a-b. Topi visits in the North grid, panel a: The highest frequency of visits to any camera in the grid was 0.08 visits/camera day. Topi were only detected in the southern part of the northern grid 4 Topi visits in the 3 South grids, panel b: The highest frequency of visits to any camera in these grids was 0.08 visits/camera day. Topi were not detected in grids 1 or 2 with dense bush. Topi visits were concentrated in grid 3 with its rolling hills and open grassland.



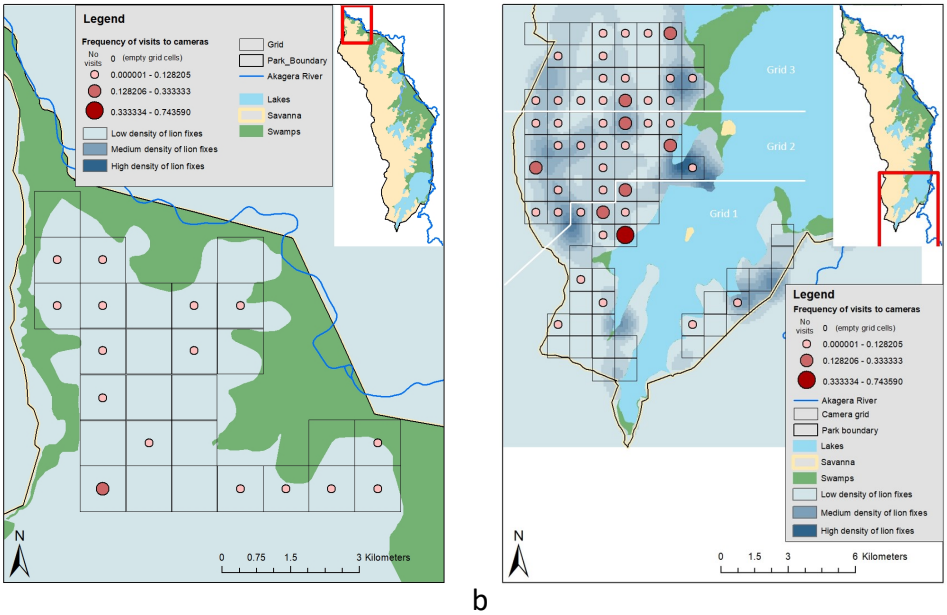
a b

Fig. B.10.a-b. Warthog visits in the North grid, panel a: The highest frequency of visits to any camera in the grid was 1.27 visits/camera day. Visits were widely distributed. Warthog visits in the 3 South grids, panel b: The highest frequency of visits to any camera in these grids was 0.49 visits/camera day. Visits were most frequent near lakes than near the western boundary.



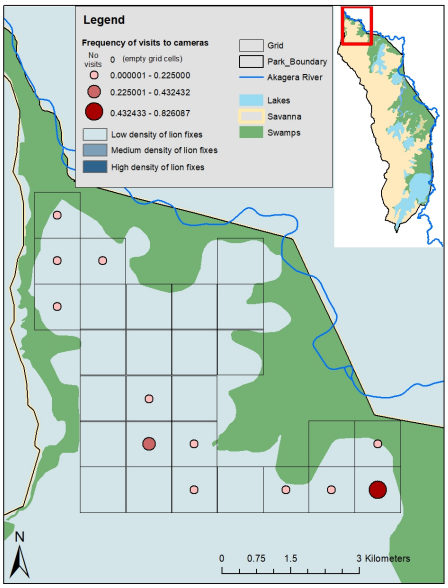
a b

Fig. B.11.a-b. Waterbuck visits in the North grid, panel a: The highest frequency of visits to any camera in the grid was 0.33 visits/camera day. Visits were widely distributed but infrequent. Waterbuck visits in the 3 South grids, panel b: The highest frequency of visits to any camera in these grids was 0.74 visits/camera day. Visits were most frequent near lakes, east of the central ridge that bisects the park.

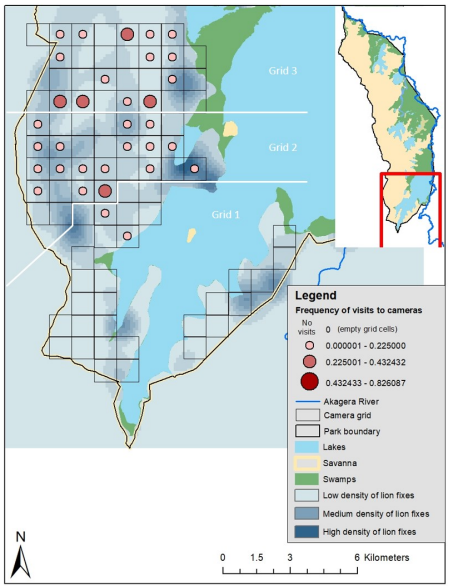


a b

Fig. B.12.a-b. Zebra visits in the North grid, panel a: The highest frequency of visits to any camera in the grid was 0.83 visits/camera day. Visits were distributed in the southeast and northwest extremes of the grid. Zebra visits in the 3 South grids, panel b: The highest frequency of visits to any camera in these grids was 0.43 visits/camera day. Visits were most frequent across grids 2 and 3 and sparse in grid 1.



a



b

C. Outcomes of training, capacity building, and outreach

We used research findings to inform the public, managers, and decision-makers at three levels of jurisdictions (local communities, Akagera National Park, and two ministries in central government). We also trained 7 Rwandan professionals, 5 graduate students (1 Rwandan, 1 Tanzanian, 3 USA), and numerous USA undergraduates, in interdisciplinary research in the field or laboratory. The identities of trainees and the general categories of skill training each received is enumerated next:

Rwandan professionals

1. Joseph Karama (director of community relations and revenue sharing programs for Akagera National Park, ANP): co-author on our final report and at least one planned article for peer reviewed publication in a scientific journal, fieldwork conducting interviews; translation between English and Kinyarwandan, and facilitation for community meeting to report back to community on the research during final community meeting (see below);
2. Ishimwe Fiston (community liaison for ANP): fieldwork conducting interviews, translation between English and Kinyarwandan, and facilitation for community meeting to report back to community on the research during final community meeting (see below);
3. Tuyisenge Martin (community liaison for ANP): fieldwork conducting interviews; translation between English and Kinyarwandan;
4. Dufitumukiza Emmanuel (community liaison for ANP): fieldwork conducting interviews; translation between English and Kinyarwandan;
5. Nyandwi Alexis (undergraduate at Kitabi College for Conservation and Environmental Management, KCCEM): data entry from trail camera campaigns, fieldwork conducting interviews, translation between English and Kinyarwandan, taking GPS locations, and studying indirect sign of hyena and leopard outside ANP, set-up and maintenance of camera traps, fundamentals of telemetry. He is currently employed by ANP;
6. Twagirimana Paul (undergraduate at KCCEM): data entry from trail camera campaigns, set-up and maintenance of camera traps, fundamentals of telemetry;
7. Niwihisemo Gad (undergraduate at KCCEM): data entry from trail camera campaigns, set-up and maintenance of camera traps, fundamentals of telemetry.

Graduate students

8. Erasme Uyizeye (Rwandan PhD student): fieldwork conducting interviews, translation between English and Kinyarwandan, taking GPS locations, studying indirect sign of hyena and leopard outside ANP, and human subjects protection training for institutional review board approval. He is currently completing his PhD fieldwork for Antioch University New England on dragonfly biogeography across Rwanda and occasionally teaching for Keene State College, NH, USA.
9. Niwaeli Kimambo (Tanzanian PhD student): co-author on our final report and at least one planned article for peer reviewed publication in a scientific journal, fieldwork

conducting interviews, laboratory mapping GPS locations and landscape features using advanced remote sensing and GIS methods, and human subjects protection training for institutional review board approval. She is currently completing her PhD at University of Wisconsin–Madison and teaching at Middlebury College, VT, USA.

10. Drew Bantlin (U.S. PhD student): all aspects of carnivore and lion prey field ecology, lead author on at least three scientific papers for peer-reviewed publications, co-author on our final report and at least one planned article for peer reviewed publication in a scientific journal, fieldwork conducting interviews, laboratory mapping GPS locations and landscape features using advanced GIS, and human subjects protection training for institutional review board approval. He is currently completing his PhD at University of Wisconsin–Madison and working for Akagera National Park as research director and rhino reintroduction monitor.
11. Jacob Olson (U.S. PhD student): co-author on at least one planned article for peer reviewed publication in a scientific journal, fieldwork conducting interviews, taking GPS locations, studying indirect sign of hyena and leopard outside ANP, human subjects protection training for institutional review board approval, and data entry from trail camera campaigns and descriptive statistics or elementary statistical analysis of those data. He completed his bachelor's in biochemistry and environmental studies at University of Wisconsin-Madison in 2019 and is beginning PhD studies in botany at Purdue University.

U.S. undergraduate students

A large number of U.S. undergraduates worked with us and received training in data entry from trail camera campaigns and descriptive statistics or elementary statistical analysis of those data. They are either recent graduates or soon to graduate with bachelor's degrees. In particular, R. Conway, S. Hermanstorfer, D. Klein, J. Knackert, and J. Olson worked sufficiently well and long to be included as co-authors on anticipated scientific papers. Also, C. Aeschbacher, S. Hermanstorfer, J. Knackert, J. Olson, and V. Russell completed undergraduate research projects about giraffes, waterbucks, zebras, hyenas, and buffaloes respectively. R. Conway went on to veterinary school for wildlife health studies. S. Hermanstorfer is applying for graduate schools in wildlife conservation related fields including at the Carnivore Coexistence Lab.

D. Next steps

Research

- We have proposed to continue research into compensation and revenue-sharing around Akagera National Park (ANP) and nationwide. The Rwandan government's Development Board (RDB) and Special Guaranty Fund (SGF) have expressed interest in collaborating. ANP has committed to sharing recent data on claims and verification. SGF committed to sharing historical data on compensation.
- We have proposed to continue research to evaluate non-lethal methods for intervening to protect livestock and crops and promote coexistence between people and wildlife outside ANP. The Rwandan government's Development Board (RDB) and Special Guaranty Fund (SGF) have expressed interest in collaborating.
- We are currently pursuing research for Drew Bantlin's PhD and other team member's peer-reviewed publications on the following topics (a) tourism and revenue-sharing in and around ANP; (b) poaching inside ANP; (c) large carnivore ecology inside and outside of ANP; (d) lion prey inside ANP; (e) methods for preventing wildlife damage to crops or livestock outside ANP; and (f) attitudes to coexisting with wildlife and living outside ANP.

Conservation

- Drew Bantlin will continue to work for ANP on direct protection of wildlife in ANP including reintroduction programs for lions and rhinos.
- Adrian Treves and Lisa Naughton will continue to advise the Rwandan government ministries mentioned above on policy for compensation and prevention of wildlife damage to property. We will continue to advise ANP as needed on our research specialties.

Appendix 1. Report to the Rwandan government and Akagera Management Company on research beyond the boundary of Akagera National Park (ANP)

Socioeconomic and Ecological Dimensions of Restoring Akagera National Park, Rwanda

1 February 2019

Adrian Treves, Lisa Naughton, Drew Bantlin, Niwaeli Kimambo, Jacob Olson, Joseph Karama
University of Wisconsin–Madison and Akagera Management Company

Acknowledgments

We thank the Government of Rwanda, The Akagera Management Company and specifically Jes Gruner and Joseph Karama for permission to conduct this research and logistical support in the field. Erasme Uyizeye provided help with field assistance and translations; Dufitumukiza Emmanuel, Ishimwe Fiston, and Tuyisenge Martin (Akagera National Park community liaisons) provided wise insights and invaluable field assistance; Twagirimana Paul, Nyandwi Alexis, Niwihisemo Gad, undergraduates from KCCEM, for data entry; and M. Brown, R. Conway, S. Hermanstorfer, D. Klein, J. Knackert, V. Russell, UW-Madison undergraduates, for data entry and analysis. Amy Vedder, William Weber and Beth Kaplin generously guided us on Rwandan conservation issues. We are grateful for financial support from National Geographic Society, Panthera, and the University of Wisconsin-Madison through the Institute for Regional and International Studies, the Morgridge center for Public Service, the Department of Geography, and the Nelson Institute for Environmental studies. Permission for research on human subjects followed approval of protocol 2018-0712-CP001 and permission for research on animals followed approval on May 14th, 2015 by J. Welter, DVM, through the waiver process for minimally invasive research. Finally, we thank all the community members around Akagera National Park who responded to our questions.

Executive Summary

This report concerns community relations with Akagera National Park with special emphasis on local people's interactions with wildlife and their experience with compensation. Regarding wildlife and livestock, we focused on the large carnivores, spotted hyenas and leopards, their predation on livestock and presence near and far from the boundaries of ANP. Regarding wildlife and crops, we focused on the large, frequent foragers on crops, such as hippopotamus, buffalo, baboon, and bushpig. We tried to address several research questions or test hypotheses as follow:

- Are wildlife crossing the boundary of ANP, and if so, which species and in which directions? Is there evidence of wildlife breeding outside of ANP?
- Are patterns of complaints about wildlife mirrored in patterns of verified losses?
- Do complaints, verified losses, or compensation paid vary as expected from research elsewhere? E.g., are losses higher closer to ANP? Are some individuals at higher risk due to lack of coping mechanisms or protective husbandry?
- Does the compensation program emphasize conservation goals or public welfare outcomes?

Methods

Our research team used interdisciplinary methods to understand human-wildlife interactions outside ANP.

From May 2015–December 2018, we conducted fieldwork intermittently for a total of 22 person-months. To study wildlife and ecology, we deployed cameras within ANP and conducted behavioral observations of predators and prey in- and outside ANP. To study human dimensions, we conducted interviews with a structured questionnaire, using a priori stratified sampling based on respondents appearing in official reports and the snow-ball method to identify potential respondents who were not in official records. We supplemented the latter with efforts to map hyena dens, sites of heavy use by hyenas and hyena trap-sites We mapped some attributes of wildlife and people around ANP.

Conclusions

Ecological studies within ANP: As ANP went from zero African lions in May 2015 to 22 lions (aged 14+ months) plus 3-4 cubs as of writing, we have amassed an extensive database of the reactions of the lions, of other carnivores, and of herbivore prey animals. For the present purpose, we did not find evidence of mass movements of competitors or prey outside of the park, little or no evidence for large-scale movements of any species in relation to lions, but some evidence of changes in behavior of individual carnivores and prey in response to lion reintroductions and movements. We will present these results in detailed final form under separate cover after D. Bantlin's dissertation is prepared and defended.

Camera deployments within ANP: Since 2015, we deployed cameras triggered automatically both night and day by the proximity of mammals larger than mice. We deployed the cameras in 3 separate arrays (roads in Phase 1, grids in Phase 2, and fence-line in Phase 3) but here focus on the fence-line deployments that are pertinent to our goals in this document. We detected no hyenas crossing the electric fence in the southern stretch of ANP comprising an 5 km stretch of fence-line. We detected 20 different mammal species along the fence-line, with 9 of these detected both in and outside ANP. We detected hyenas outside the fence kilometers away from ANP, but none actually crossing the fence. We detected several leopards crossing the fence in both directions although these seem to be the

same young individuals. We detected leopards at two camera stations outside the fence hence outside ANP. An eye-witness reported seeing a leopard jump the fence near the main gate. We detected numerous other species inside and outside the ANP fence. Arboreal crossings by baboons and vervet monkeys are regular in either direction. Many species move in proximity to the western boundary fence, both inside and outside of the par

Social scientific studies outside of ANP: We interviewed 85 respondents along the entire western boundary of ANP and up to 12.7 km from the park. Most respondents lacked a full understanding of verification and compensation procedures. Virtually all respondents deployed some method of protecting their property. Attitudes to compensation, to ANP, and to wildlife varied but were not strongly negative. Most respondents were inexperienced with foreign researchers and interviews but were familiar with the outreach conducted by ANP and welcomed the community liaisons. Every respondent complained of either crop or livestock damage by wild mammals. A majority complained of hyena predation on livestock plus baboon damage to crops. Buffalos and hippos are the greatest cause of human injury or death. Such incidents were relatively rare (30 of 737 total complaints from ANP records, including eight deaths (all from hippos and buffalo). None of the 85 residents we interviewed reported suffering injury or loss of a family member to wildlife. Many respondents did not file official complaints or pursue the process through to compensation. A minority reported receiving compensation, more often for livestock than crop loss. Fewer received compensation near ANP than those far from the park, contrary to our expectations. We were also surprised to learn that proximity to ANP was not associated with higher risk of wildlife losses.

Hyena ecology outside of ANP: A reproducing subpopulation of hyenas exists outside of ANP. Even though we only discovered inactive den sites, 95 verified kill sites and two cubs brought to ANP corroborate our indirect findings that hyenas reside in many rural areas and reproduce outside ANP. We describe attributes of hyena traps and recommend switching to all-metal traps, although these have not yet captured hyenas.

Mapping: We present several maps and figures to depict key spatial patterns. As in other sites where people coexist with large mammals, the spatial distribution of threats to human safety and property is highly variable, with some sites facing high rates of verified losses and others relatively low rates of verified losses. The composition of species causing verified losses also varied geographically, as is typical for other sites. A key finding was that leopards were verified in fewer villages than were hyenas, consistent with the above-mentioned differences in frequency of complaints about the two carnivores. Carnivore-related, verified losses of property occurred up to 12.7 km from ANP, corroborating the above findings about hyenas and leopards observed outside ANP. Regarding crop-raiding wildlife, baboons were the most frequently blamed for verified losses, but hippos, buffalos, and bush pigs also caused frequent losses of crops and rare threats to human safety. Although no village experienced zero verified losses to wildlife, some experienced either zero losses of livestock or zero losses of crops. We emphasize that verified losses are a subset – possibly a minority – of alleged losses, and therefore, no village experienced zero alleged losses of property.

Introduction

Our goal was to understand patterns of human interactions with large, wild mammals outside of Akagera National Park (ANP). We focused on patterns of human attitudes toward wildlife and ANP and human experiences of protecting property, such as crops and livestock, and human experiences of interactions with wildlife. Regarding wildlife and livestock, we focused on the large carnivores, spotted hyenas and leopards, their predation on livestock and presence near and far from the boundaries of ANP. Regarding wildlife and crops, we focused on the large, frequent foragers on crops, such as hippopotamus, buffalo, baboon, and bushpig. We addressed several research questions and tested hypotheses as follow:

- Are wildlife crossing the boundary of ANP, and if so, which species and in which directions? Is there evidence of wildlife breeding outside of ANP?
- Are patterns of complaints about wildlife mirrored in patterns of verified losses?
- Do complaints, verified losses, or compensation paid vary as expected from other research, when considering geographic patterns (e.g., higher losses closer to ANP) and socio-demographic patterns (e.g., higher losses among individuals with fewer coping mechanisms and protective husbandry)?
- Do compensation patterns or individual effects appear to be designed well for conservation outcomes? For public welfare outcomes?

Our research is situated within broader socio-political conditions that reflect history, current law, and current constraints on human resources, infrastructure, material wealth, and capacities. Therefor first consider the legal instruments promoting biodiversity.

In the two-plus decades since Rwanda's genocide the country has experienced consistent, rapid growth. Beyond rebuilding economies and institutions, the Rwandan government has prioritized environmental restoration, following these constitutional provisions,

> "Every citizen is entitled to a healthy and satisfying environment. Every person has the duty to protect, safeguard and promote the environment. The State shall protect the environment. The law determines the modalities for protecting, safeguarding and promoting the environment." (Article 49, Republic of Rwanda Constitution 2003).

International donors have invested millions to stabilize hill-slopes, reduce water pollution and promote sustainable agriculture. Our proposed research concerns efforts to restore Rwanda's natural ecosystems. Rwandan legal instruments prioritize national parks for preserving natural wealth; "Rwanda's three national parks, Volcanoes National Park, Nyungwe and Akagera, covering just over 8% of the national territory, are at the very frontline in protecting this natural wealth, the ecosystems and the goods and ecological services they provide." (p. 4, Rwanda Biodiversity Policy, Republic of Rwanda, Kigali, 2011).

Background to compensation

Many conservationists endorse paying for wildlife damage as a means to build support for conservation among communities neighboring protected areas. Compensation may be justified on

moral grounds if the direct cost of conserving wildlife is felt by a narrow minority (Treves et al. 2009). Others point to the political importance of compensation; it can convey legitimacy to wildlife agencies and protect them from accusations of indifference to human wellbeing (Anthony and Schwemmer 2015; Naughton-Treves et al 2003). Yet there are persistent doubts about compensation; such payments may not affect local attitudes or behaviors (Naughton-Treves et al., 2003) and payment may reduce incentives for guarding animals or crops (Bulte and Rondeau 2005). Problems of cost and corruption surface frequently in studies of compensation (Ravenelle & Nyhus 2017). Yet compensation programs are commonplace in Europe and North America and new payment programs are proliferating in the Global South (Ravenelle & Nyhus 2017). In Table 1, we summarize scientific occlusions about some of the potential the advantages and disadvantages of compensation programs by multiple criteria.

