Research Project Update, Unofficial Report

Re: Lion GPS-Satellite Monitoring and Human-Wildlife Conflict Assessment in and around Etosha National Park, Namibia

1 May 2018

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Project Summary

Carnivore populations face threats from increasing human populations and rapidly diminishing, suitable habitat. Large carnivores such as African lions (Panthera leo) commonly attack livestock on lands adjacent to protected areas. This can lead to human-wildlife conflict (HWC) events that result in retaliatory lion killings. Conflict is a primary driver of wild lion population declines which are estimated to have decreased by 43% in the last 20 years. Etosha National Park (ENP) in Namibia is an IUCN designated Lion Conservation Unit and is home to the country's largest surviving and only stable lion population. Lions cross onto farmlands bordering ENP leading to 40 to 50 lions reported as killed from HWC annually. Park officials suspect that HWC events are further increasing each year. Recent social, political and land use changes may be altering HWC reporting in regional offices, causing an artificial decrease in documented HWC events. Combining spatial-statistical modeling techniques can accurately predict future HWC and lion mortality risk by accounting for both present lion population distribution and past conflict hotspot locations around a park. The "conflict risk maps" resulting from these analyses will highlight high priority areas to focus future conservation actions and conflict mitigation strategies, serving to better understand and conserve Etosha and its lions.

Project Status, 01 May 2018

This project uses data from 20 GPS satellite collared lions in ENP and historical HWC event records from around ENP since 1975 to examine lion home ranges and related future HWC risk across ENP's landscape.

- The application of kernel density estimation methods (KDE) was used to study home range area size and utilization of 3 lions with complete, > 1 year datasets, encompassing full wet and dry seasons from late 2016 to present (Fig 1-4)
- Differences in lion home range size and shape were compared for data subsets of various sampling frequency intervals to determine the most effective collar readaing interval. No significant differences to HR size between various collar fix intervals was found (Table 1)
- Lion home range size and shape significantly differed between individuals and within some individuals across seasons. Core areas concentrated around waterholes suggest the importance of water resources and its surrounding vegetation or land use class to lion space utilization patterns (Fig 1-4).
- Setting additional collars and further fix times of active collars to the minimum number of fixes, ~4 hours and no more than 6 a day, may prolong battery life and be economically beneficial to project operations while still maintaining data integrity and accuracy for future analysis.
- Further analysis of home ranges for all other collars will occur as they record complete datasets within the next 1-2 years. Using Time local Convex Hull (T-LoCoH) home

range methods may reveal individual, fine-scale space use patterns. Completing KDE method home range estimates for all other collars will highlight broad-scale home range estimations

- Human wildlife conflict data indicated a lack of accurate data reporting beginning in 2005 in ENP and regional office records, making HWC estimates unreliable 2004-2010, absent from 2011-2014, and severely underpopulated with confirmed HWC vs. mortalities from 2015 to present date.
- Confirmed HWC numbers show a fit to a steadily increasing curve for number of HWC events over the past 40 years, despite the data gaps. Average number of lions killed per year = 22, ranging from 2-71 events annually from 1975-2017.
- Almost 80% of HWC incidents in the last 40 years have occurred on Commercial game/livestock farms. Almost 5% of recorded incidents have lacked the geographic specificity to determine the HWC event's location or follow up with involved parties to confirm lion mortalities stemming from HWC.
- Further HWC analysis require further document acquisition and review of additional data sources as well as confirmation of regional geofeature data via GPS point collection to confirm HWC incidences in the last decade, Additional sources of HWC documentation have been identified in national MET archive records and are scheduled to be reviewed and digitized in the third quarter of 2018.

Detailed Methods and Results

GPS Satellite Collaring

GPS-Satellite telemetry enables tracking of an individual animal over a long period of time and can provide accurate information on animal movement and home range sizes. To date, 22 lions have been fitted with GPS-satellite collars within Etosha National Park; 12 lion collars are currently functioning and operational across the park, 6 lion collars have been removed or retrieved from conflict or mortality situations, and 4 collars are currently nonfunctional.

Home Range Analysis

It is necessary for collars to transmit at least 365 days encompassing at least one full dry and one full wet season cycle in order to accurately estimate the home range of a lion reliably (W. Getz, pers. Comm.).). Currently, only four of the collars have a "complete" dataset and are being analyzed to determine home range (Table 1). Home range analysis have been conducted using a kernel density estimation (KDE) method producing for two of the four collars for all data and for data by dry vs. wet season (For 2016-Present seasons were: Dry- June to November, Wet- December-May).[1]

Home range results are shown below in Figures 1 and 2 as utilization distributions, i.e. a "hotspot" map for the kernel density function showing the probability of a lion's utilization of space across ENP's landscape. Table 1 shows size of home range area (km^2) per KDE model for the contours indicative of an animal's true range: 99.99% , indicating total extent of the data points, "Total" ; 95%, indicating the animal's realistic home range, "Home Range"; 50%, indicating the core area of an animal's home range it most frequently uses, "Core". A one-way ANOVA with Tukey HSD test was conducted to assess significant differences for home range sizes at 95% and core size at 50% between data sampling frequencies and seasonal datasubsets.