Table 1. Possible advantages and disadvantages of compensation for wildlife damage

Possible advantages

1. May offer rural people fair reimbursement for direct costs of wildlife
2. May engender local support for wildlife conservation or protected area management
3. May foster attitudes of coexistence with wildlife
4. May reduce incentives for poaching or encroaching on protected areas
5. May increase the authority or political legitimacy of wildlife agencies

Possible disadvantages

6. May raise public perception that wildlife belongs to outside authorities who are liable for the animals' (mis)behavior
7. May lead to extortion (demands to pay people not to kill wildlife)
8. May lower beneficiaries' motivations to protect their property
9. May be expensive or difficult to phase out or reduce payments
10. May be distributed unfairly or corruptly

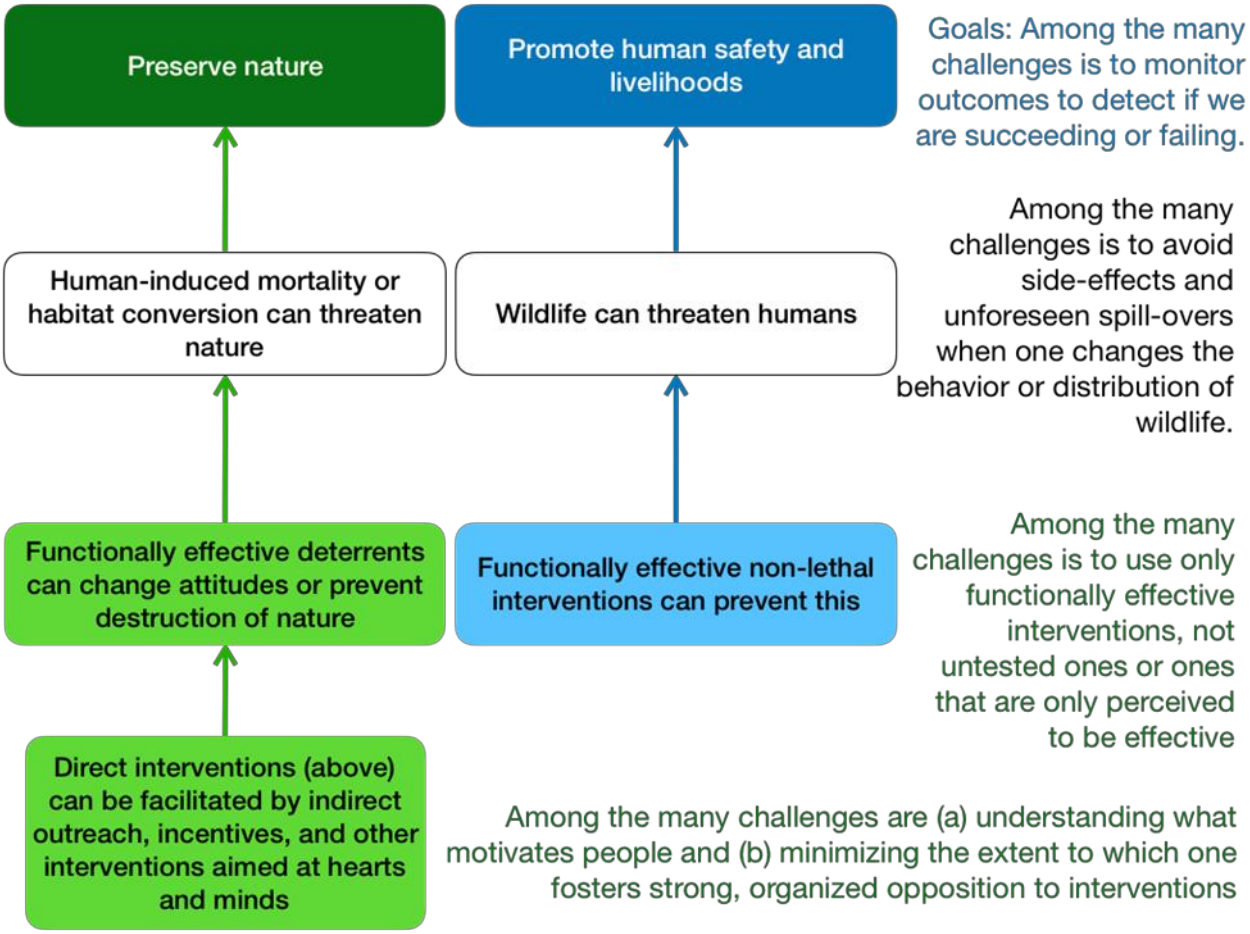
Rwanda hosts one of Africa's most ambitious wildlife compensation programs and its administrators and managers deserve praise for their work on this noteworthy initiative. Our findings about the experience with compensation around Akagera are intended to help these leaders assess the achievements and challenges thus far.

Rwanda launched its national compensation program in 2011 and designed it primarily as a 'social protection' measure to keep citizens from "falling into calamity" (Dr. J. Nzabonikuza SGF Director in *New Times*, 2017). Funding for the program comes from tourism earnings and is managed by the Special Guarantee Fund (SGF). Details on the compensation program are available at the SGF website (http://ikigega.rw/index.php?id=3&L=0). But key aspects of special importance for ANP administrators, as according to the Official Gazette No. 25 of 18/06/2012 and the Prime Minister's Order Nº26/03 of 23/05/2012, are presented in Appendix 1.

Given the geography of ANP and our goals, we focused on the western boundary and oriented our activities to the electric fence and the communities within a dozen kilometers or so from ANP. We present ecological and social scientific materials and procedures in the Methods section below. But to frame our study, we first summarize some of what is known about compensation and about conflict and coexistence with large mammals from studies elsewhere.

In many regions of the world, large mammals pose a threat to human safety or property and in turn, people react against such threatening animals. Human-induced mortality is a major threat to most large-bodied carnivores and many other large mammals listed as threatened by the IUCN. To both preserve nature and protect human safety and livelihoods, sometimes including the welfare of domestic animals in that charge, attention in recent years has turned to non-lethal methods for fostering coexistence between people and wildlife. Figure 1 offers a conceptual framework for understanding and managing human-wildlife coexistence.

Figure 1. Schematic conceptual model of change to promote human-wildlife coexistence.



Methods

First, we compiled and tabulated all complaints registered with AMC of wildlife damage to livestock and crops and wildlife-caused human injury and death from December 2014–September 2018. Second, we conducted fieldwork as follows:

Interviews: During June-July 2018, we conducted field interviews in the villages neighboring Akagera. Our sampling designed was informed by official records of people's complaints about wildlife threats and damage. These records include the village, cell, and sector in which the respondent lived in addition to their family names. We aimed to interview individuals from villages along the entire western border. Within each village and at most interviews, we were accompanied by a Community Officer (E. Dufitumukiza, M. Tuyisenge and F. Ishimwe) who alerted leaders of each village (umudugudu) of our planned visit. Before interviewing any individuals, we spoke with village leaders and sought their permission after explaining the goals of our research. All approved our work.

With the help of community liaisons and village leaders, we located the complainants in the field and with the help of our colleagues (see Acknowledgments), we began the recruitment script in Kinyarwanda. Then at the start of each individual interview, we again described the purpose of our work and explained that participation was voluntary, and citizens' identities would be kept confidential. If they agreed, we administered the oral consent script, also in Kinyarwanda. If they agreed to continue and answer questions, we began the interview in Kinyarwanda using the questionnaire in Appendix 2. We aimed to interview equal numbers of men and women, but men were more likely to assume the role of speaking for the household.

The questionnaire is in English and our Kinyarwanda colleagues translated on the fly into Kinyarwanda. We, non-Kinyarwanda speakers, followed up with most or all questions to confirm it had been translated accurately and the answer recorded accurately. We kept all records confidential and we report the results here in aggregate. We do not present individual respondent's answers.

After an interview with a respondent located as above from the official records, we asked the respondent or the village leader to point us to another household in walking distance to interview (snow-ball method). By chance, some of these additional individuals were official complainants but many were not. Therefore, our sample of 85 respondents contains both official complainants (some of whom did and some who did not receive compensation) and individuals who had not filed official complaints (some of whom reported losses to us, and some of whom did not),

In the 3+ year time window of interest for our study late 2014 to mid-2018. We conducted interviews with these additional respondents using the same methods as above, except we recorded village, cell, sector, and family name because if we had no official record of their complaint at the outset.

At the core of our investigation of compensation are these questions:

- What wildlife species cause the most frequent conflict? How does this vary by village and distance from the park edge?
- What wildlife do people feel most positive about? (in the park and on their own property)
- Why do some people file complaints for compensation and others don't? (vs. farm size, length of residence, gender, education level)
- What are people's experiences with compensation? Does it make them feel more positive about wildlife?

- What do people do to protect their crops and livestock from wildlife? Does compensation reduce motivation to protect crops and livestock? Do protective methods show evidence of effectiveness in lowering risk to livestock or crops?
- Do local people perceive benefits from the parks? If so, what kind of benefits?

Fence-line camera campaign: We fitted 23 camera traps at 12 locations along the southern fence line of ANP from 8 September 2017 to 15 January 2018. Each location was within three meters of the fence line, inside the park. Camera locations were located 300m apart along the southern fence line of ANP, covering approximately 5 km of fence line. We fitted two cameras facing opposite each other at each location. Cameras looked down the fence line to capture animals and people passing on both sides of the fence and along it. We elected to keep the distance between camera locations smaller to increase the chances of cameras capturing animals or people crossing the fence. We checked cameras once during the study period to replenish batteries and memory cards, and again at the end.

One additional camera was placed along the fence line, by chance, as part of a separate camera trapping effort. This camera was deployed from 30 May 2018 to 6 July 2018. We did not check this camera site until after the present study period was over.

We analyzed the photos captured for diversity of species detected at camera sites, for both inside and outside the fence, animals crossing the fence, and the frequency of visits by hyenas and leopards to the camera sites.

Hyenas and leopards in the communities: We investigated kill sites, hyena den sites, and carnivore trap sites in the communities around ANP. We focused our efforts in the communities adjacent to the southern part of the park because of logistical constraints but did manage to gather some data in the central and north communities too. We started our exploration from the main gate of ANP each morning, moving outward from the gate to nearby properties. The following days, we started data collection from where we left off or in new areas to avoid surveying locations twice. We approached property owners and people working on the property and asked them directly if they had knowledge of any kill sites, den sites, or trapping sites on the property or nearby. If they did, we conducted an interview about the type of site on their property. If the initial respondent did not have any knowledge, we moved to the next property and sought out a new respondent with knowledge of the hyena activity.

We recorded basic descriptive data for each site, regardless of type. This data included GPS coordinates, the name of the property owner where the site was located, and date. We also noted landscape features, including altitude and slope, land cover, and distance to water source. Depending on if the landcover was bush or crops, we rated the thickness of the bush or crop height relative to a hyena's height. We rated bush as light (1), medium (2), or dense (3). We marked crop height relative to a hyena as low (1), medium (2), or high (3). We recorded distance to nearest homestead and livestock shelters, and if there was livestock visible from the site or not.

For kill sites, we recorded the type, sex, and age of livestock killed and the wildlife species involved. We interviewed respondents about the carnivore deterrents in use, including if the kill site was in a structure and if guards or dogs were defending the herd. If the respondent used a boma, we rated the boma quality 0 if the carnivore could enter without any impediment, 1 if the carnivore could enter above or below the fence but not through, 2 if the carnivore could enter either above or below the fence, but not both or through, and 3 if the boma was impenetrable to carnivores.

For den sites, we followed the directions provided by respondents or were showed the location. We recorded the type of den and the direction it was facing. Dens were recorded as burrow or cave. We defined burrows as tunnels in the dirt with hyena digging and modification. Caves are natural tunnels in rocky areas with little or no hyena modification. We searched for signs of hyenas to determine if the den site was active or inactive.

In addition to discovering carnivore trap sites through exploration, we contacted community leaders for information on trap locations. We recorded the material of the trap and the bait used and noted if it was armed and maintained. We interviewed respondents about the success of each trap, the duration it had been at the location, and how often it was checked. If the trap was successful in capturing a carnivore, we recorded additional information about the species captured and the capture event.

Using hand-held GPS units during fieldwork, we recorded locations of interviews and other phenomena of interest as described previously. We super-imposed all GPS locations over base maps of Akagera and its neighboring villages using cadastral and ANP boundary datasets (ref source) and geo-referenced landmarks visible from Google Earth Pro. We used ArcMap 10.5.1 software to make maps.

Analyses: After mapping, we measured the straight-line distances from interview sites to the ANP boundary and aggregated results by village. We conducted simple comparisons of means and variances using Welch's test that does not assume equal variances.

Results

Official reports: Official reports contained a total of 738 complaints from December 2014 until September 2018 (Table 2). Seventeen records (2.3%) could not be ascribed a location. In Figures 2, 3, 4, and 5, we show the geographic distribution of the remaining 731 official complaints aggregated at the scale of villages. Although all neighboring villages show official evidence of conflicts, the type of wildlife responsible and frequency of losses varied significantly. Figure 2 displays all official complaints aggregated for 2014-2018, whereas Figures 3 and 4 display crop and livestock damages, respectively, for the same time period. Appendix 3 and 4 present geographic distribution of official complaints of livestock and crop damages by year, respectively. Appendices 5, 6, 7, and 8 show geographic distributions of official complaints of buffalo, hippo, hyena, and leopard, respectively, by year.

Year	Type of Damage	Verified Complaints
2014*	Crop	0
	Livestock	2
	Human injury/death	0
	Total	2
2015	Crop	41
	Livestock	61
	Human injury/death	8
	Total	110
2016	Crop	52
	Livestock	128
	Human injury/death	17
	Total	197
2017	Crop	122
	Livestock	143
	Human injury/death	2
	Total	267
2018**	Crop	31
	Livestock	110
	Human injury/death	3
	Total	144
*only December 2014		
**only through September 2018		

Table 2. Summary of verified complaints by types of damages by year.

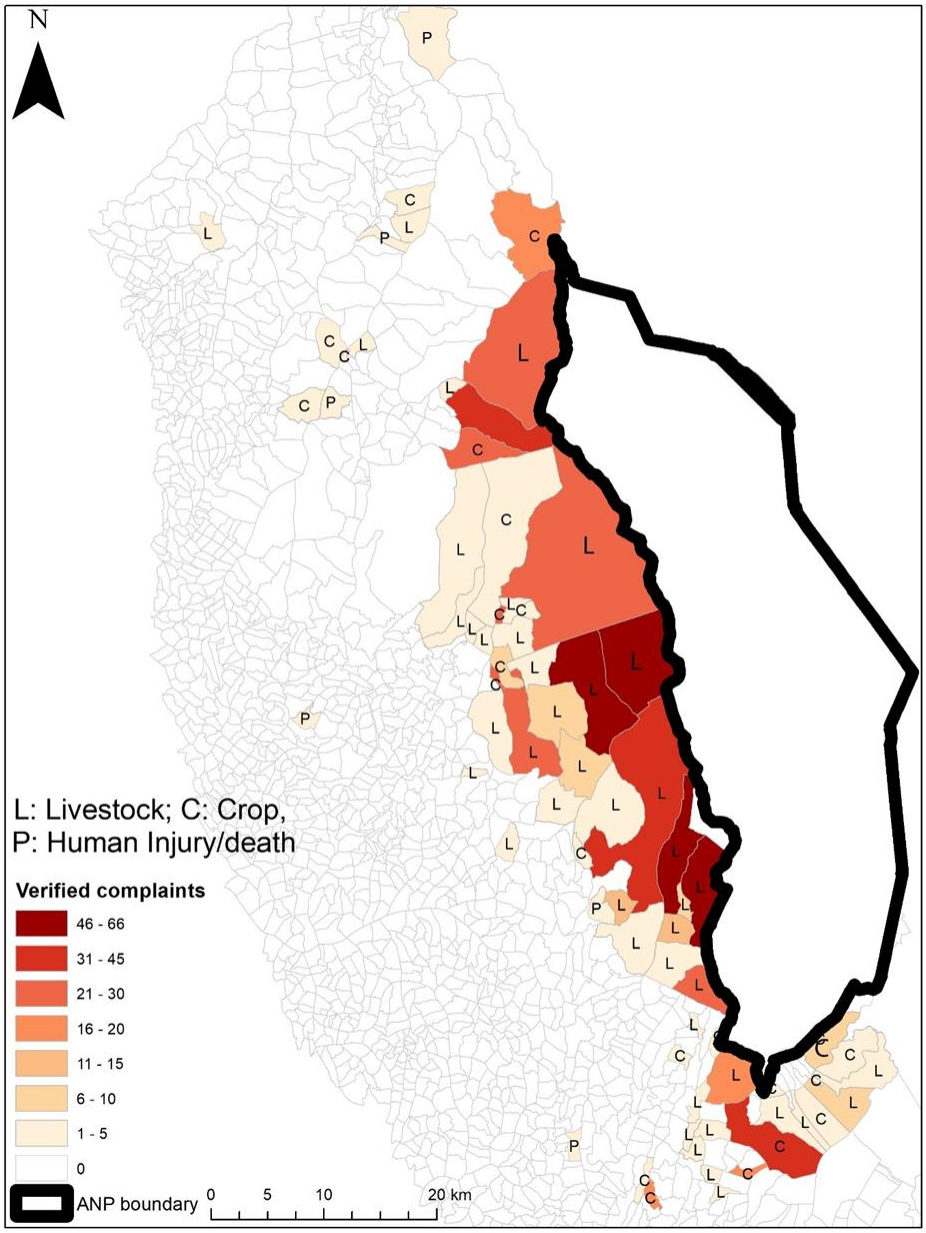


Figure 2. Geographic distribution of verified complaints about all forms of wildlife damage around Akagera National Park. Rwanda, 2014–2018 by village (background colors estimate the total number of verified complaints by all species, as per the legend), where the dominant type of loss in that village is mapped by letter (C = crop, L = livestock, P = human injury/death).

Tragically, there were 22 claims of wildlife-caused human injury and eight of human death in the claims record. Buffalo were involved in eleven injuries and two deaths, hippos in four injuries and six deaths, leopards in five injuries. Baboons and bushbucks were each blamed for a single case of human

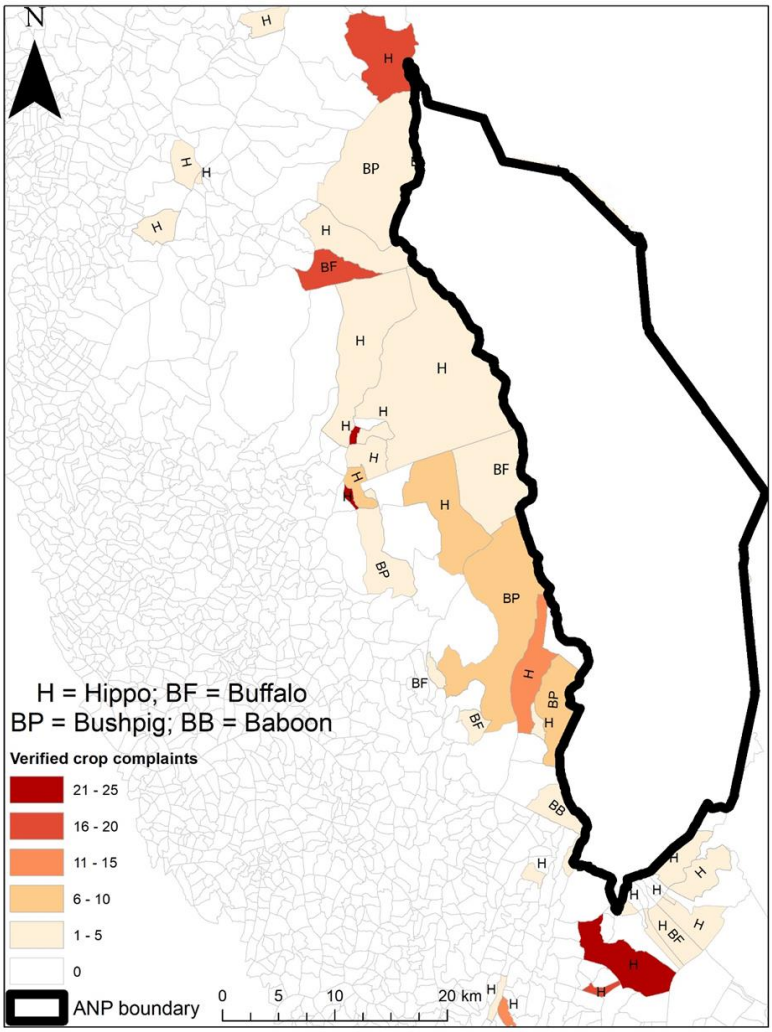


Figure 3. Geographic distribution of verified complaints about crop loss around Akagera National Park. Rwanda, 2014–2018 by village (background colors estimate the total number of verified complaints of crop loss by all species, as per the legend). The four species causing the greatest number of incidents of crop damage are denoted by village.

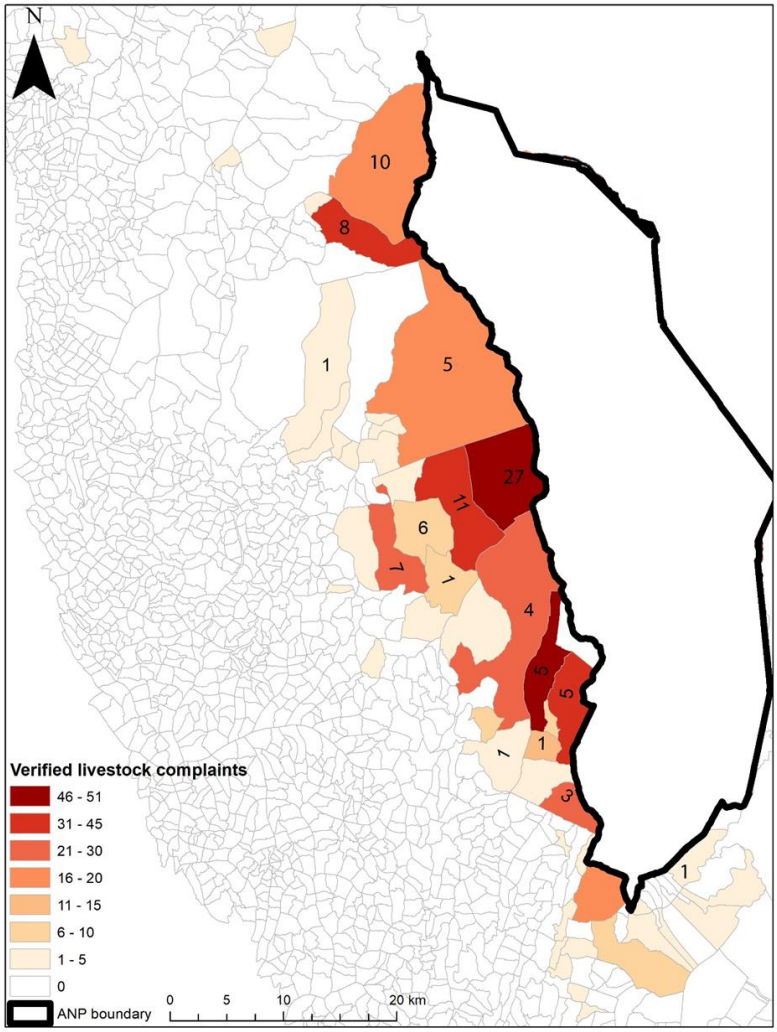
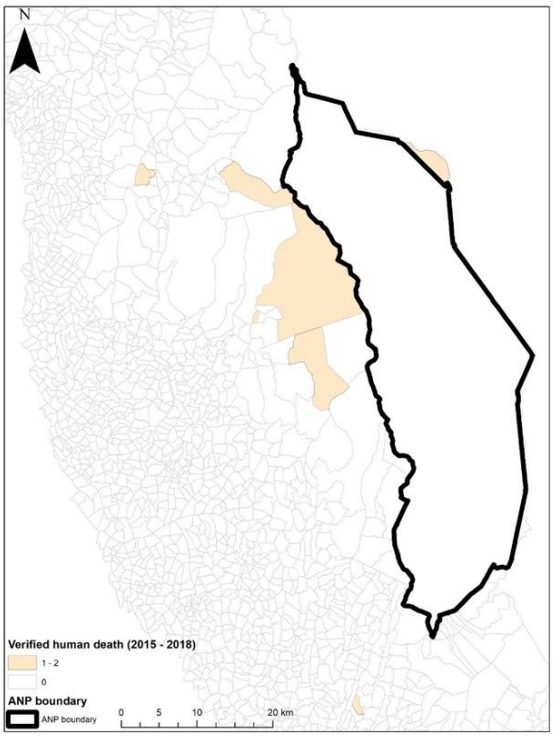


Figure 4. Geographic distribution of verified complaints about livestock loss around Akagera National Park. Rwanda, 2014–2018 by village. Background colors estimate the total number of verified complaints of livestock loss by all species, as per the legend, which are dominated by hyena predation. Numbers within polygons estimate the number caused by leopards.



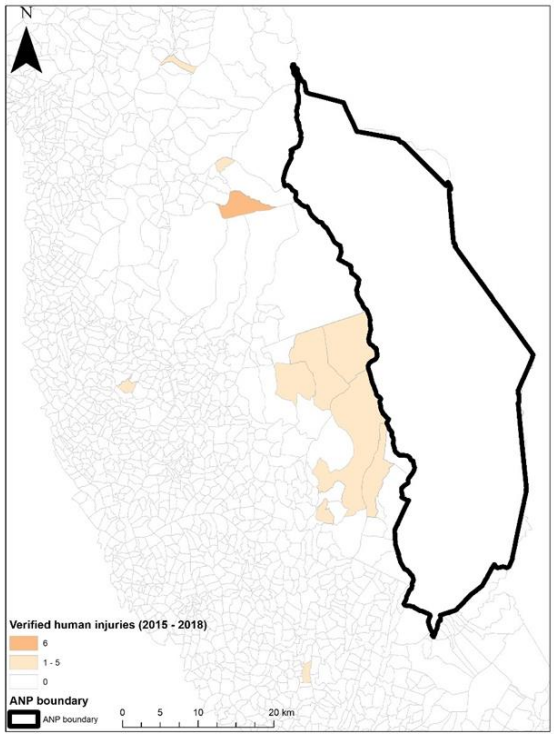


Figure 5. Geographic distribution of verified complaints of wildlife-caused human death (left) and injury (right) around Akagera National Park. Rwanda, 2014–2018 by village. Background colors estimate the total number of verified complaints of human death or injury by all species, as per the legend.

injury. Figure 5 shows the geographic distribution of verified complaints of wildlife-caused human death and injury.

Unfortunately, it was not possible to ascertain which of the 738 complainants had been paid. As we understand it, to date AMC has not received any information from SDG about payments since the compensation program started in 2014. Meanwhile, according to an interview in 2017 with the SGF Director published in New Times, between Jan 2013 and Aug 2017, SGF paid 2,648 wildlife claims in the Eastern Province, home to Akagera. Given that the ANP has records of only 738 compensation claims for roughly the same period, evidently there is a significant amount of livestock and crop losses in the Eastern Province far from Akagera National Park. Our interview data provide self-reports of payments, but only for the 85 respondents.

According to the records, 578 individuals filed 729 verified complaints (average 1.3, mode: 1, range 1-14) but dominated by complainants with one verified complaint, Figure 6) over the 32-month period.

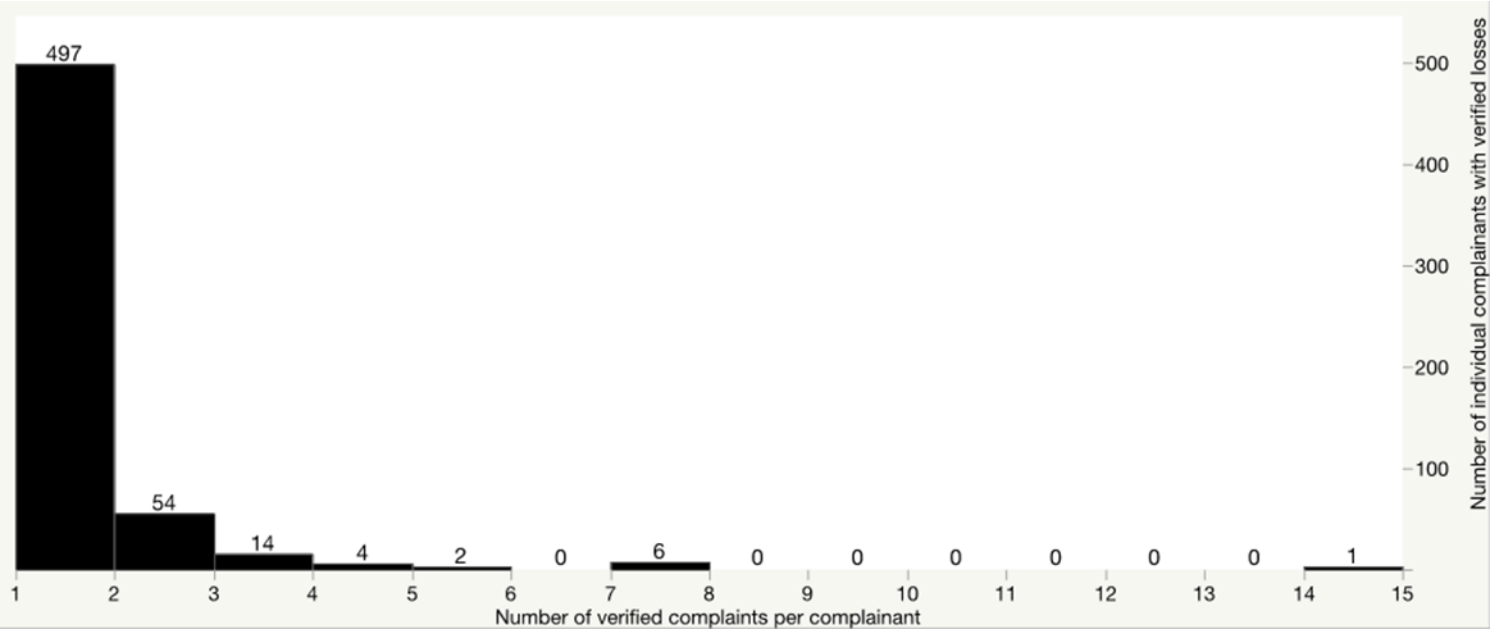


Figure 6. Frequency of verified complaints by 578 complainants (n=729 separate incidents).

The single case with 14 verified complaints (livestock losses to hyena) appears to occupy a 'hot spot of conflict', or this could be a case of an individual being proficient with the complaint process, or the frequency of complaint might mean that frequent compensation has deterred the person from guarding livestock (the neighboring livestock owner suffered zero losses to wildlife in the same period). All three factors could explain the observed pattern. Extrapolating from interview data on *average* livestock payments received per complaint (described below), this individual may have been paid a total on the order of 5,300,000RWF (US$6,000) if all fourteen complaints were approved.

Results of Interviews: In June 2018, we completed 85 interviews in the communities west of Akagera National Park. No one declined. All data in this report section derive from the field interviews. Interview sites were all on or near respondents' properties at an average distance of 3.3 km from the ANP boundary (sd 3.2, range 0–12.7 km) although the majority were <5 km of the boundary. Hereafter, we treat the interview location as part of a farm owned by the respondent although this is an assumption.

The following attributes of respondents reflect a subsample of the 85 as some respondents did not answer all questions or records were imperfect. Respondents or their households commonly owned livestock: 59 (86%) reported owning cattle (median 10–20, n=69) and 57 (95%) reported goats (median 20–40, n=60), twelve respondents only had cattle, one respondent reported owning neither. Respondents' reported an average property size of 10.4 ha (range 1–90, n=76), with the vast majority holding <20 ha; but this estimate should be interpreted cautiously given that eleven respondents described cooperatively managing adjacent properties belonging to family members for grazing livestock (Appendix 9). They reported owning their land for an average of 11.4 years (range, <1 to 23 years, n=79), but the average was not representative because of a clear bimodal distribution with a gap at 10–15 years (Appendix 9). The relatively recent occupancy length is explained in part by the fact that the study region was part of Akagera National Park before 1997. Of 83 respondents, 69% reported secondary education or higher.

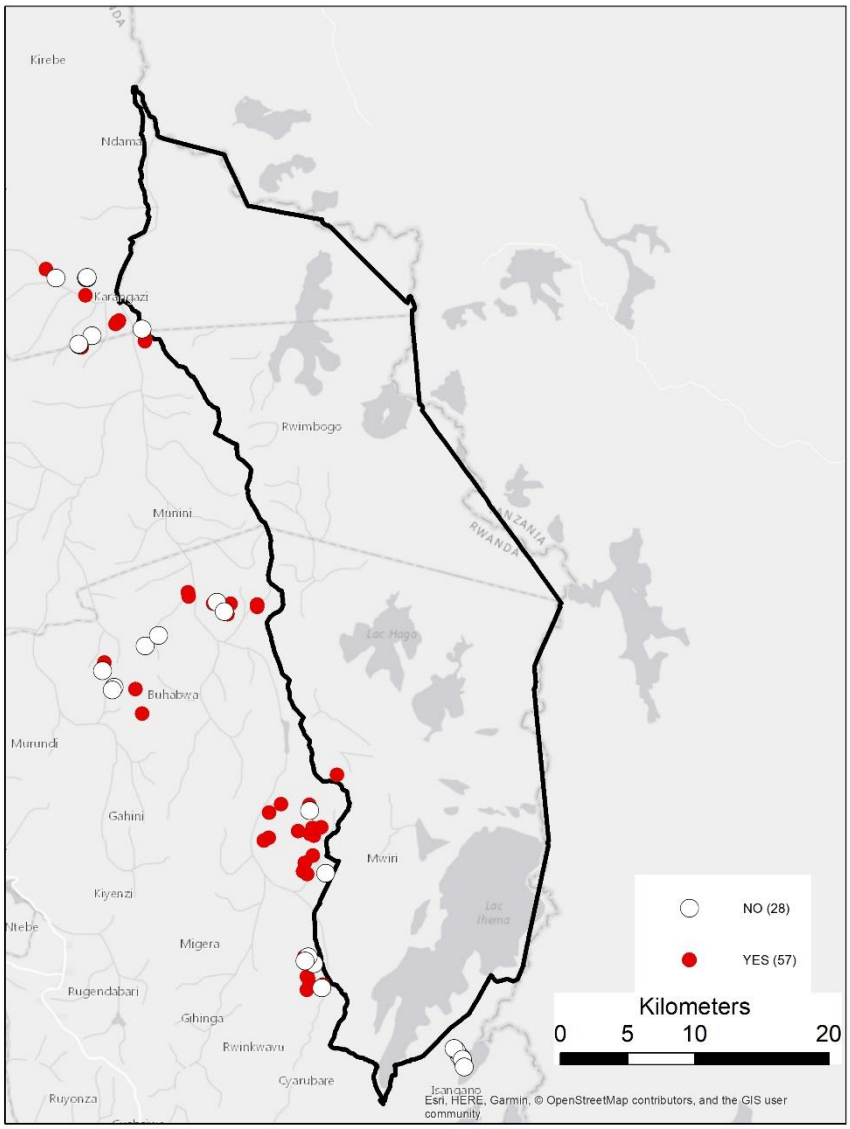


Figure 7. Geographic distribution of interview respondents who reported livestock damage.

All respondents reported wildlife encounters. Of the 85 respondents, 57 (67%) reported one or more livestock losses (Figure 7) and 63 (74%) reported one or more crop losses (Figure 8), with 40 (47%) respondents reporting both types of losses. Only five respondents reported no damage. We did not interview anyone in a household where someone had suffered an injury or death to wildlife.

Two-thirds of the total of 85 respondents reported that hyenas killed their livestock, with only one respondent (3%) having both predators verified. Of the 57 reporting to us that predators took livestock, only 37 (65%) filed official complaints, mainly attributed to hyenas (83%). Of the 37, 24 (65%) were compensated.

We conducted simple inferential statistical tests to identify attributes of respondents reporting loses of livestock during interviews, which might be associated with whom complained officially and whom was

compensated. None of the following attributes were associated with either official outcome: gender, property size, length of residence, or education.

We ran simple inferential statistics to test if respondents who reported to us that they had experienced livestock losses to wildlife (n=57) owned land at different distances from the boundary of ANP than respondents who did not report to us experiencing such losses (n=28). Differences in distance were not significant (3.8 sd 3.7 km v 3.0 sd 3.0 km respectively, F=1.0, p=0.33). By contrast, 37 respondents who reported their livestock losses to officials owned land further from the ANP boundary (3.7 sd 3.5 km) than our 19 respondents who had not filed official complaints (1.8 sd 1.2 km, F=9.0, p=0.004), seemingly due to a cluster of such official complainants in the central area of our study (Figure 9).

Likewise, of the 37 respondents who filed official complaints to officials, the 24 who received compensation owned land further from the ANP boundary (4.9 sd 3.7 km) than the 13 who did not receive compensation despite filing an official complaint (1.5 sd 1.1, F=17.3, p=0.0003, Figure 11) (Figure 10).

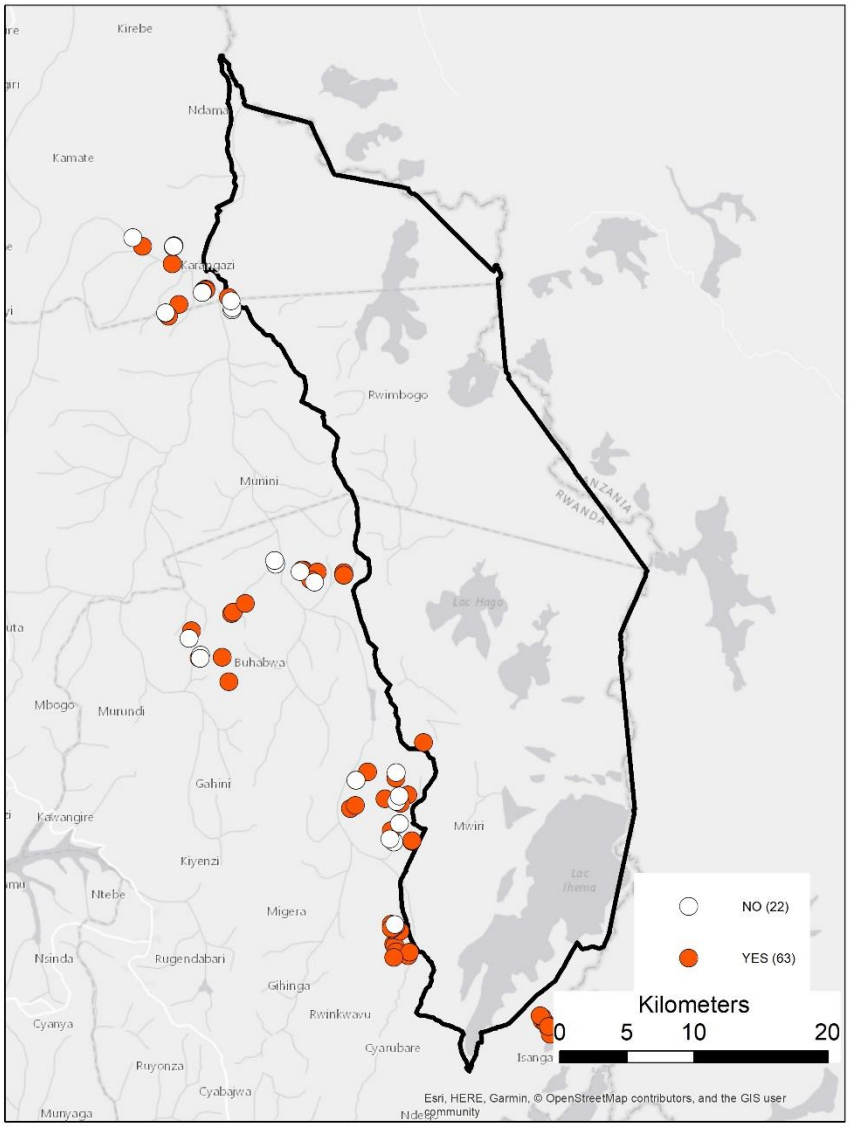


Figure 8. Geographic distribution of interview respondents who reported crop damage.

Turning to compensation, of the 63 who told us they'd experienced crop loss, only 14 (22%) formally made complaints (1–5 incidents each) (Figure 11), and of these, 5 of the 14 (36%) reported receiving payment (Figure 12). Of the individuals who reported to us that they had received payment, only 18 could recall or opted to tell us the precise amounts. These individuals reported 35 payments because of multiple incidents affecting some of them. In the case of crop loss complaints, the four payments reported averaged 17,000 RWF [~US$19] (range 14,000RWF-25,000RWF]. For livestock claims, the average reported payment for a single livestock claim was 375,400 RWF [~US$428], range 60,000 to 700,000 RWF [~US$69-US$800]. The total reported amount received for up to three recent livestock claims by a single household averaged 542,320 RWF [~US$619] (highest value 980,000 RWF for two claims) [US$1119].