Table 1 shows no significant difference between home range size calculated between different sampling intervals, however it does show a significant difference between Lion 1821 annual home range size/core and both seasonal home range sizes/cores. There was a noticeable difference in home range shape between individuals as evidenced in Figure 1-3. Individual lion home range size also varied greatly; Lion 1822 (95%UD) = 599.85 km^2 , Lion 1821 (95% UD)= 1200.80 km^2, and Lion 1679 (95% UD) 395.17 km^2(Table 1). Core areas with the highest visit density (indicated in red on Figures 1-4) concentrated around waterholes. This is expected based on the standard of lion home range and movement in the literature, suggesting the importance of water resources and its surrounding vegetation or land use class to lion space utilization patterns in Etosha.

					Home Range Size (km2)							
					UD- All		UD- Wet		UD-Dry			
Lion	Sex	Study Period	Sampling Frequency	N(Fixes)	95%	50%	95%	50%	95%	50%		
1822	F	26 Dec 2016- 29 Apr 2018	~3-5 hrs	1526	599.85	120.74	563.85	122.89	568.60	108.24		
1821	M	26 Dec 2016- 29 Apr 2018	~3-5 hrs	2195	1200.80*	164.17*	1484.70	263.52	1441.70	268.44		
					UD-All		UD-4 hour		UD-3 Hr		UD-Dusk-Dawn	
					95%	50%	95%	50%	95%	50%	95%	50%
1679	M	17 Jul 2016- 3 May 2017	~1 hr	6860	395.17	60.41	397.13	60.54	394.72	60.28	398.72	60.45

Table 1. Lion home range sizes (km^2) for KDE method. Analysis performed in HRT 2.0 for ArcGIS 10.2, Kernel Density Estimation, smoothing bandwidth (h)= adhoc value for smallest continuous 95% isopleth per dataset, 100 m^2 resolution. Stars* indicate significance $p<0.05$