Sixty-three respondents reported that they opted NOT to file an official complaint on at least one occasion. The top three most common reasons for not filing a complaint were being unaware of the program or not understanding the rules (29%), lack of evidence (29%), or too costly or time-consuming

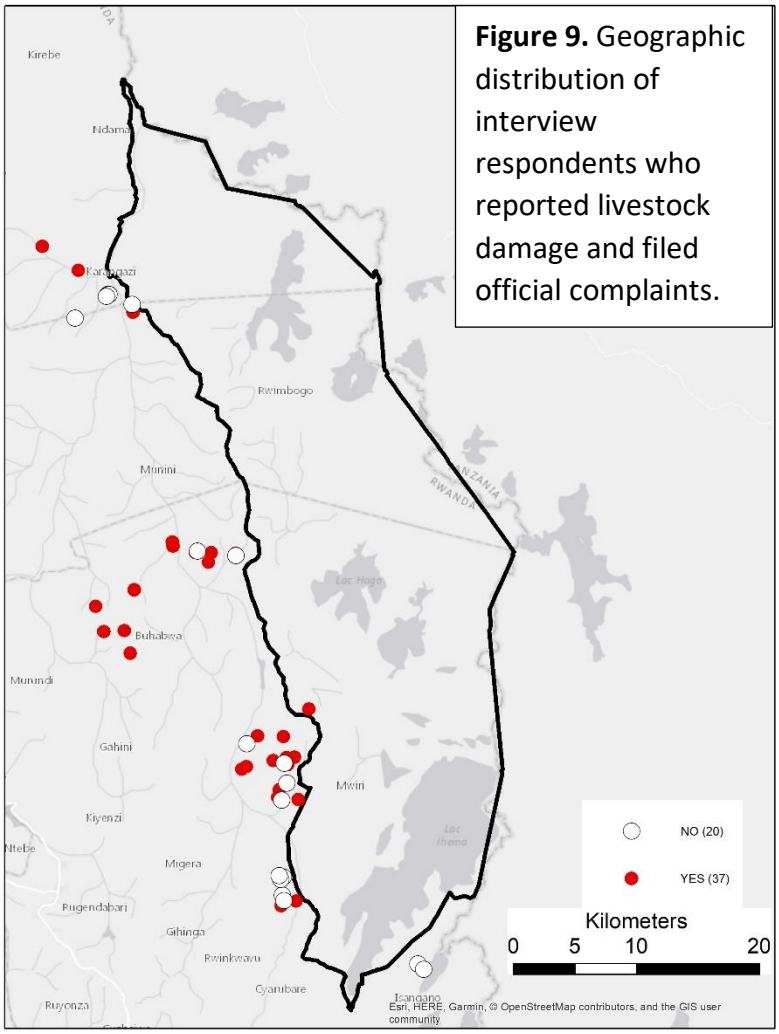


Figure 9. Geographic distribution of interview respondents who reported livestock damage and filed official complaints.

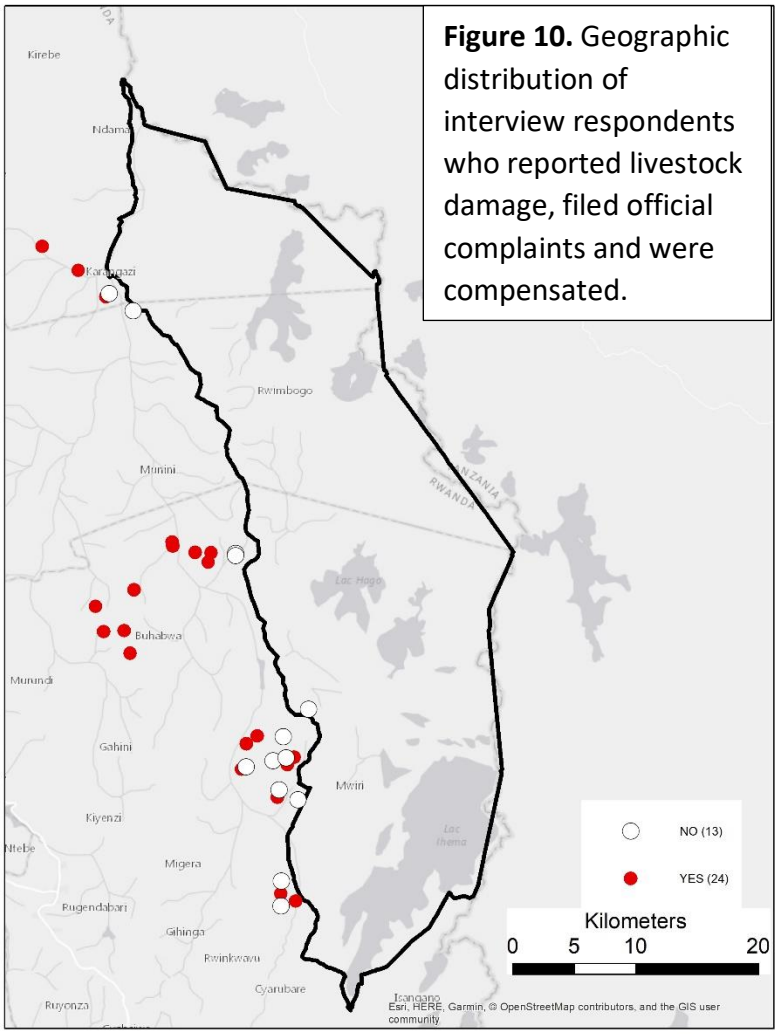


Figure 10. Geographic distribution of interview respondents who reported livestock damage, filed official complaints and were compensated.

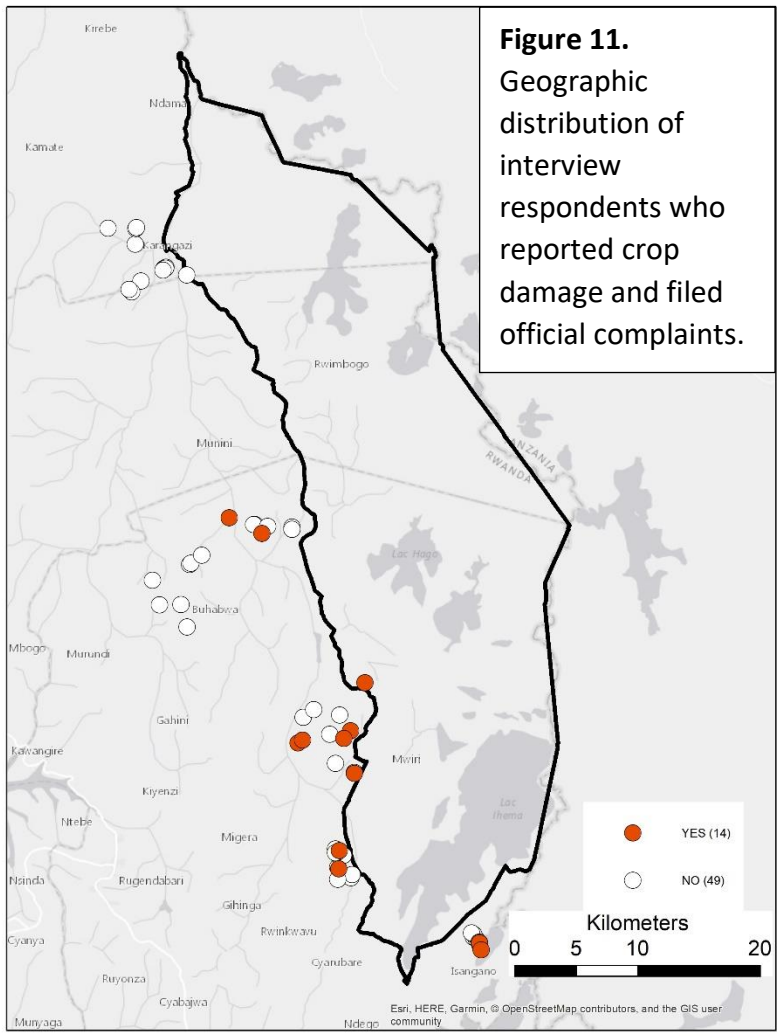


Figure 11. Geographic distribution of interview respondents who reported crop damage and filed official complaints.

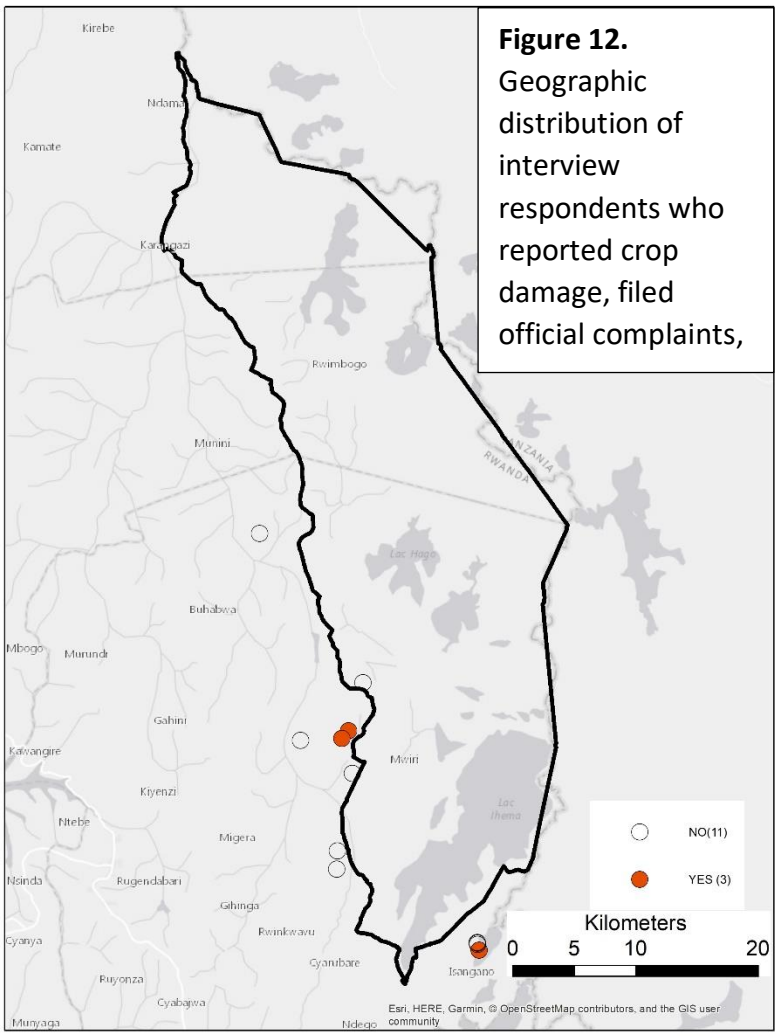


Figure 12. Geographic distribution of interview respondents who reported crop damage, filed official complaints,

to make a claim (21%) (multiple responses, n=63). In the case of crop damage, 17% reported that the damage was not enough to merit the costs of filing a claim. Eleven others (17%) were discouraged from filing a complaint because their previous complaint was denied or a neighbor's claim had been denied.

We next tested for correlates with the decision to file a claim for compensation. Contrary to predictions from the literature, propensity to file a complaint showed no relationship with gender, property size, length of residence, and education. This suggests the better off or more educated do not necessarily feel more entitled or confident about filing a claim. For example, of the 18 individuals who were unaware or didn't understand the program, the majority (13) had a household member who had completed secondary or post-secondary education. However, our sample size is modest and some comments during interviews suggest that the common bias in compensation programs elsewhere might be present here as well; namely the very poor smallholders may feel overwhelmed by the compensation procedure, and those with political connections felt more confident about filing multiple complaints.

When asked if compensation improved their tolerance for wildlife, over half (66%) said yes, 14%, no, and the rest struggled to answer the question (Figure 13). When asked if they enjoyed seeing wildlife on their farms, 54 (64%) answered yes, 24 (28%) said no and seven did not answer (8%) (Figure 13). Among those who enjoyed viewing wildlife on their land, the most popular species mentioned were impala (41%), zebra (22%), and rabbits (10%) (multiple response, n=54). Even more respondents (70%) reported enjoying seeing birds on their land, and some went on to describe the beauty of cranes, herons, and egrets in particular. When asked which animals they liked *within* the park, elephants were most often mentioned (54%), giraffe (37%), zebra (25%), lion (20%), and rhino (12%) (multiple response, n=76). Nine other species were also mentioned as animals they would like to view in the park. Table 3 summarizes attitudes towards specific wildlife species.

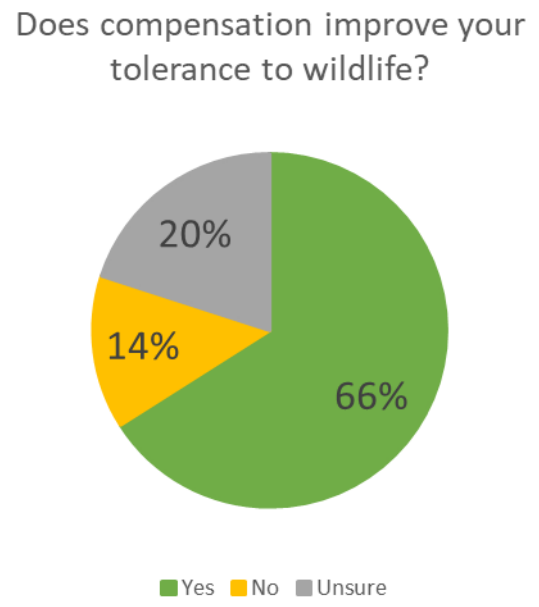
When asked about the benefits from living in proximity to the park, 24 (28%) respondents reported a single benefit, 35 (41%) reported multiple benefits (mentioned more than one benefit), and 26 (31%) reported no benefits (Table 4). The question was open ended, so respondents answering only one benefit may have interpreted the questions as asking for only one benefit but also have others. The most common type of benefit reported was infrastructural (41%).

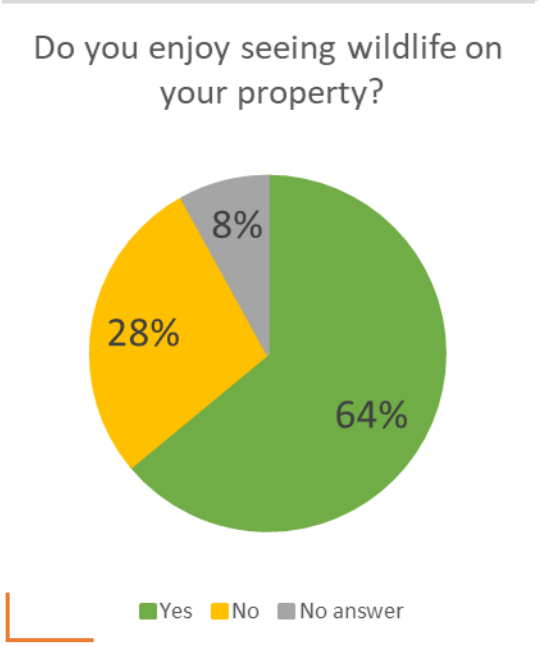
The top three specific benefits mentioned the most times during interviews included school construction (24), tourism bringing income to communities (17), and fencing of the park by AMC (13) (Table 5).

Figure 13.

29%

Percentage of interview respondents who were unaware of the compensation program or did not understand the rules.





Species reported as favorite in the Park	Number of reports	% of reports	Species reported as most concerning	Number of reports	% of reports	Species reported as preferred on property	Number of reports	% of reports
Multiple species	46	54.12	Single species	63	74.12	None	46	54.12
Single species	28	32.94	Multiple species	20	23.53	Single species	25	29.41
None	6	7.06	None	2	2.35	Multiple species	14	16.47
All species	4	4.71	**Total responses**	**85**	**100**	**Total responses**	**85**	**100**
Doesn't know the species	1	1.18						
Total responses	**85**	**100**						
Elephant	41	27.89	Hyena	37	34.58	Impala	21	38.89
Giraffe	27	18.37	Leopard	29	27.10	Zebra	12	22.22
Zebra	19	12.93	Hippo	13	12.15	Hare/Rabbit	6	11.11
Lion	15	10.20	Baboon	12	11.21	Bushbuck	5	9.26
Rhino	11	7.48	Bushpig	8	7.48	Antelope/Deer	3	5.56
Buffalo	6	4.08	Buffalo	5	4.67	Vervet	3	5.56
Impala	6	4.08	Tsetse Fly	1	0.93	Waterbuck	3	5.56
Topi	6	4.08	Vervet Monkey	1	0.93	Topi	1	1.85
Crane	4	2.72	Zebra	1	0.93	**Total**	**54**	**100**
Eland	3	2.04	**Total**	**107**	**100**			
Birds	1	0.68						
Bushbuck	1	0.68						
Fish	1	0.68						
Hare/Rabbit	1	0.68						
Hyena	1	0.68						
Leopard	1	0.68						
Vervet	1	0.68						
Warthog	1	0.68						
Waterbuck	1	0.68						
Total	**147**	**100**						

Table 3. Summary of interview respondents' answers to the questions about their attitudes towards wildlife.

Benefits Reported	**Number of reports**	**% of reports**
Single benefit	24	28.24
Multiple benefits	35	41.18
None	26	30.59
Total responses	**85**	**100**

Benefits of Park	**Number of reports**	**% of reports**
Community Support	29	19.21
Infrastructure	51	33.77
None	26	17.22
Miscellaneous	25	16.56
Wildlife Mitigation	15	9.93
Items Provided	5	3.31
Total	**151**	**100**

Table 4. Summary of the number of benefits and type of benefits from living near Akagera National Park reported by interviewees.

Community Support	**Number of reports**
Student visits to Park	8
Cooperative support	6
Compensation for losses	5
Education material from Park	3
Adult visits to Park	2
General agriculture support	1
Trainings led by Park	1
Health Care	1
Jobs at Park	1
Park organized events	1
Total	**29**

Infrastructure *(construction of…)*	**Number of reports**
Schools	24
Clinics	7
Water access	7
Roads	5
Village/Cell/Sector Offices	5
General Infrastructure	3
Total	**51**

Items Provided	**Number of reports**
Goats	4
Bicyles	1
Total	**5**

Miscellaneous	**Number of reports**
Tourism brings income	17
Wildlife brings happiness, pride	6
Tree planting	2
Total	**25**

None	**Number of reports**
No benefit from Park	25
Total	**25**

Wildlife Mitigation	**Number of reports**
Fence	13
Human-wildlife conflict mitigation projects	2
Total	**15**

Table 5. Summary of specific benefits reported by interview respondents, by type of benefit.

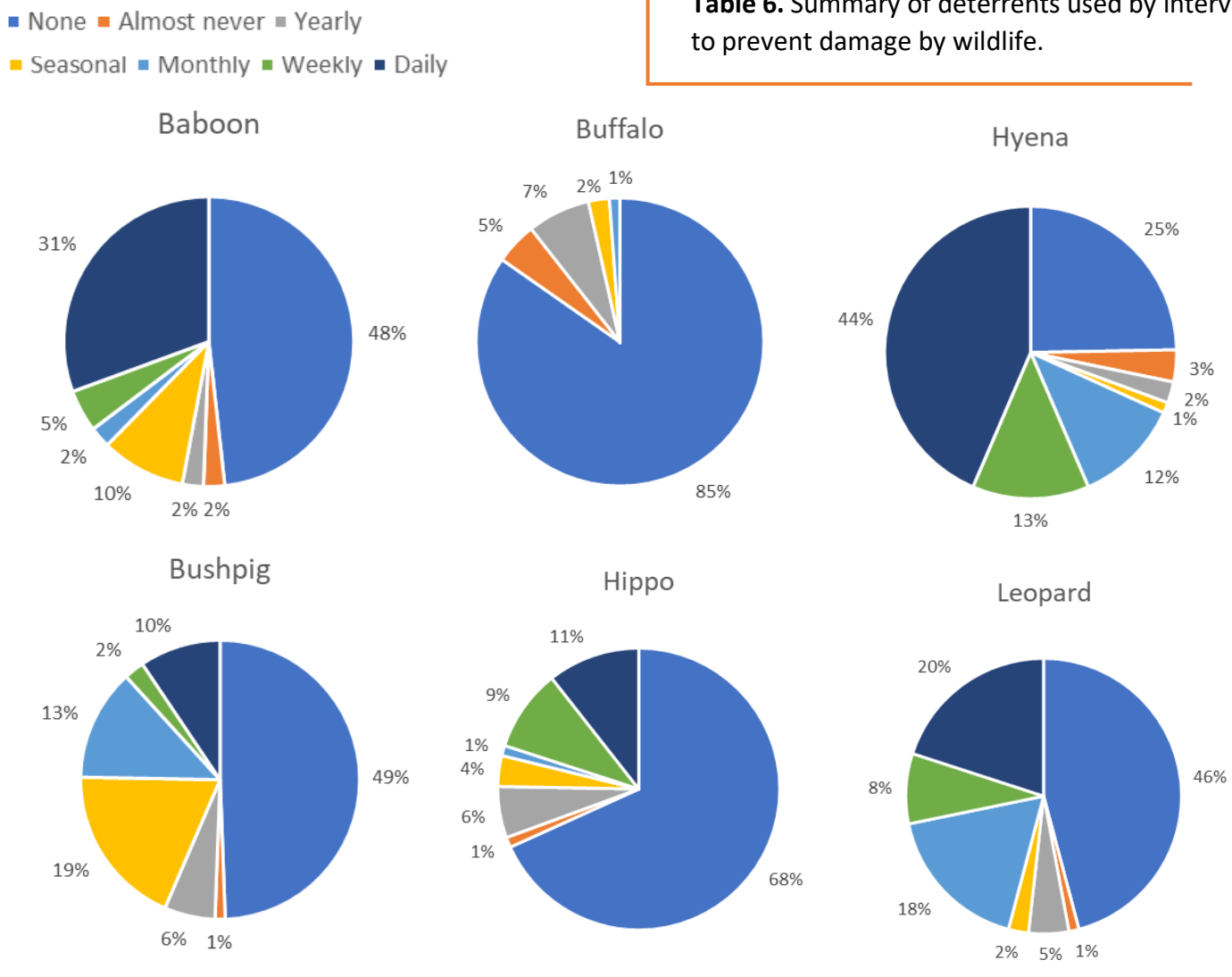
Virtually all respondents deployed some method of protecting their property, with a few exceptions (Table 6). Property owners most commonly implemented bomas, however we did not record any perfect bomas in this round of interviews. We suggest improvement of boma quality for protection of livestock. A combination of different material such as euphorbia and wire is effective in protecting against predation. The maintenance of bomas needs to be a top priority.

Wildlife visited respondent's properties with different frequencies (Figure 14). 44% or more respondents reported hyenas visiting daily and 31% reported baboons visiting daily. Leopards were the third most reported species for daily visits. Despite the frequency of reported daily visits, *no visits* was still the most common response for all species except hyenas.

Type of Deterrent Reported	# of reports	% of reports
Barn/Shelter	61	10.54
Boma	81	13.99
Guards	208	35.92
Day Guard	*40*	
Unspecified Guard	*46*	
Night Guard	*122*	
Dog	90	15.54
Electric light/lamp	2	0.35
Fence	64	11.05
Fire	59	10.19
Live Trap	4	0.69
Park Fence	1	0.17
Torch/flashlight	7	1.21
Trench	2	0.35
Total	**579**	100
No deterrents used	286	

Table 6. Summary of deterrents used by interviewees to prevent damage by wildlife.

Figure 14. The reported frequency that wildlife visit respondents' properties for the six most often complained about species.



Fence line Camera campaign: All camera locations detected animals. 96% of cameras detected animals inside the fence (Table 7). The only camera that did not detect animals inside the fence did, however, capture images of bushbuck outside the fence. 91% of cameras captured animals outside the fence. Cameras detected 8.22 species per site inside the fence (range 0-16). Species diversity detected outside the fence was less, at 2.17 species per camera. Total diversity of species detected was greater inside the park. 20 species were detected inside the park, including elephants and giraffes. 9 species were detected outside of the park. We recorded mongoose captures as "mongoose" regardless of species, due to lack of experience by research interns. We suspect that there are as many as four mongoose species detected, including slender and white-tailed mongooses that D. Bantlin confirmed. Splitting the mongoose species individually would bring the mammal species detected to 22-24.

Only two species were detected crossing the fence. Cameras captured leopards crossing under the fence and vervet monkeys crossing through it. Camera 32 captured leopard cubs moving both into and out of the park underneath the fence. No adult leopards were detected crossing the fence (Image 1).

Pair	1				2				3			
Camera	29		30		32		48		47		51	
Detection	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Species	Baboon Buffalo Bushpig Hyena Impala Leopard Reedbuck	Leopard	Baboon Buffalo Hyena		Baboon Buffalo Bushbuck Bushpig Hyena Impala Leopard Mongoose Serval Vervet monkey Warthog	Baboon Leopard	Baboon Buffalo Bushbuck Hyena Impala Leopard Mongoose Vervet monkey	Baboon Bushbuck Bushpig	Baboon Buffalo Bushbuck Bushpig Hyena Leopard Porcupine Vervet monkey	Baboon Bushbuck Vervet monkey	Baboon Buffalo Bushbuck Hyena	Baboon Bushbuck Hyena

Pair	4				5				6		
Camera	0		36		49		53		38		no second camera
Detection	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	
Species		Bushbuck	Aardvark Baboon Buffalo Bushbuck Duiker Hyena Impala Leopard Mongoose Serval Vervet monkey	Baboon Bushpig Hyena Impala Vervet monkey	Baboon Buffalo Bushbuck Duiker Hyena Leopard Mongoose Porcupine Vervet monkey	Baboon Bushbuck Bushpig Hyena Vervet monkey	Baboon Buffalo Bushbuck Bushpig Hyena Leopard Mongoose Reedbuck Vervet monkey	Baboon Bushbuck Duiker Vervet monkey	Aardvark Baboon Buffalo Bushbuck Duiker Hare Hyena Leopard Porcupine Vervet monkey	Baboon Bushbuck Duiker Hare Hyena	

Pair	7				8				9			
Camera	26		28		24		25		21		22	
Detection	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Species	Hyena Impala	Hyena	Buffalo Bushbuck Bushpig Hyena Impala Reedbuck Warthog		Baboon Buffalo Bushpig Elephant Hyena Impala Topi Vervet monkey	Hyena	Baboon Buffalo Bushpig Hyena Impala Topi	Hyena	Baboon Buffalo Bushbuck Elephant Hyena Impala Warthog Zebra	Hyena	Baboon Buffalo Bushbuck Bushpig Elephant Hyena Impala Jackal Leopard Reedbuck Vervet monkey Warthog Zebra	Baboon Hyena

Pair	10				11				12			
Camera	10		20		3		8		2		34	
Detection	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Species	Baboon Buffalo Bushbuck Bushpig Giraffe Hyena Impala Leopard Reedbuck Vervet monkey	Bushbuck Hyena	Baboon Buffalo Bushbuck Bushpig Giraffe Hyena Impala Reedbuck	Baboon Bushbuck Hyena	Baboon Buffalo Bushbuck Bushpig Genet Giraffe Hyena Impala Leopard	Baboon Hyena Impala	Baboon Buffalo Bushbuck Bushpig Elephant Giraffe Hyena Impala Leopard Reedbuck Warthog	Hyena Impala	Buffalo Bushbuck Bushpig Elephant Giraffe Hyena Impala Leopard Reedbuck Topi Vervet monkey Warthog	Hyena	Aardvark Baboon Buffalo Bushbuck Bushpig Duiker Elephant Giraffe Hare Hyena Impala Leopard Reedbuck Serval Topi Warthog	Impala

Table 7. Summary of species detected at each camera along the southern fence line, inside and outside of the park.

Hyenas visited the camera sites 517 times over 130 camera trap days (Camera Trap Day, *CTD,* = 24-hour period with a functioning camera deployed). 398 of these visits were inside the fence. The number of hyena visits, both inside and outside the fence, to camera sites ranged from 0-60 visits (Figure 15). The average frequency of visits inside the park to camera sites was 0.13 visits/CTD (range 0-0.46 visits/CTD). For outside the park, the average frequency was 0.04 visits/CTD (range 0-0.2 visits/CTD)

Leopards visited cameras 69 times. Only one visit was outside the fence. The number of leopard visits to camera sites ranged from 0-15 visits. The average frequency of visits inside the park to camera sites was 0.02 visits/CTD (range 0-0.12 visits/CTD). For outside the park, the average frequency was 0.0003 visits/CTD (range 0-0.01 visits/CTD).

The lone camera not part of the original set-up detected 10 species inside the park. Bushpigs, hyenas, and leopards were also detected outside the fence. Honey badgers were also detected at this camera, but not at any others. The frequency of hyena visits to the camera site inside the fence was 0.46 visits/CTD (17 visits). The frequency of leopard detection was very high at 0.16 visits/CTD inside the park (6 visits). We detected both carnivores at high rates outside the park as well. The frequency of hyena visits outside the fence was 0.24 visits/CTD (9 visits). For leopards, the frequency was 0.16 visits/CTD (6 visits), immensely higher than at cameras in the original set-up.

Image 1. Young leopards crossing through the southern fence. We found no evidence of adult leopards crossing.

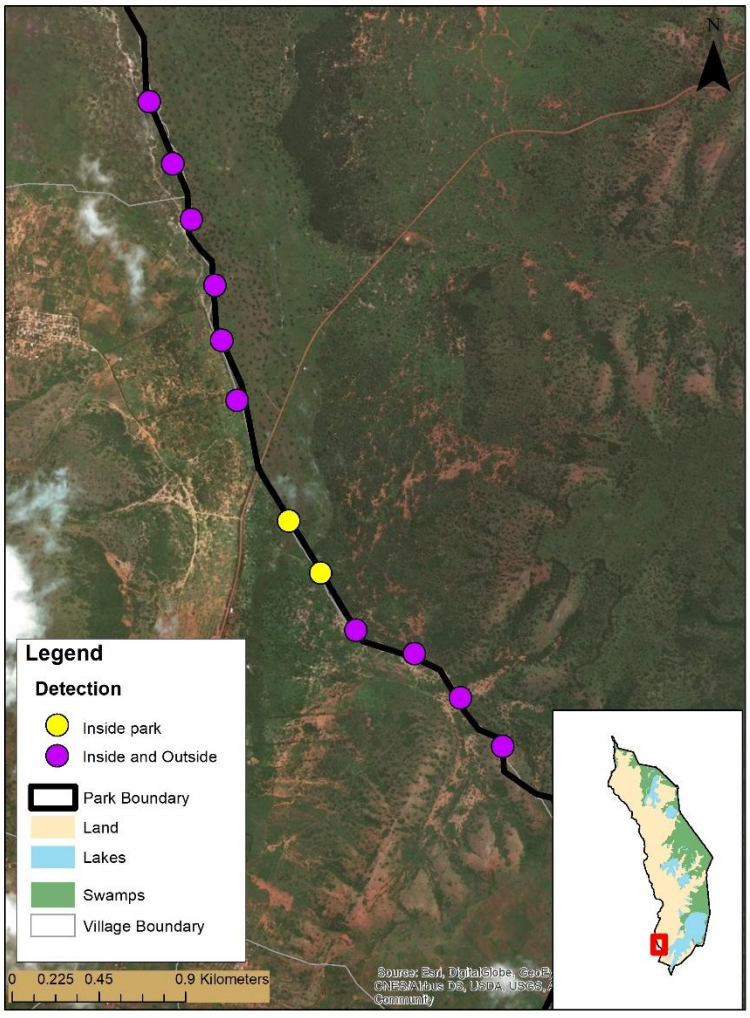


Figure 15. Map showing detection of hyenas inside and outside the park at camera sites along the southern fence line.

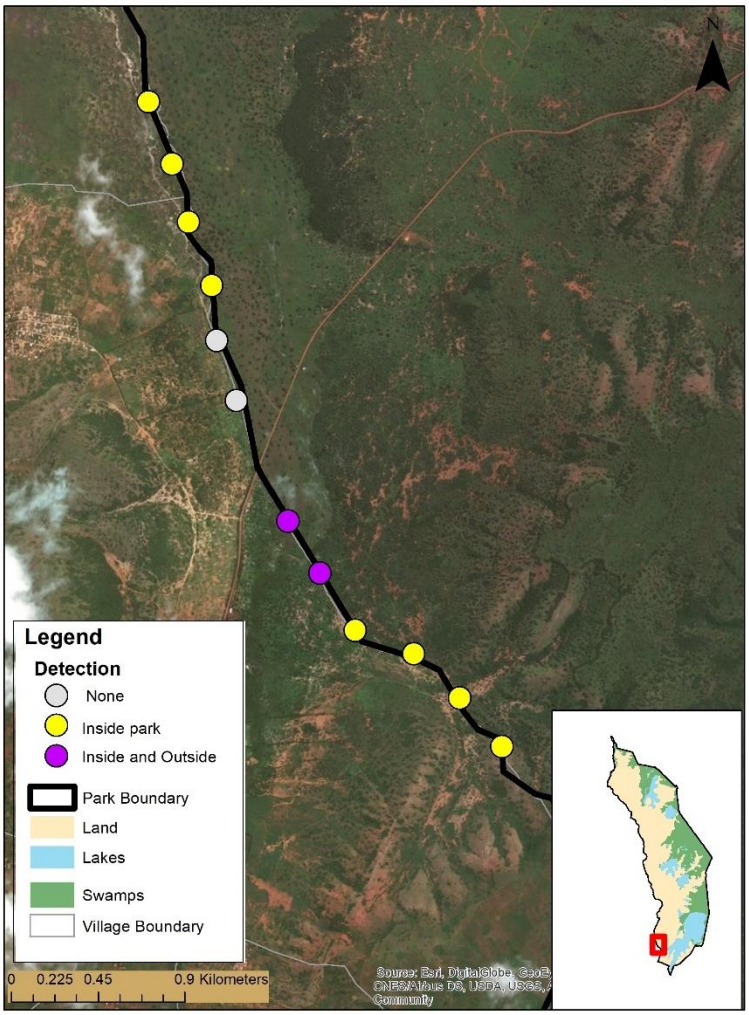
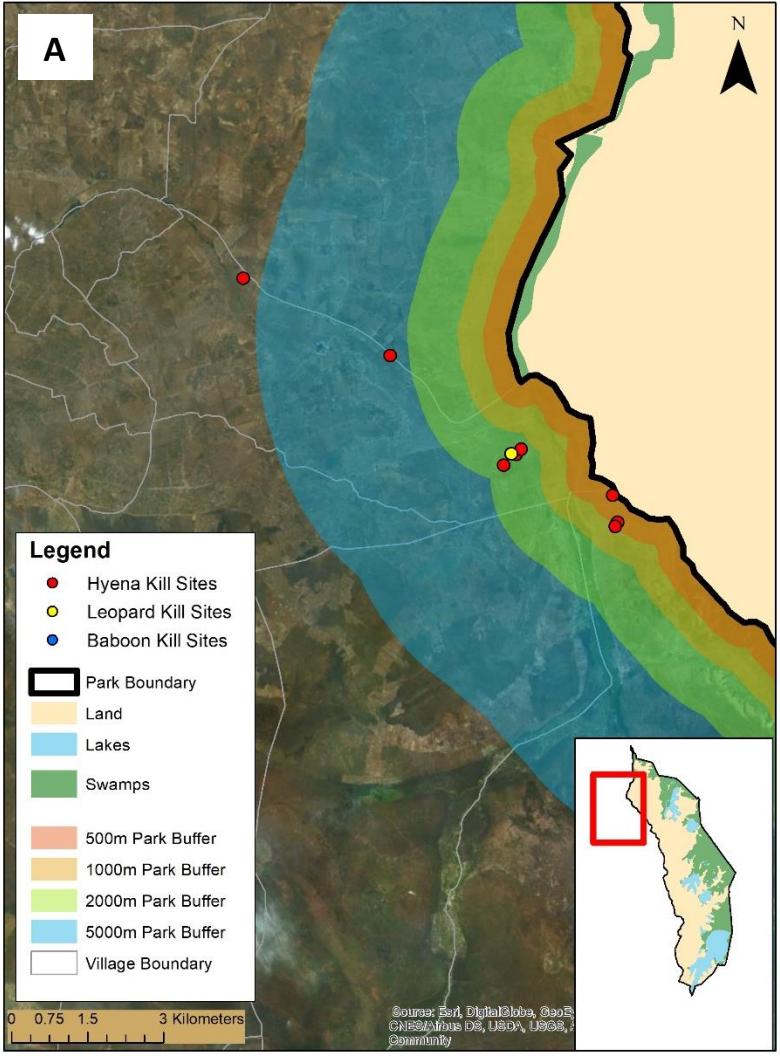


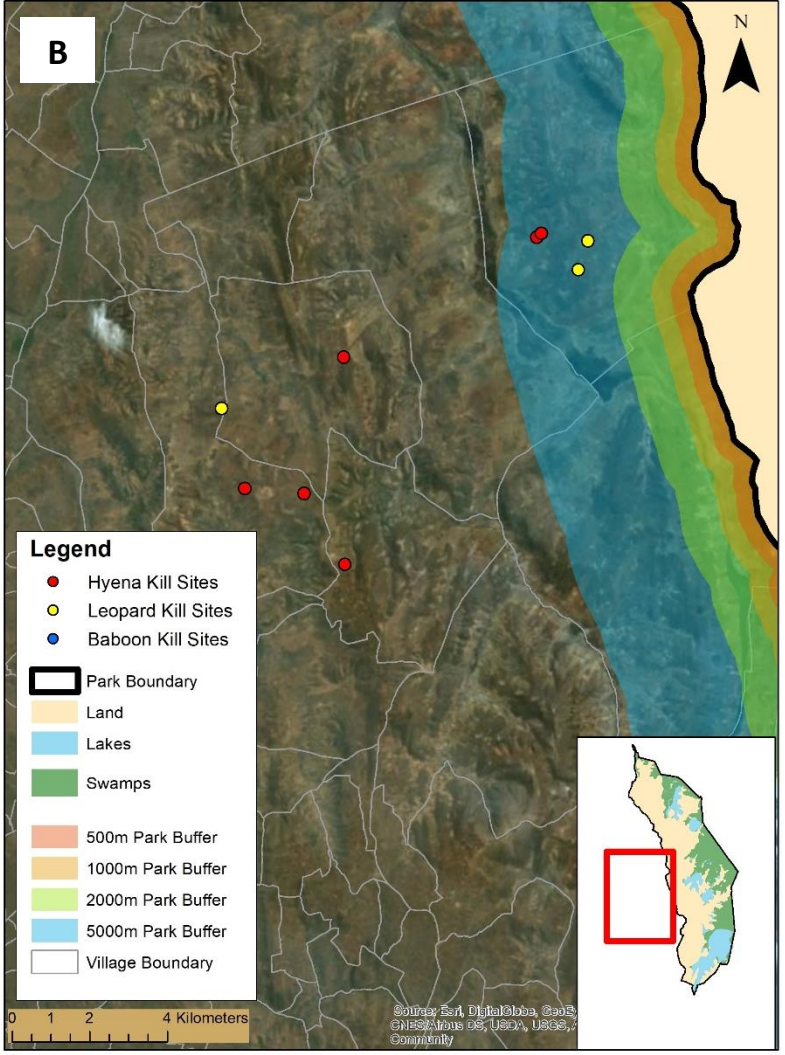
Figure 15. Map showing detection of leopards inside and outside the park at camera sites along the southern fence line. Two cameras had no captures.

Hyenas and leopards in the communities: We interviewed a respondent that trapped two hyena babies in his trap. Hyenas are active and reproducing outside of ANP. We collected data from 111 total kill-sites and hyenas accounted for 95 kill-sites (Figure 16 A, B, C). We found goats to be the most preyed upon livestock (43%) with cattle being a close second (37%).

We identified 26 trap-sites with 10 unique hyena captures (Figure 17). We found traps in a diverse range of landscapes and some in bushes to disguise them from both wildlife and humans. Specific community members concentrated traps on their properties, because they were responsible for maintaining the. Traps material was either metal or wood (Image 2). Community leaders informed us that ANP assisted with the purchase of the 3 metal traps we identified. No metal traps captured any wildlife. A total of 5 out of 26 traps were successful in capturing 10 hyenas. All animals captured were hyenas and they were captured at night. ANP took each hyena and relocated it inside of the park. The park compensated each farmer responsible for the capture. Traps were mostly lack of success in capturing any carnivores. The caretakers of the traps did not maintain, bait, and check the trap frequently. This caused the unsuccessfulness of the traps. Damaged traps are useless for capturing wildlife. Humans caused most of the damage to the wood traps; Locals stole the wood of the trap for fuel wood. We suggest moving to metal traps to avoid this kind of damage.

Despite the 95 hyena kill-sites, we did not discover any active hyena dens. It is possible that we identified seasonal dens, since hyenas are known to have many den sites across their home ranges (Figure 18, Image 3). We propose using camera traps near these identified hyena den sites to see if these dens are indeed seasonally used or not used at all. Once we identify active hyena dens, metal traps would be placed near the den site. Metal traps last longer and would subject to less risk of damage by humans. We suggest communities implement more traps in their villages and designate specific people to check the traps frequently. ANP and the communities should support the increased effort of trapping hyenas and other wildlife.





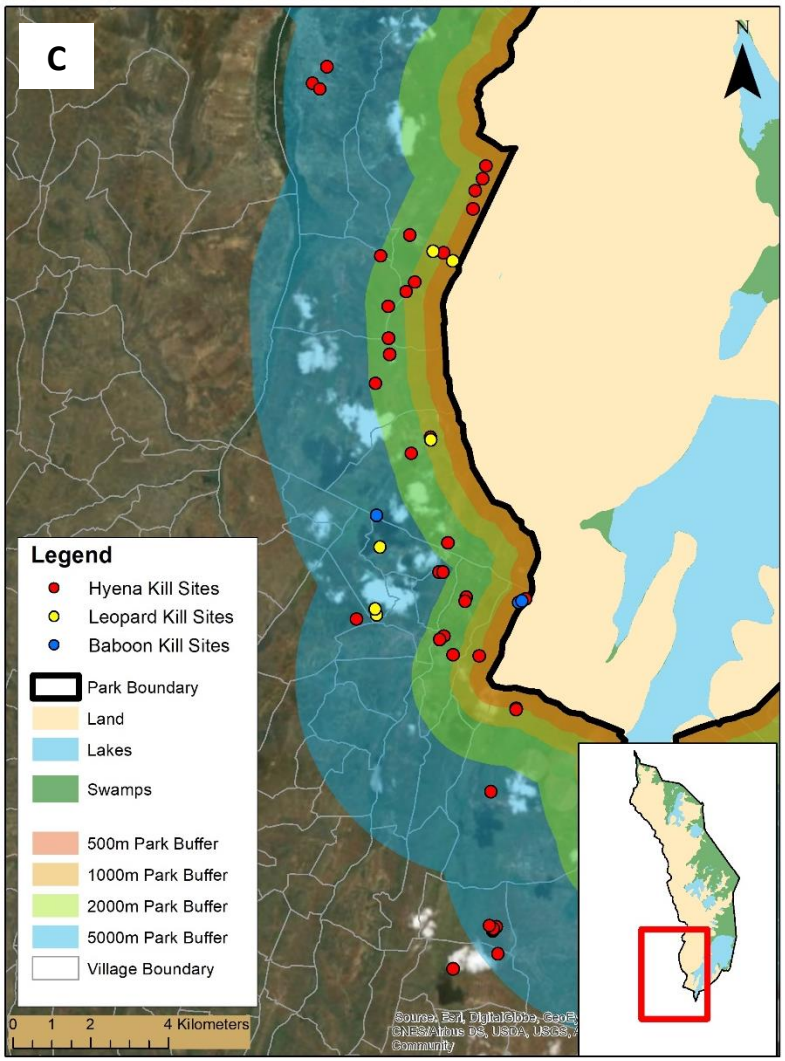


Figure 16. Geographic distribution of kill sites around Akagera National Park. Colored bands indicate the distance from the park boundary that the kill occurred, up to 5km. Kill site maps are split into North (A), Central (B), and South (C) along the park boundary.