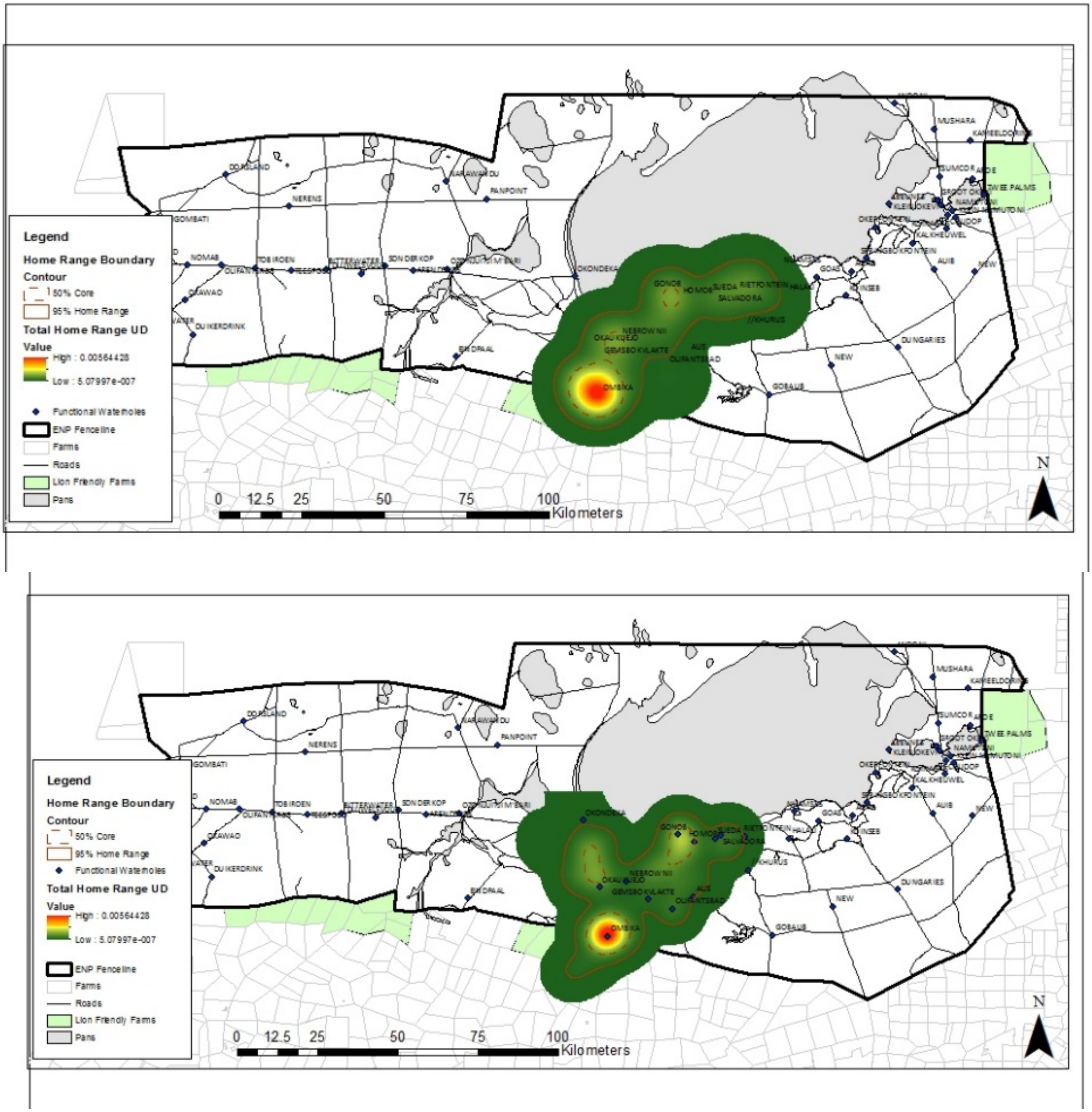


Figure 1.1 KDE heat map of home range utilization distribution for lion 1821. From top to bottom respectively:all data points for dry season(Jun-Nov)(N=833), and all data points for wet season (Dec-May)(N=1362).

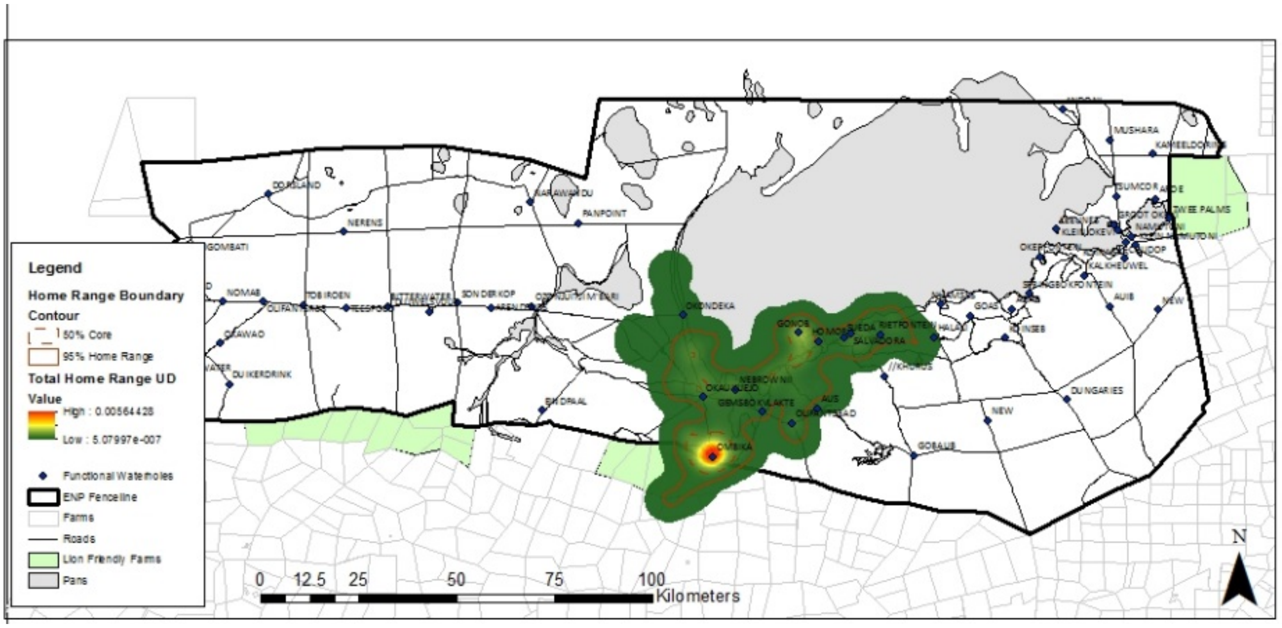


Figure 1.2 KDE heat map of home range utilization distribution for lion 1821. For all datapoints in collection range (N=2195)