Image 2. Wood (A and C) and metal traps are deployed in the communities around Akagera National Park.

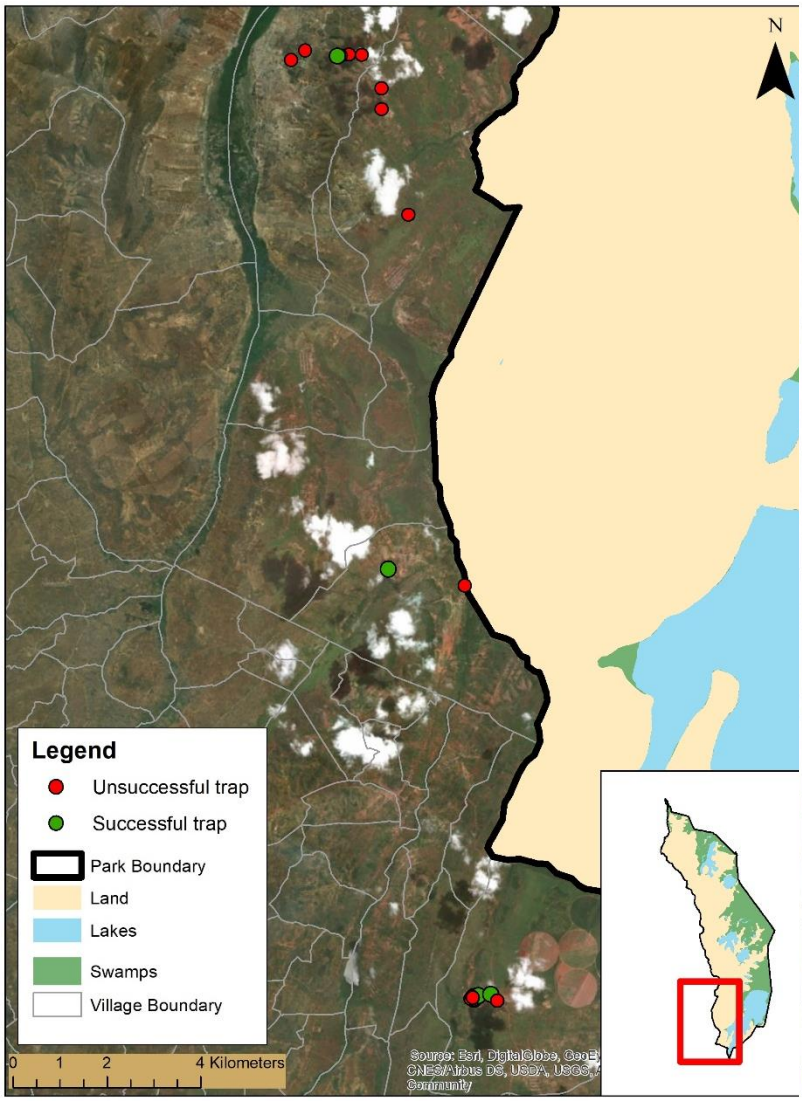


Figure 17. Successful and unsuccessful trap sites around the southern part of Akagera National Park.

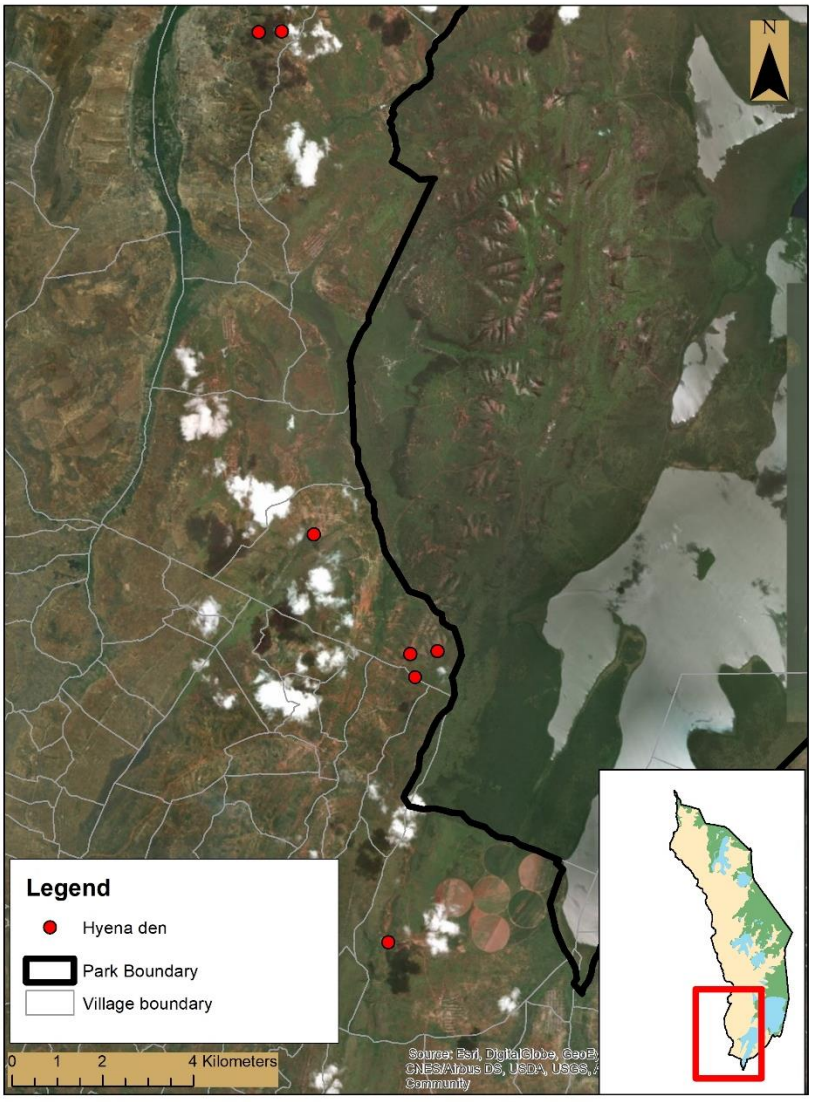


Figure 18. Hyena den sites around the southern part of Akagera National Park. All dens identified were either seasonal or old.

Image 3. Seasonal or old hyena dens. We did not discover any active dens. We recommend using camera traps to differentiate seasonal from old, unused dens. The notebook in the photo is for scale.

Next steps and recommendations

Wildlife outside Akagera National Park: According to our results, few if any terrestrial large-bodied mammals are leaving ANP to cause damage in neighboring villages. Even as far as 13 km from ANP we recorded abundant signs of hyenas, as well as periodic reports of leopard predation on livestock. Clearly these two large carnivore species live and breed outside the park. Meanwhile, arboreal mammals such as baboons are crossing the electric fence at several points and may be using ANP as a refuge from which to foray into farms. We assume that baboons and other herbivores would be an even more serious problem for farmers if there were fewer wild predators outside ANP and we would be willing to design a study to test the assumption. We recommend predator populations on both sides of the fence be protected into the future, both to respect the Rwandan constitutional provisions and for ecological reasons including to help reduce baboon abundance or boldness. The potential benefits of predators for controlling baboons and other crop-damaging wild prey could be mentioned by community liaisons and ANP staff, when discussing hyenas and leopards, to avoid aggravating public opinion of predators (Meriggi & Lovari, 1996).

Not surprisingly, official records indicate buffalos and hippos are the most dangerous species to humans directly. Such incidents were relatively rare (30 of 737 total complaints from ANP records, including eight deaths (all from hippos and buffalo) and 22 injuries (from buffalo, hippo, leopard, baboon and bushbuck). None of the 85 residents we interviewed reported suffering injury or loss of a family member to wildlife. Yet due to the tragic nature of such events and their importance in shaping perceptions of wild animals and ANP, careful planning is warranted to reduce future such events. We recommend efforts to scare wildlife or relocate wildlife found to approach people in a manner suggestive of habituation or lack of fear. Warning signs could be posted in particularly dangerous places (e.g. hippo-frequented land). If there is evidence that the same individual animal is implicated in multiple attacks on people, euthanasia may be necessary.

Concerning prevention of wildlife damage, during interviews virtually everyone reported they took steps to protect their property. The lone exception was a man reporting hippo and buffalo damage who said he would climb a tree and just watch the animal damage his house. Otherwise, we found the most common practices were guarding, dogs, fencing with thorns or wire, and inexpensive visual deterrents. Regarding defenses against hyenas and leopards, respondents reported an average of 3.1 defense strategies (range 0–7), with the top three most common defenses being guarding (65%, of which the majority did night guarding), boma/kraal among 54% of respondents and dog (41%) (n=85). Other defenses include fire and barn shelter (36% and 38% respectively)), fence with 24%. Four individuals reported using lights or live traps. We recommend additional targeted research to discern which of these methods are functionally effective in preventing damages and under what conditions or designs. The results of such research might then be added to the community liaison toolkit outreach messages or material contributions to communities. Eventually effective defenses could be a condition on compensation payments, particularly for chronic loss sites.

More generally, we commend ANP on its efforts at engagement with communities outside the park and its many varied efforts at outreach. We recommend community outreach be continued with one possible addition, targeted community listening sessions, in which concerns and suggestions are heard on a specific topic. While it is tempting for knowledgeable staff to speak more and listen less at such

events, this should be avoided. Even when misinformation is aired by community members, it provides ANP with information and should not necessarily be squelched because local perceptions often matter as much as actual losses. But two important caveats – i) previous research shows that HWC complaints are amplified in large group discussions (Naughton-Treves, 1997), ii) listening sessions will be more productive when they focus on one or two issues and seek actionable information– e.g. feedback on the protocol for compensation or recommendations for reinforcing kraals. Indeed, if ANP is considering a new policy or practice, consultation via focus groups is advisable. By contrast asking participants to list everything they don't like about the park risks opening the conversation to all discontent with governance and authority in the region. Accordingly, a focus group with village leaders (umudugudu) plus other key community members would be wise. Varied representation is key in any meeting, e.g. include women and those with both large and small landholdings, many and few livestock, etc.

Compensation: It is widely accepted that compensation programs are less prone to corruption when a third party is responsible for making the payment. Thus the fact that SGF is not involved in field verifications appears to be a sound design. But in the long run, ANP managers will be better able to work with communities if they receive the full information on payments from SGF as indicated by statute (see Appendix noting this rule). Full reporting is especially important in the case of multiple significant payments to individuals (e.g one resident appears to have received 5,300,000RWF (US$6,000) over three years for fourteen complaints). Similarly, the possible existence of >1,000 wildlife damage payments in the Eastern Province during the study period without ANP knowledge deserves further consideration (see Appendix 1 for details). Experience from other sites show that once compensation is initiated it is difficult to reduce or repeal. Controversy over payments has even led to proposed degazetting of some protected areas and threats of retaliatory poaching. Given the political sensitivity, we recommend ANP seek to know as much as possible about past and future payments. Moreover, ANP is well-placed to make suggestions on how to improve the SGF program and all parties' compliance with statute. For example, two interventions used at other sites to improve the fairness and efficacy of compensation are:

- Making the claim procedure simpler and less costly, especially for first time complainants.
- Placing best management practices conditions on those with multiple complaints such as reinforced kraals.

The wildlife complaints database documented by ANP is exceptionally clear and thorough. The staff engaged deserve praise. We recommend continuing such thorough record-keeping, especially in light of our related recommendations above.

Looking ahead, we recommend GPS locations be registered during field verification of damage to livestock or crops or in cases of human injury. This would allow the construction of risk maps with greater confidence and in turn, highlight areas to experiment with conflict mitigation technologies or strategies.

As is indicated in the legal code, ANP has the opportunity to promote animal husbandry and crop protection strategies – even as a condition on payment. Experience in many other sites suggests that prevention can save money in the long run. We recommend investment in training and building rural citizens' capacity to defend their property using non-lethal methods, particularly those that require a

lower investment of ANP in staff time or funding than relocation. Moreover, relocation into ANP without marking animals or following their fates might be counter-productive or might face objections on several grounds. Instead, farmer-based, inexpensive methods for non-lethal protection of property, using local materials, might provide a sustainable and long-lasting effect of protecting wildlife and livelihoods if designed scientifically and implemented with substantive local engagement. If animals will be relocated to ANP, we suggest marking and monitoring the individual. If they continue to spend time near humans, they may need to be lethally removed.

Most of the wildlife causing damage appear to be living outside the park. The legal code emphasizes that compensation should be paid for wildlife originating from protected areas. Continuing to pay for hyena, baboons, hippos and buffalo living outside the park may be the ethical choice and/or curry public favor (see interviews). But costs would likely mount if more people decide to file complaints. Nearly all interview respondents reported having losses to wildlife, but only a minority filed complaints. (See Table 1). Authorities ought to deliberate on whether the best course is to continue paying for any animal no matter how far from ANP, nor how many complaints nor what animal husbandry. We recommend phasing in caps of conditions on payments.

No matter what the decision about where and which animals to pay for, targeted outreach to conflict 'hotspots' might improve the thoroughness of the ANP database and broaden the spread of financial restitution to more individuals who claim losses but for various reasons do not file official complaints or succeed in winning compensation for legitimate complaints.

Although conflicts with wildlife appear to be common and of considerable local concern, the majority of respondents indicated they perceived benefits from the park (including road maintenance). Most also held positive attitudes toward flagship species. Many praised ANP for organizing visits for local children. We recommend continued investment in such outreach.

Fence: The fence is popular with local residents, especially those from the southern part of the park. We recommend its maintenance, especially given the abundance of large mammals moving alongside it on both sides of the fence (e.g. elephants on the interior, cattle on the exterior).

The maintenance of the fence thus far seems to have prevented crossings for most wildlife but for some primates and subadult leopards. Looking ahead, we predict elephants and/or other large ungulates might eventually break through, and leopards might jump the fence. Planning for these rare (we hope) events deserves consideration.

Hyenas: A reproducing subpopulation of hyenas exists outside of ANP. Despite only discovering inactive den sites, 95 verified kill sites and two cubs brought to ANP corroborate our indirect findings that hyenas reside in many areas and reproduce outside ANP. We describe attributes of hyena traps and recommend switching to all-metal traps, although these had not yet captured hyenas as of July 2018.

Relocating hyenas that were born and acclimatized to foraging in communities could have counterproductive effects. We recommend discussion of several alternatives and would be happy to participate in such discussions. If relocated animals continue to spend time near humans, they will likely need to be lethally removed.

Future directions for research: We would be happy to contribute to plans for further research on any of the following topics that we perceive as high priority.

Human-dimensions research: While it often seems that national parks containing large mammals need research on wildlife, we recommend adding to it with additional investment in research on human dimensions. Such research should focus on neighboring communities, especially on the following:

- motivations and participation in poaching;
- a spatially-explicit survey of protections for property in place and desired by neighboring community members;
- evaluations of the effectiveness of current methods for protecting property and evaluations of effectiveness of enhanced methods (local methods improved in some way); and
- perceptions and empirical measures of property damage before and after interventions.

The SGF program is still young. It might be timely to convene a special forum for Rwandan protected area managers about experiences with compensation with an eye to making adjustments to improve the sustainability and efficacy of the program. Again, we'd be happy to share results from ANP and from other sites where we've evaluated compensation.

Experiences elsewhere shows that both enforcement of anti-poaching rules and investigation of poaching patterns are essential within and outside protected areas. Anti-poaching activities outside the park are of course subject to different laws and rules of engagement, but may help address problems within the park.

Wildlife research: We recommend continuing the campaign we began of deploying trail cameras along the length of the fence inside ANP, but oriented to also capture wildlife moving along the fence outside of ANP if at all possible. The goal would be to monitor fence crossings, detect if predators are using the fence to corner prey, and inventorying large mammals outside ANP for possible intervention. We recommend placing such cameras in a manner that allows detection of arboreal mammals using large trees to cross the fence-line. An ancillary benefit of such a camera campaign might be to enhance anti-poaching efforts.

We also consider wildlife research within ANP to be important within the context of our topic of human-wildlife interactions. For one, poaching within ANP deserves analysis. Possibly, a historical analysis of records would both inform managers now and showcase the successes of ANP. If such an analysis were done scientifically and published, it might add credibility to arguments for continuing the past patterns of investment in anti-poaching efforts. Again, trail cameras seem useful to inform park managers about changing patterns of poacher activity, identify important wildlife that are susceptible to poachers, and help to define when and where to intervene. Furthermore, we recommend continuing the efforts to mark and monitor lions, so managers can understand their use of fence-line areas. We recommend additional attention be directed to leopards, particularly in a handful of locations that seem to be associated with fence crossings. Adding leopards to the list of important species for monitoring obviously entails trade-offs, so we would be happy to discuss low-cost methods for identifying individual leopards and monitoring their movements in a less-intensive way than the monitoring of lions.

Appendices

Appendix 1: Key rules for compensation and sharing compensation records according to:

(I) Official Gazette No. 25 of 18/06/2012 on the Law N° 52/2011 OF 14/12/2011 Establishing the Special Guarantee Fund for Accidents and Damages caused by Automobiles and Animals (SGF) and determining its mission, organization and functioning (downloaded 20/1/19 from http://www.rlrc.gov.rw/fileadmin/user_upload/Laws/) and

(II) the Prime Minister's Order Nº26/03 of 23/05/2012 Determining the rates, calculating method and criteria for determining compensation to the victim of damage caused by an animal (downloaded from http://www.minicom.gov.rw/fileadmin/minicom_publications/law_and_regurations/Compensation_Law_J_O_34_22Aug2011.pdf)

What wildlife are covered?

[..] *any animal on the list established by an Order of the Minister in charge of conservation of National Parks or any animal from the National park according to the list of animals in those national parks encountered outside the park or outside another protected area.* (Article 1).

Who verifies claims and what is the timeline?

Any damages caused by the wild animals must be reported to the Executive Secretary of the Sector where the accident took place within a period not exceeding seven (7) days [..]he/she shall call upon a committee[1] *to confirm the damaged property within five (5) working days to the place of the event and make a report thereof. That committee meets at least when the 3/5 are present. The expert immediately makes the report that shows the damaged property and its value, that report shall be annexed on the statement. The said report shall be submitted to the Sector authority within three (3) working days from their visit to the place of the event, the victim must get the report free of charge, and the victim shall submit the report to the compensation authority before expiration of the duration stipulated by law. [..]* Upon receiving all compensation request letters, and where compensation request is valid, the compensation awarding department shall, in a period not exceeding thirty (30) working days, clearly explain to all interested persons modalities for awarding compensation, including relevant figures. [..] With regards to transport cost, they shall recover the money spent once to follow up their case with the Fund and transport fees paid on the day their compensation is awarded, based on public transport rates applicable in the country. *(Article 12)*

[1] *The committee that approves damages caused by the animals shall be composed of 1° The representative of the Police in the area where the accident took place; 2° The head of the village where the accident took place; 3° The Executive Secretary of the cell where the accident took place; 4° The Executive Secretary of the sector or his\her representative; 5° A representative of the institution in charge of park management in that area.* (Article 5).

Are there restrictions on payments?

Any person that applies for compensation for damaged property who did not prevent the animal from causing damages according to the written regulations of the park, shall lose his\her right to compensation. […] *any person who is himself/herself the cause of an accident or injury inflicted to him/her by an animal because he/she overstepped the authorized area, or provoked the animal.* (**Article 24).**

Official rules information sharing about compensation

> *SGF shall notify the agency in charge of national parks about the amount of money paid in relation with to such files for refund within a period of one (1) year from the date of notification. (Article 30 in* CHAPTER VII: TRANSITIONAL AND FINAL PROVISIONS of LAW N° 52/2011 OF 14/12/2011 ESTABLISHING THE SPECIAL GUARANTEE FUND FOR ACCIDENTS AND DAMAGES CAUSED BY AUTOMOBILES AND ANIMALS (SGF) AND DETERMINING ITS MISSION, ORGANISATION AND FUNCTIONING

Additional details: The possible existence of >1,000 wildlife damage payments in the Eastern Province during the study period without ANP knowledge deserves further consideration. According to a newspaper report of an interview with the SGF Director, between Jan 2013 and Aug 2017, SGF paid 5,189 wildlife-related claims in Rwanda, over half (2,648) of which were from the Eastern Province, home to Akagera National Park (Dr. J. Nzabonikuza, in *New Time* 2017, download https://www.newtimes.co.rw/section/advertorial/999). Given that the ANP has records of only 738 compensation claims for an overlapping 3 year 10 month period apparently there was a significant amount of livestock and crop lost in the Eastern Province far from Akagera National Park.