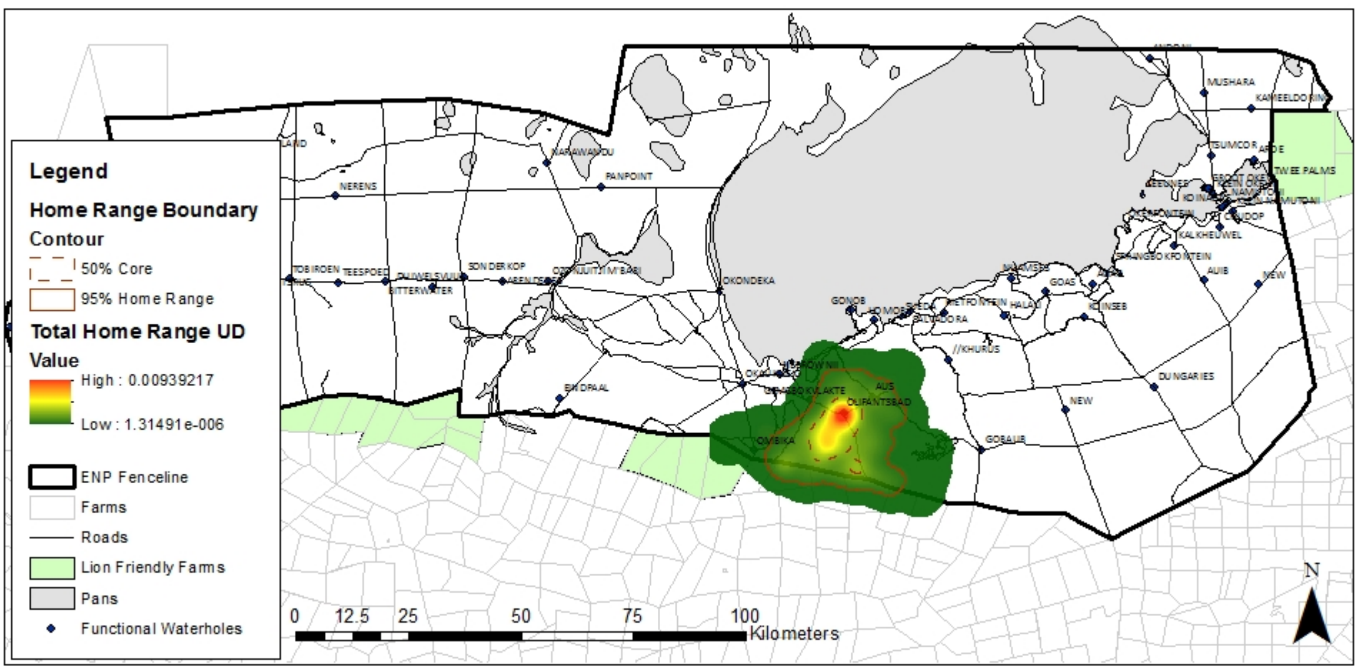
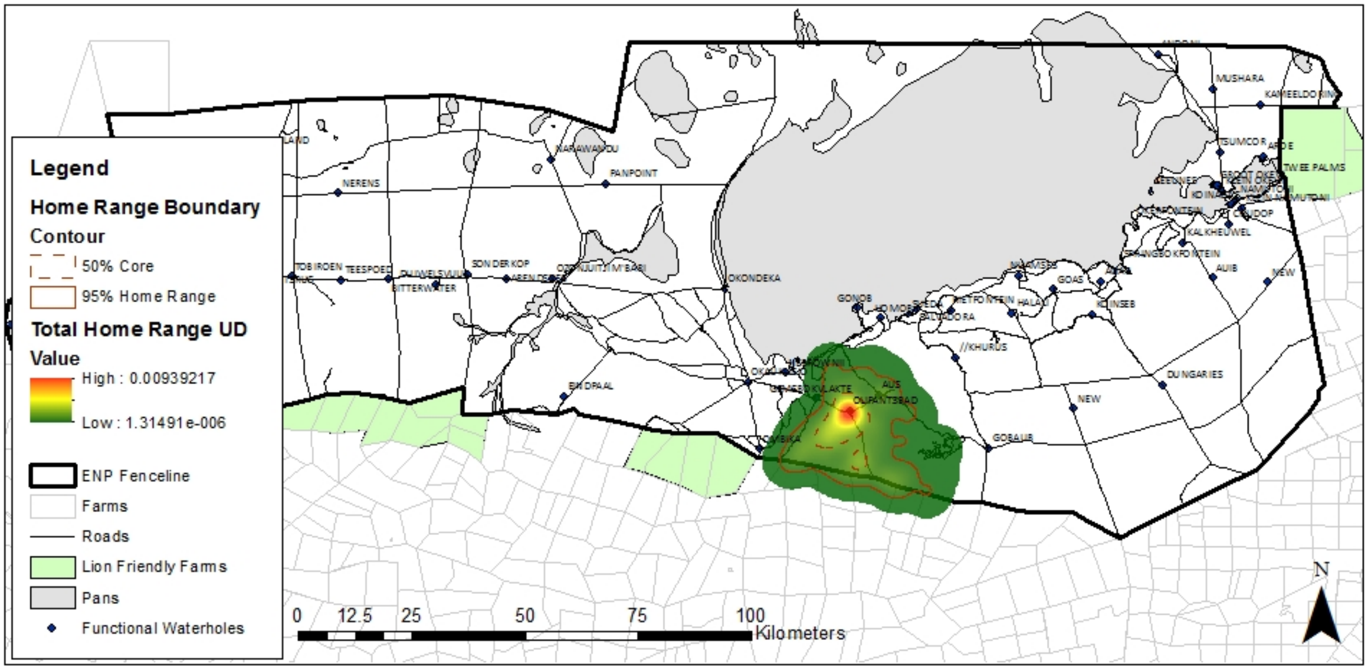


Figure 2.1. KDE heat map of home range utilization distributions for lion 1822 for all datapoints in collection range (N=1526).