Appendix 2: Questions used in field interviews, June 2018

Date (day/month/year):_____ Name(s) of interviewer(s)_____ Cell:_____Village _____

Section A. Who is the respondent and what experience has he or she had with conflict and compensation?

Name of respondent _____M __ F ___ GPS at site of interview: S°01._____ E°030._____
Name of official complainant (if respondent is not the official complainant) _____

Name of land owner (if respondent is not the official land owner)_____

A1. Has there been any wildlife damage to crops or livestock on this property the past three years?

____YES to crops ___ YES to livestock ___ (if YES for either, go to Question A2)

____NO (if no, go to section D)

A2. Did you or the owner make an **official complaint** to request compensation?

____YES for crops____YES for livestock (if YES for either, go to Section B)

____NO. If NO, proceed to section C.

Section B for people who registered an official complaint (or their relatives or the caretaker of their land)

B1.Are you the official complainant? ___Yes___ No_If no, how are you related to complainant?____ relative ____caretaker ____other

B2.How many official complaints have you or the owner made for this land in past 3 years? _____Livestock _____ crops

B3. Tell us about your experience with official complaint and compensation process, starting with most recent (up to 3 claims)

Month, Yr of incident	Type of wildlife	Type of loss	Were you paid? Yes/No	If yes, how much paid?	If not paid, why not?	If paid, was it enough?	If not enough, why not?	How long did you wait to be paid? (from time of incident) circle
		Crop/Livestock	Y/N			Y/N		<6 mo, <1yr, 1-2,
		Crop/Livestock	Y/N			Y/N		<6 mo, <1yr, 1-2,
		Crop/Livestock	Y/N			Y/N		<6 mo, <1yr, 1-2,

_____

____

Section C. for ANYONE who says they had A LOSS (whether or not they officially reported it).

C1. If you did not register a complaint, **why not**?

_____

_____

____

C2. In the past 3 years *how many total incidents* have you had of:

crop loss _____
goat loss: _____ total incidents. #1:____ lost of____ total; #2:____ lost of____ total; #3:____ lost of____ total
cattle loss: _____ total incidents. #1:____ lost of____ total; #2:____ lost of____ total; #3:____ lost of____ total
human injury _____

Now tell us about the ONE **most recent unclaimed (not reported**) incident:

C3.What month and year did it happen?_____ (or *season* and year if can't recall month)

C4.What wildlife did damage? baboon bushpig buffalo hippo leopard hyena other_____

C5. If livestock damage: _____# of Cows injured or killed, _____# of goats injured or killed

C6. If crop damage: Crop type damaged_____

C7. If human injury, please describe_____

Section D Background information for everybody

D1. Does the owner live directly on this farm? Yes or No (if no, circle: nearby village, Kigali, elsewhere in E Province)

D2. When did the owner acquire this property? _____ years ago, or _____ don't know

D3. How big is this property (*just your household*)? <1 ha, 1-5 ha, 5-10 ha, 10-15, 15-25 ha, if >25 ha, amount? _____
Do you own any property elsewhere? Y N
If family members live nearby, how much do you **together** own? 1-5 ha, 5-10 ha, 10-15, 15-25 ha, if >25 ha, amount? _____

D4. Which 2 crops cover the greatest area on your property? gnuts, sweet potatoes, sorghum, maize, cassava, rice, bananas, beans, other _____

D5. How many livestock do you own in total? Cows: <5 animals, 5-10, 10-20, 20-40, 40-60, >60, Goats: <5 animals, 5-10, 10-20, 20-40, 40-60, >60

D6. Wealth indicators (circle all that apply *for household or respondent*): bicycle? cell phone? smart phone? motorcycle? woodlot? pays people to work on farm? family member has job off farm (occasional? Steady?) owns shop? owns bar?

Ignore this next question UNLESS the respondent is NOT in the owner's family, then also record: Wealth indicators *for owner* (if respondent not owner): bicycle? cell phone? smart phone? motorcycle? woodlot? pays people to work on farm? family member has job off farm (occasional? Steady?) owns shop? owns bar?

D7. Highest education of anyone ***in whole family*** none? Primary? Secondary? technical college? University?

D8. Is anyone in your household employed with the park? Yes No if yes, what job? _____

D9. Wildlife frequency/strategy

Wildlife	How often visit this property?	Day guard	Night guard	Dog	Fire	Fence	Any live trap on land	Kill	Barn?	Shelter?	Boma or kraal
Baboons	Daily, weekly, seasonal, monthly, yearly, almost never										
Bush pigs	Daily, weekly, seasonal, monthly, yearly, almost never										
buffalo	Daily, weekly, seasonal, monthly, yearly, almost never										
hippo	Daily, weekly, seasonal, monthly, yearly, almost never										
leopard	Daily, weekly, seasonal, monthly, yearly, almost never										
hyena	Daily, weekly, seasonal, monthly, yearly, almost never										

D10. Which animal are you most worried will come to your farm?

_____Why?_____

D11. Is there a crop or livestock you cannot grow because of wild animals? Yes No Which? _____

D12. Is there a part of your farm you cannot use because of wild animals? Yes No Not sure

D13. Does (or *would)* receiving compensation make you feel more tolerant of wild animals visiting your land?

___Yes___ No Explain:

_____

_____

_____

D14. Are there any wild animals you enjoy seeing on your property? Yes No. which ones? _____

Do you enjoy seeing birds? Yes no why?_____

D15. What animal or animals do you feel proud to have living in Akagera Park? (list up to 3)_____

D16. Any benefits from the park? Explain

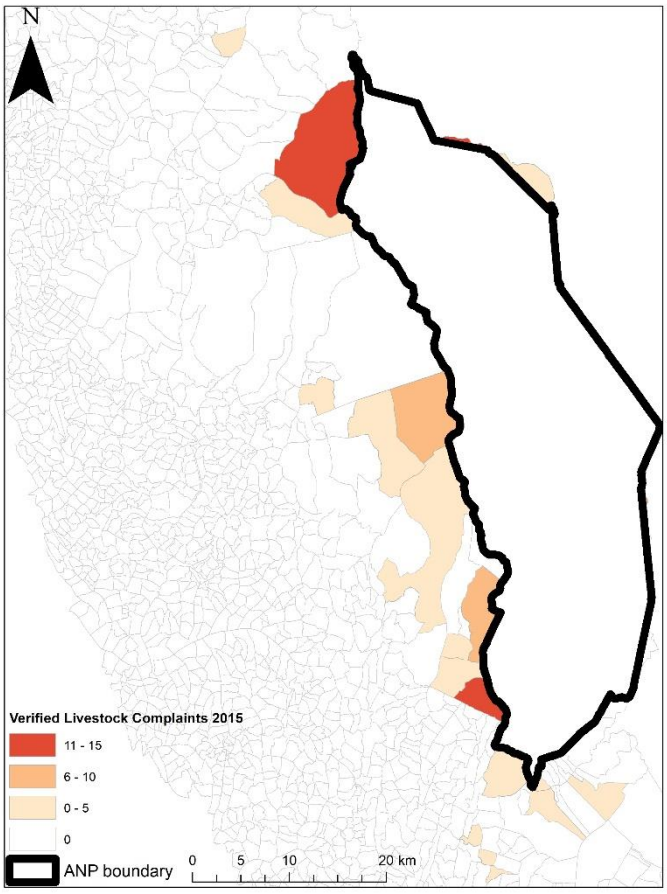
_____

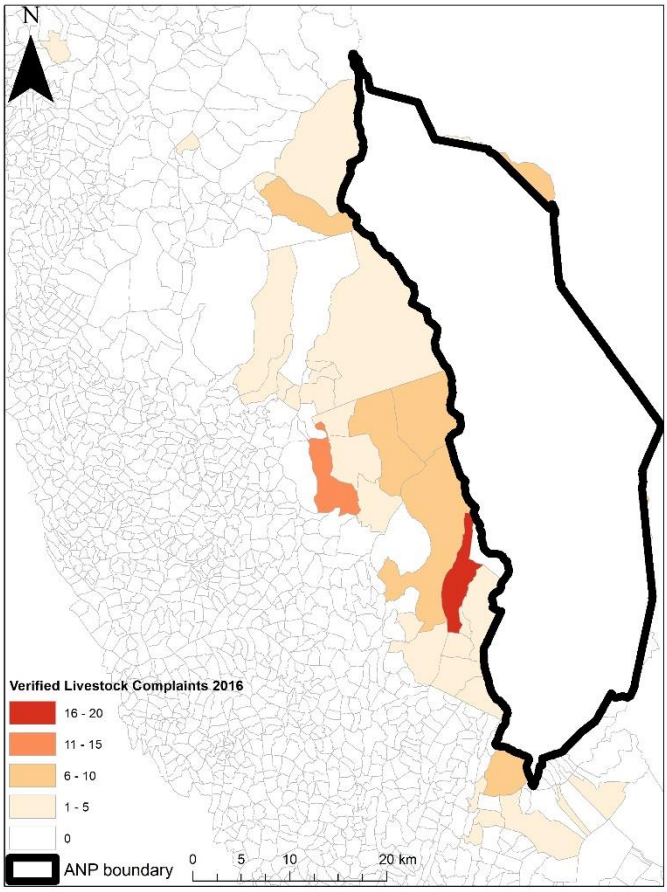
_____

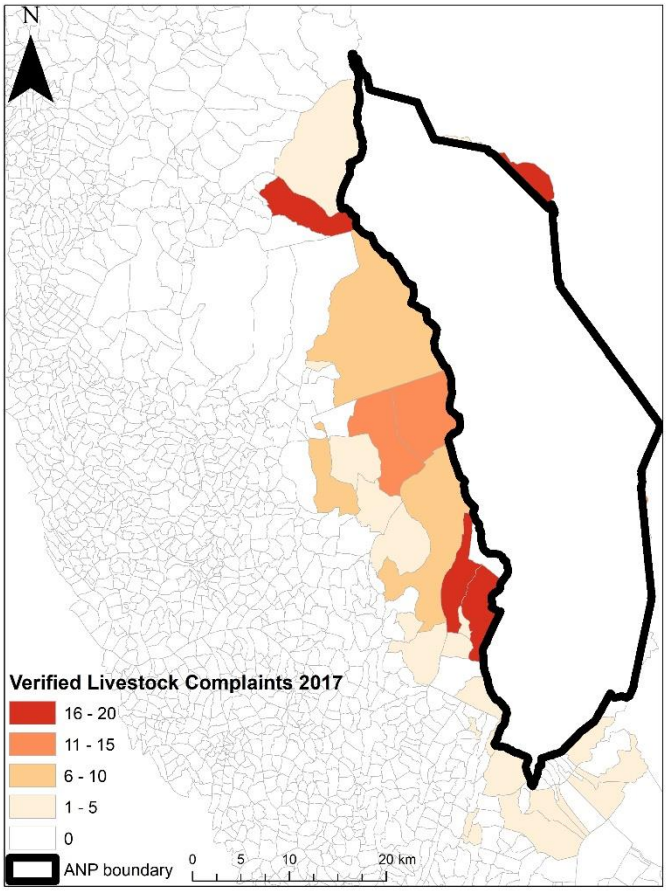
_____

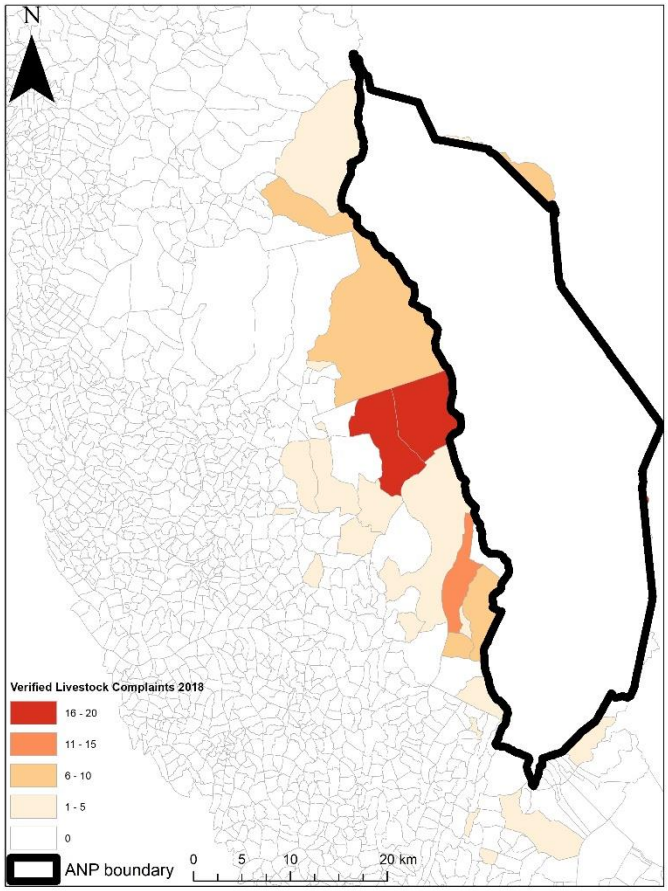
ANY COMMENTS/OBSERVATIONS:

Appendix 3: Geographic distribution of verified complaints about livestock damage by wildlife around Akagera National Park. Rwanda, by year, 2015–2018 by village (background colors estimate the total number of verified complaints by all species, as per the legend).

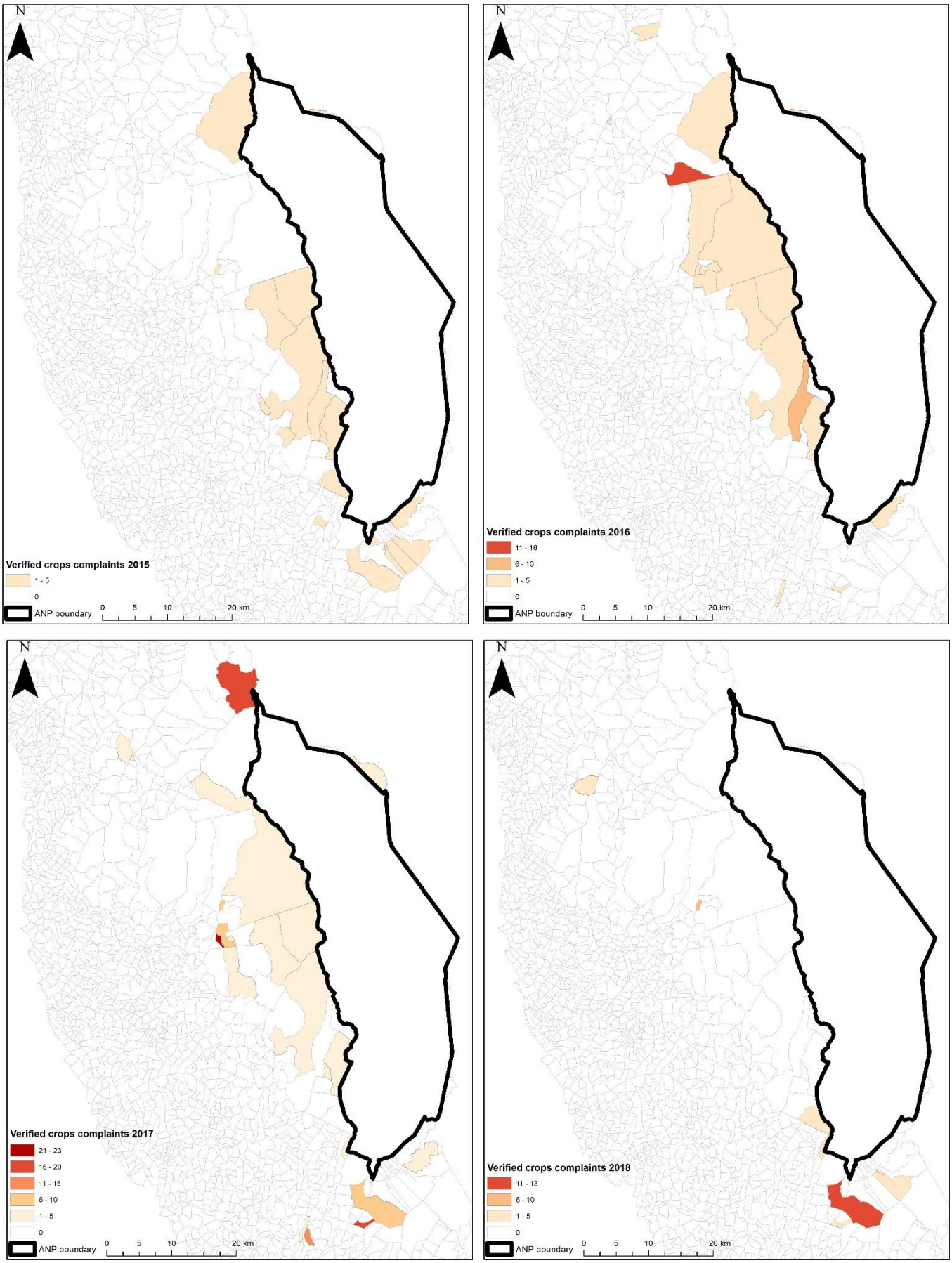




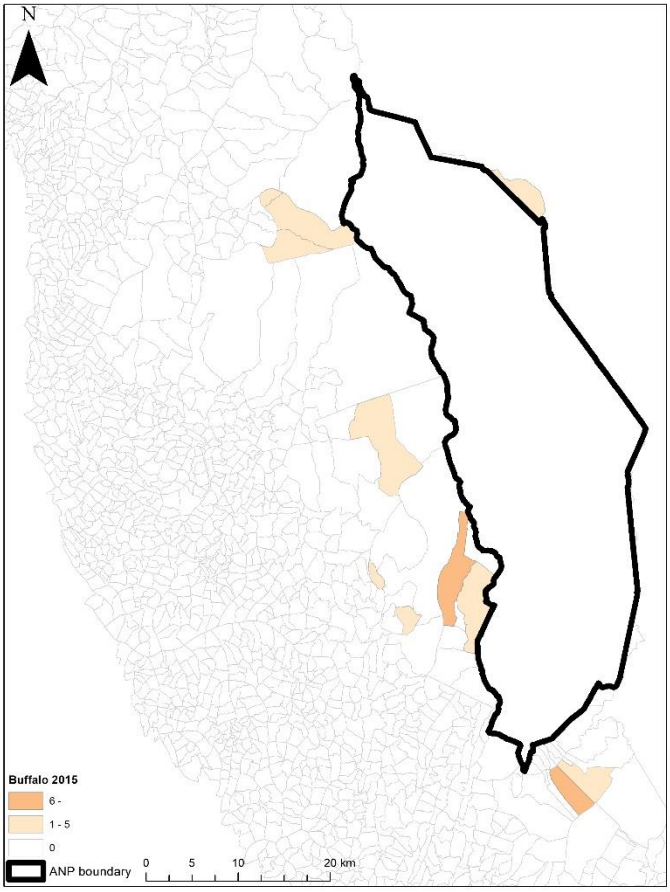


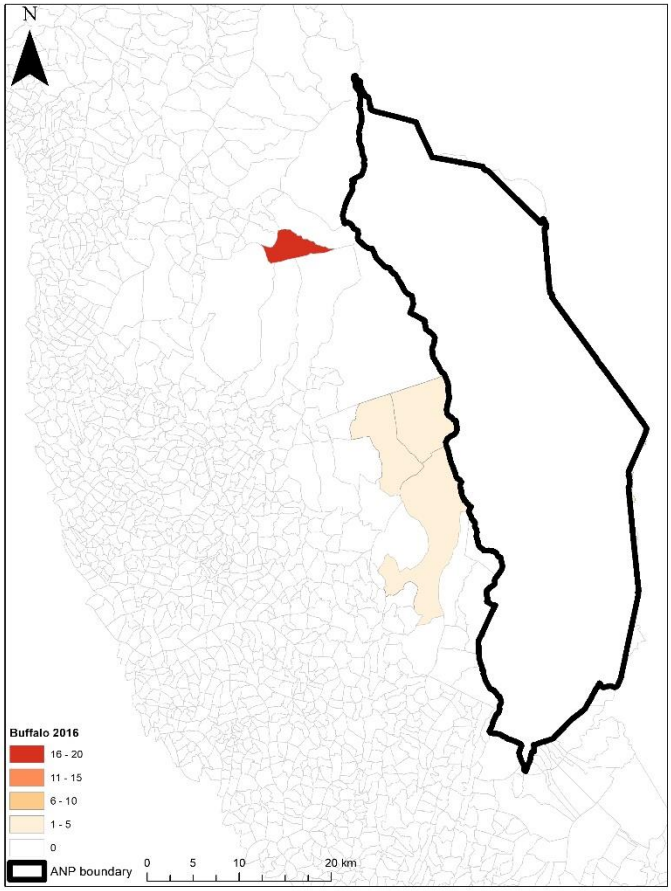


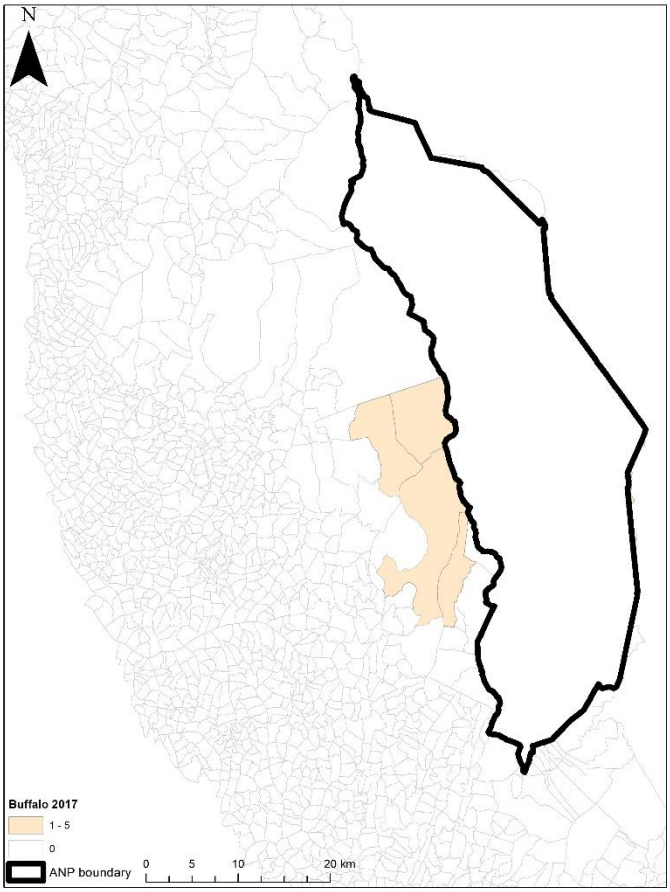
Appendix 4: Geographic distribution of verified complaints about crop damage by wildlife around Akagera National Park. Rwanda, by year, 2015–2018 by village (background colors estimate the total number of verified complaints by all species, as per the legend).



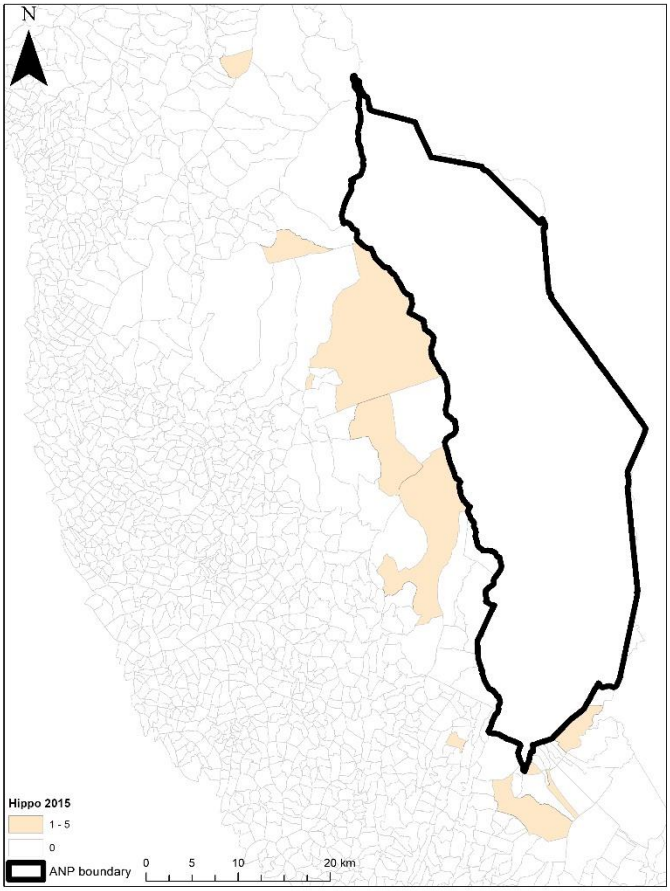
Appendix 5: Geographic distribution of verified complaints about crop damage by buffalo around Akagera National Park. Rwanda, by year, 2015–2017 by village (background colors estimate the total number of verified complaints by all species, as per the legend). There were no verified complaints in 2018.

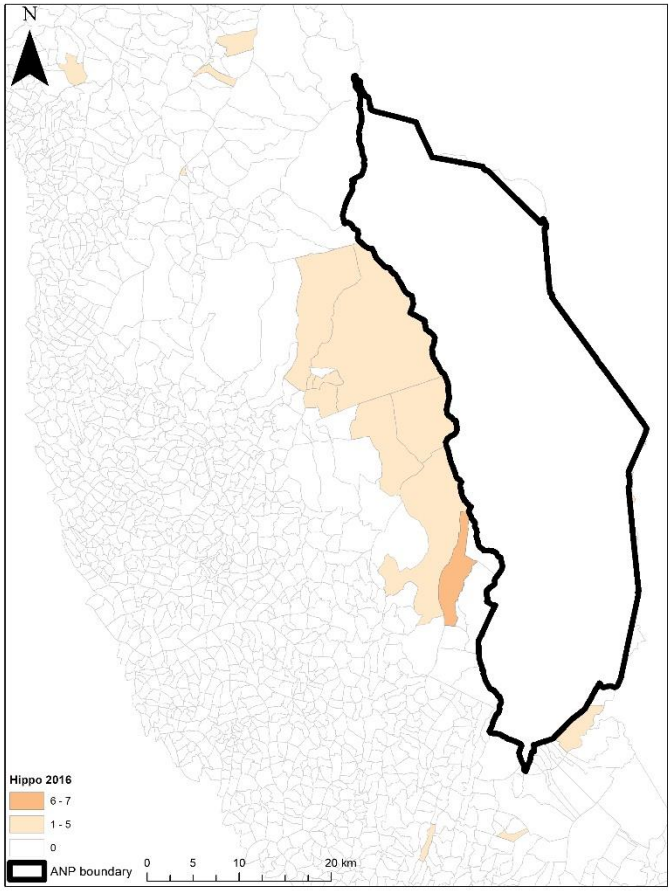


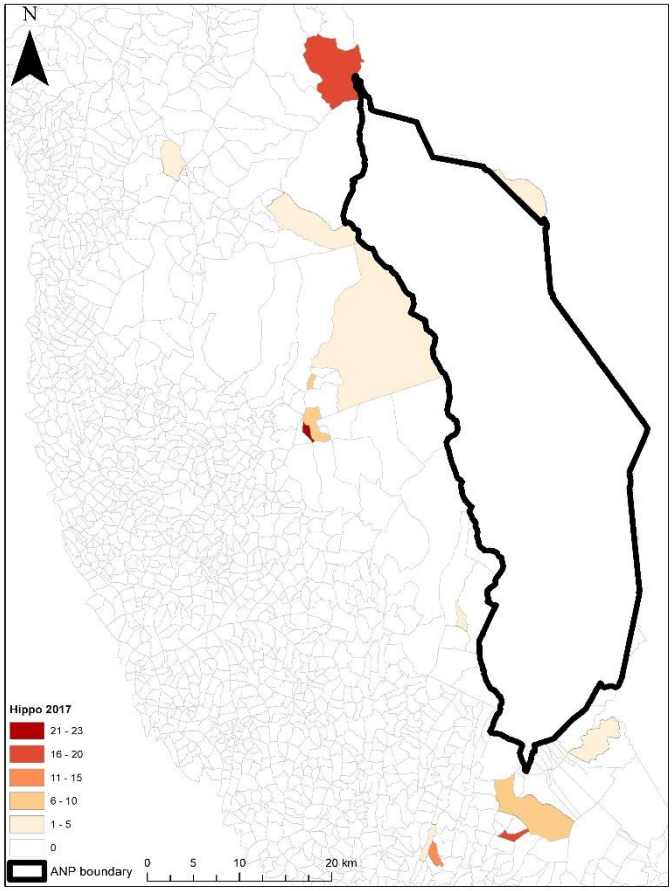


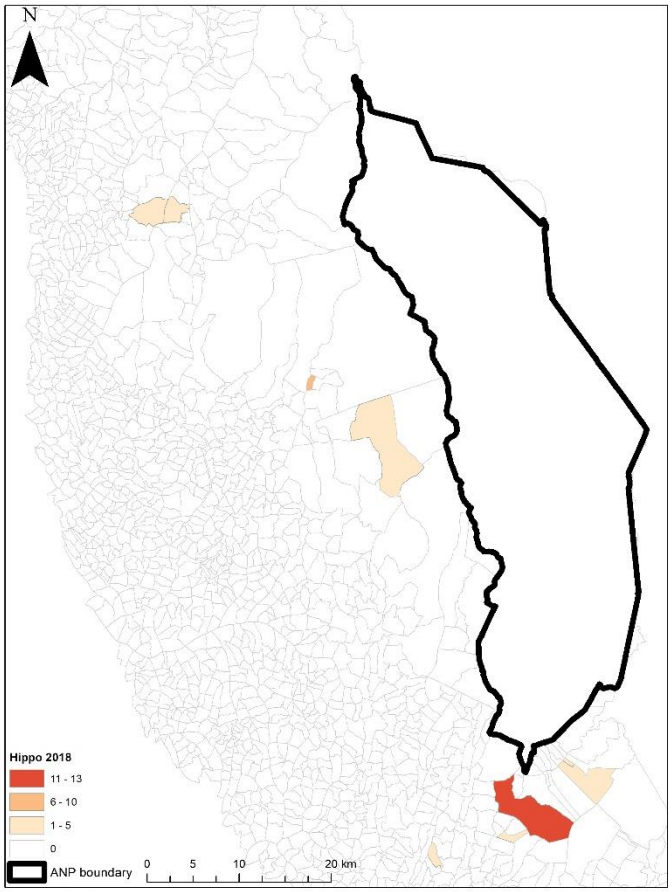


Appendix 6: Geographic distribution of verified complaints about crop damage by hippo around Akagera National Park. Rwanda, by year, 2015–2018 by village (background colors estimate the total number of verified complaints by all species, as per the legend).

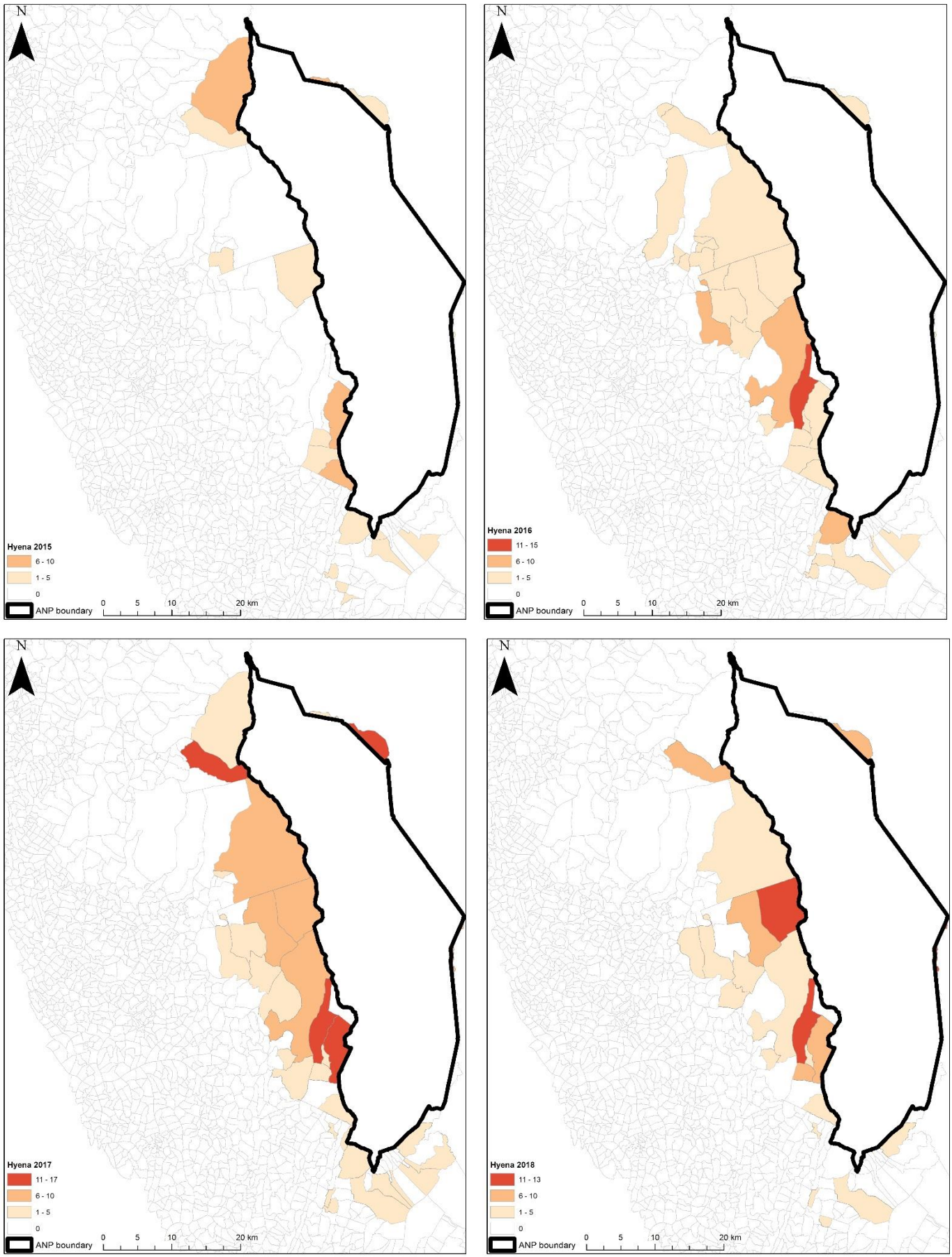




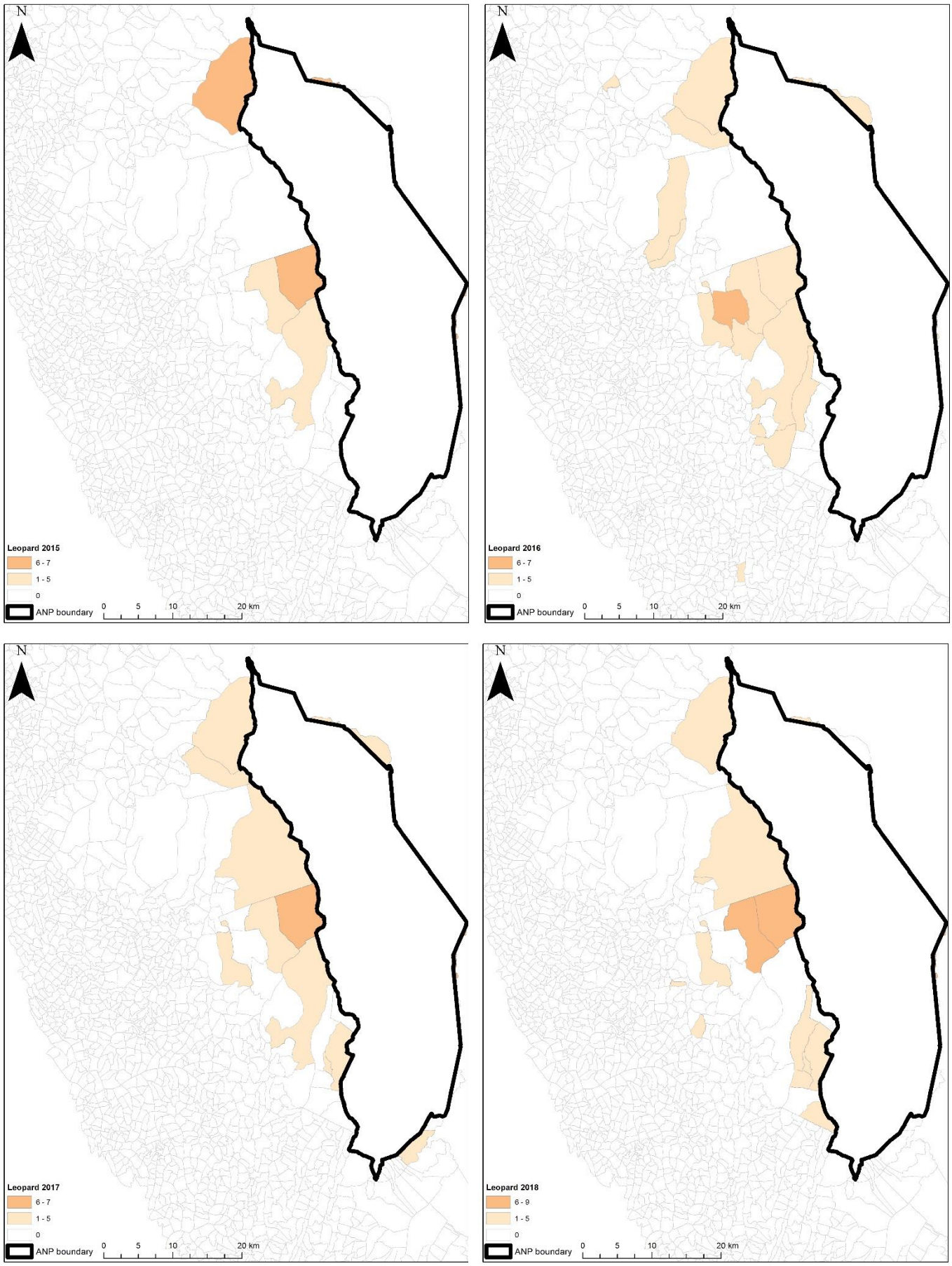




Appendix 7: Geographic distribution of verified complaints about livestock damage by hyena around Akagera National Park. Rwanda, by year, 2015–2018 by village (background colors estimate the total number of verified complaints by all species, as per the legend).

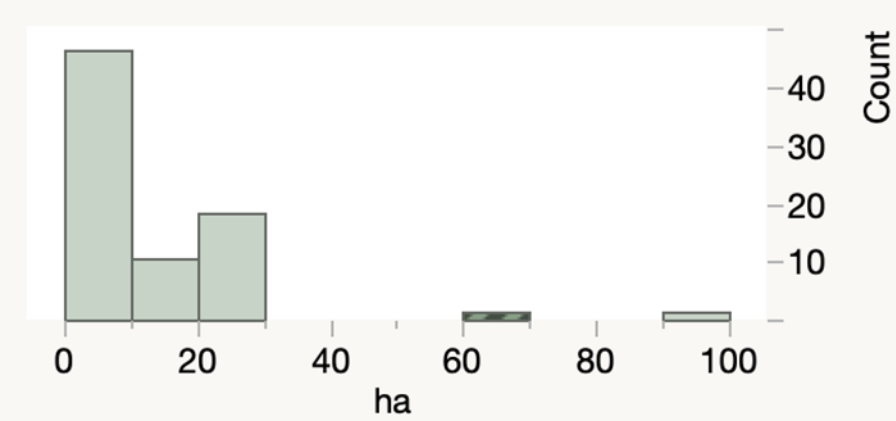


Appendix 8: Geographic distribution of verified complaints about livestock damage by leopard around Akagera National Park. Rwanda, by year, 2015–2018 by village (background colors estimate the total number of verified complaints by all species, as per the legend).



Appendix 9. Summary of selected attributes of interview respondents. (A.) summarizes farm size owned by respondents and (B.) summarizes length of residence on the property.

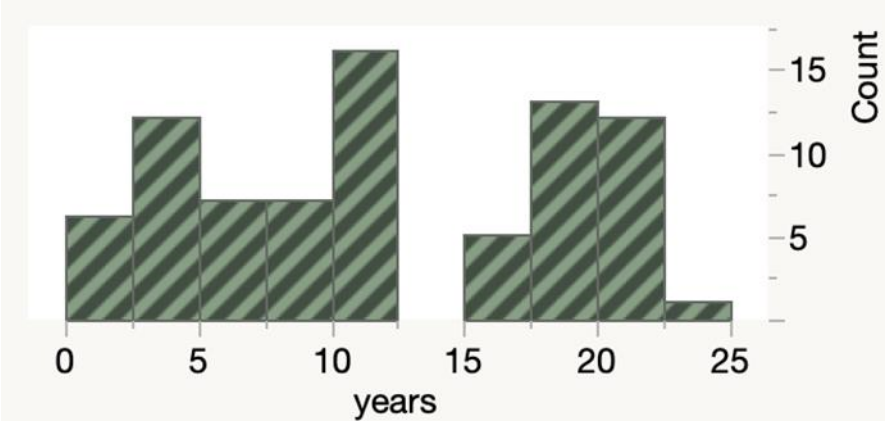
A.



Farm size (ha) is on the x-axis and number of respondents is on the y-axis.

n=76

B.



Length of residence in years is on the x-axis and number of respondents is on the y-axis.

n=79

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