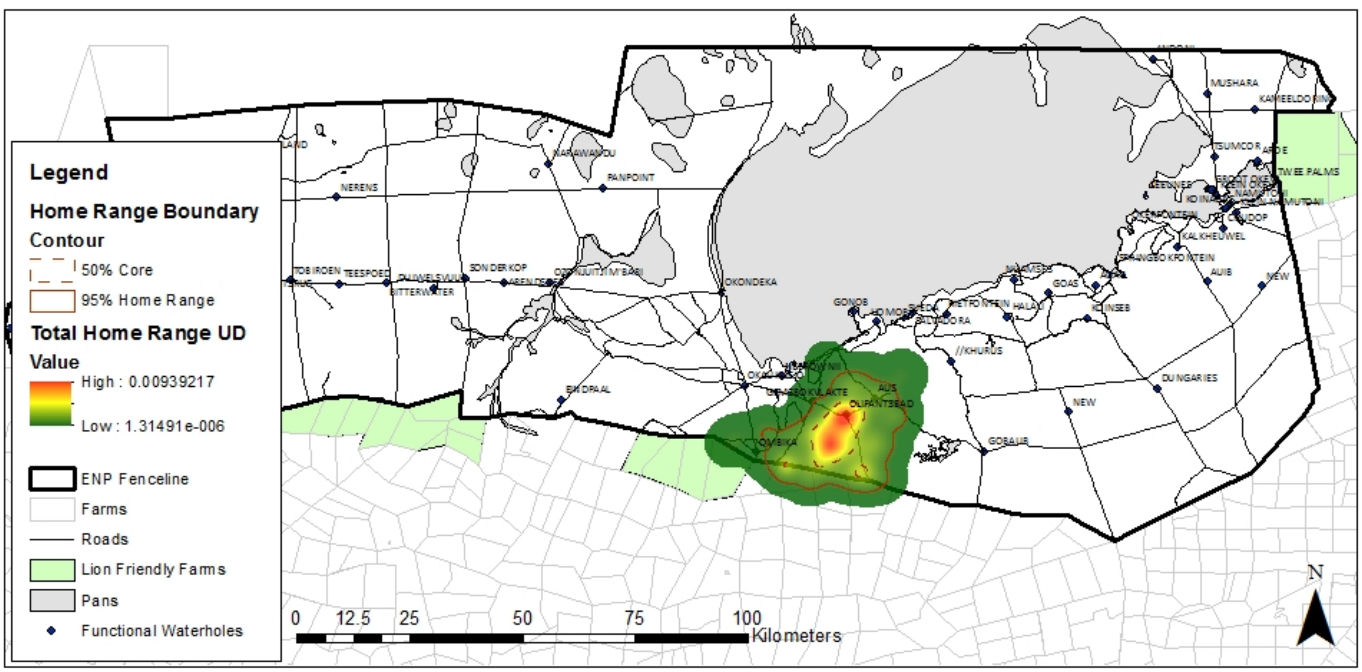


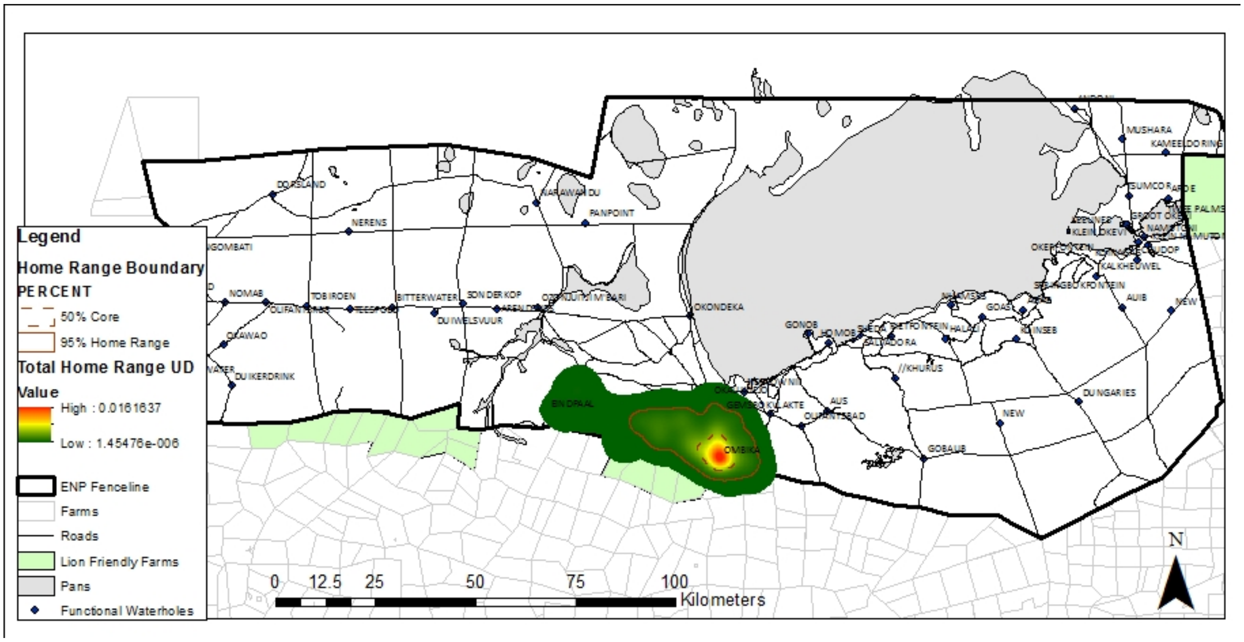
Figure 2.2. KDE heat map of home range utilization distributions for lion 1822. From top to bottom respectively: all data points for dry season(Jun-Nov)(N=584), and all data points for wet season (Dec-May)(N=942).

Sampling Intervals (Collar Reading Times) and Accuracy

The GPS satellite collars can be set to digitally transmit readings to the AWT platform at varying sampling frequencies. To date, collars deployed on Etosha lions have been set to read at a number of sampling frequencies including hourly, every 3 hours, every 4 hours and every 5 hours. Literature suggests a precedent for various sampling frequencies in order to accurately calculate home range size for lions in particular, including every 3-4 hours, every hour and hourly from dawn to dusk when lions are most active with 2 set fixes during daylight hours (i.e. hourly from 18:00h-07:00h, and at 10:00h & 15:00h) (Loveridge et al. 2016).

In order to maximize battery life-thereby prolonging a collar's reading life in the field, as well as minimizing project costs- it is preferable to set collars to transmit fixes at a minimum number of reads per day that still produce accurate analyses. A home range analysis for a single collar dataset subset by multiple sampling intervals was therefore conducted to determine if 3 hour intervals produced significantly different results than hourly dusk-dawn intervals etc. and determine ideal collar reading frequency for all lion collars in ENP moving forward.

Analysis was undertaken for the only available collar with hourly readings for >1 year (Lion 1679) for datasets of all hourly points, 3 hour intervals, 4 hour intervals, and the above "hourly dusk-dawn +2 fixed daytime point" sampling intervals. Home range analysis for each data subset was run using the same KDE method for estimating utilization distributions as described above. Results are shown in Figures 3-4 for UD heat maps and 99.99% total range, 95% home range, and 50% core contours of models respectively. A one-Way ANOVA and Tukey hsd test was conducted to assess significant difference between home range size across data sampling frequencies (Table 1). No significant difference was found.



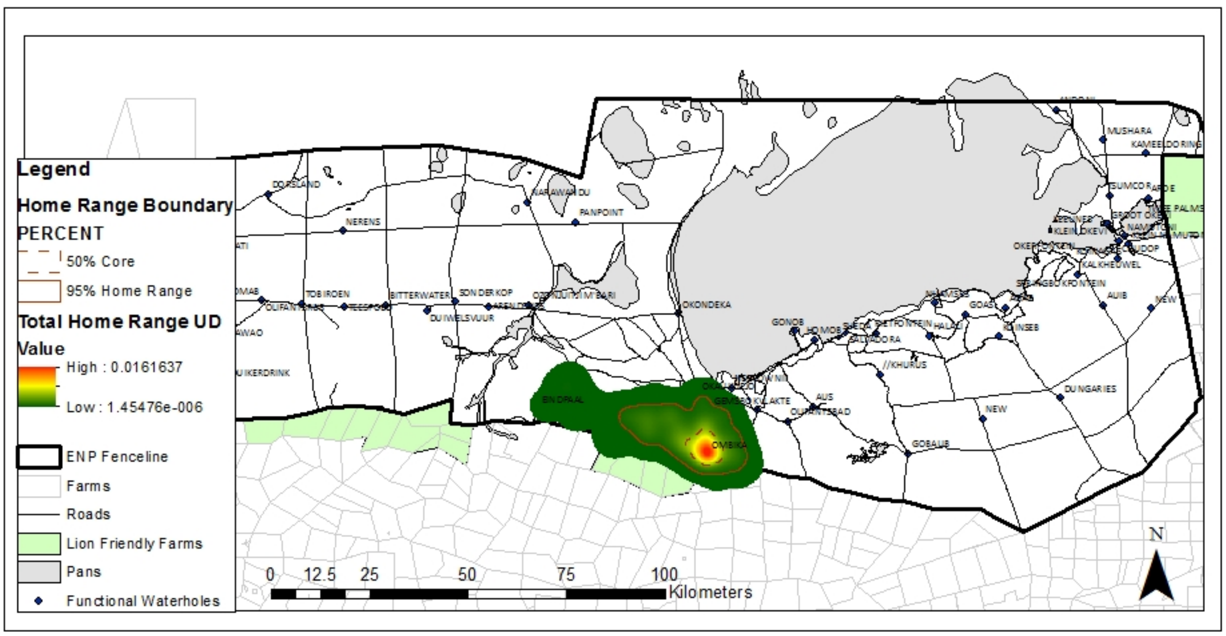


Figure 3. KDE heat map of home range utilization distributions for lion 1679. From top to bottom respectively: 3 hour interval (N=2282), 4 hour interval (N=1717).

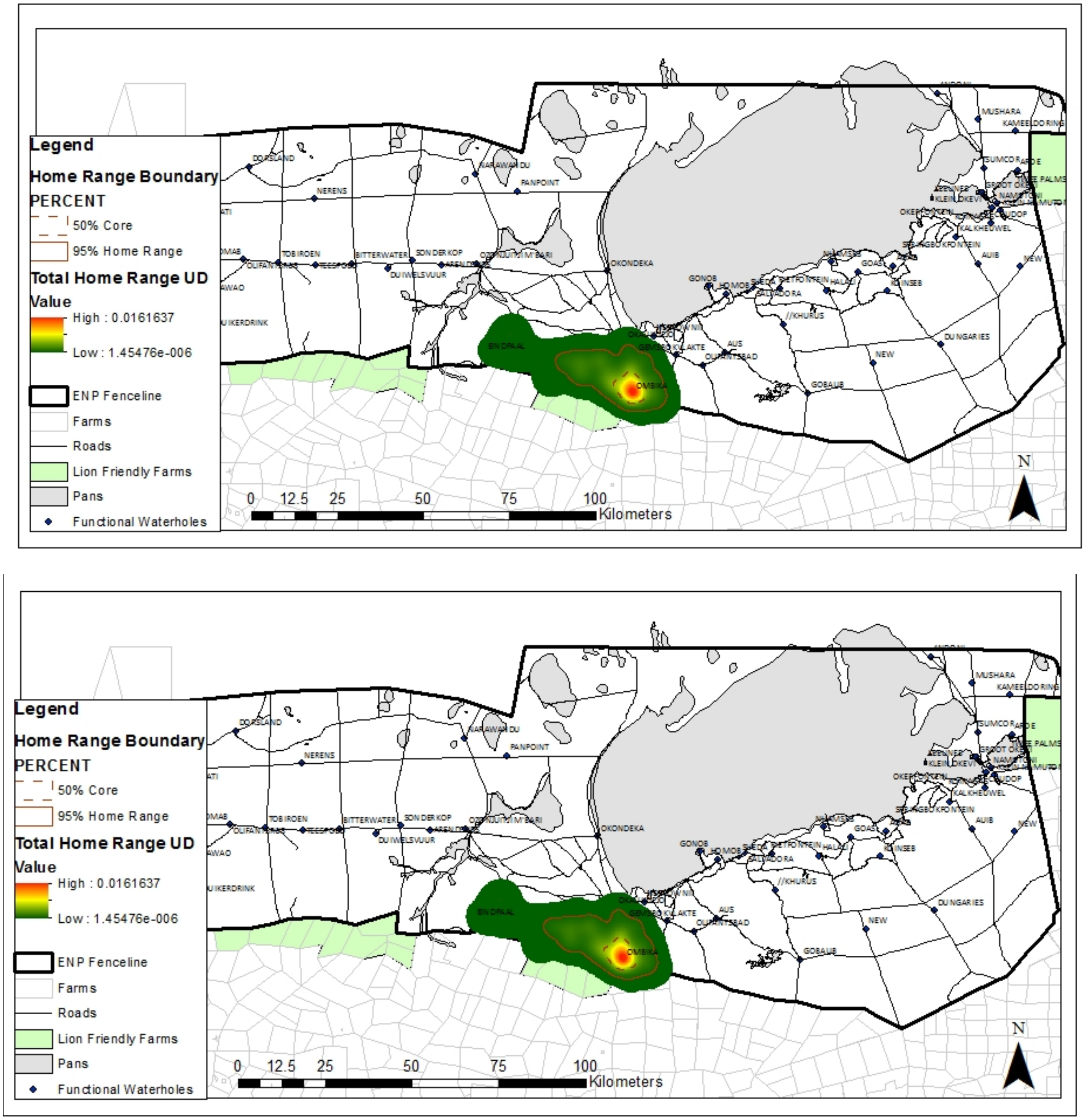


Figure 4. KDE heat map of home range utilization distributions for lion 1679. From top to bottom respectively: all datapoints in collection range (N=6860), and dusk-dawn hourly + 10h and 15h interval (N=4589).

Human Wildlife Conflict

Examination of historical records from MET offices in ENP and Outjo indicate that an average of ~50 lions per year were reported on surrounding farms from the 1980s to early 2000s and about 30 lions were subsequently reported shot or poisoned per year as a result of HWC (Figure 5). In 2005, the number of mortalities jumped to 55 lions reported killed annually, however, this increase coincided with many recording gaps in the following years. After 2005, there was a noticeable sharp decline of documented HWC in MET regional records up through 2010, and little to no documentation or synthesized record keeping of HWC since. The number of lions killed per year, per year by current farm/land use type of all kills currently known from 1975-present are shown in Figure 5, Table 2, and Table 3 below.[2]

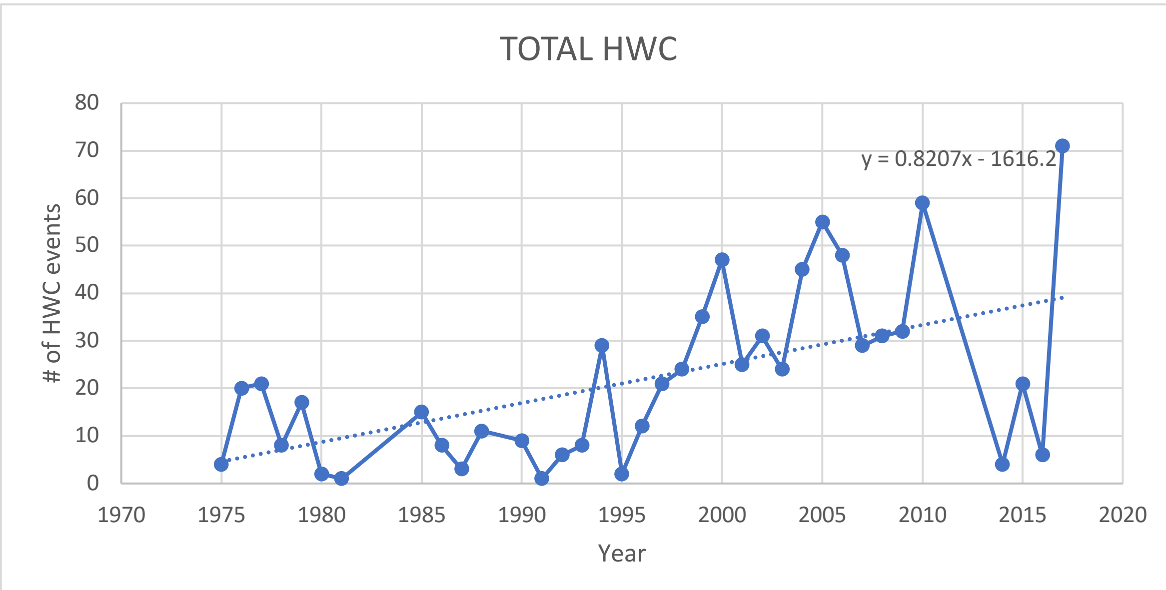


Figure 5. Number of HWC events per year around Etosha National Park, 1975-2017. Data from 1975-2010 represents known lion mortality HWC events only, data from 2011-2017 represent documented HWC events *indicating* mortality, further confirmation from additional data sources in required.

Table 2. Summary Statistics of HWC events around ENP 1975-2017

	ALL HWC RECORDS
TOTAL NUMBER EVENTS	815
ANNUAL AVERAGE	21.8
STDEV	18.12
KNOWN MORTALITY VS. HWC EVENT	742
% OF HWC EVENTS KNOWN MORTALITY EVENTS	91.04%
ANNUAL RANGE	2 -71
NUMBER OF YEARS WITHOUT DATA	7
NUMBER OF YEARS WITH DATA	35
DATE RANGE	1975-2017

Table 3. HWC events per farm type/ land use type, as farms are designated today. Note that some farms are both "Commercial Farms" and "Game Reserve".

Farm Type	Description	Code	Total Number HWC Events (1975-2017)	Number of Farms where HWC has occurred	% of Total HWC Events
Resettled Farms	Communal, livestock only	RF	106	46	13%
Commercial Farm	Private, Livestock/Game, No	CF	632	98	78%
Commercial Hunting	Private, game only	CH	124	6	15%
Conservancy	Communal, game, wild	C	33	8	4%
Game Reserve	Private, commercial, Grouped CF Farms, no CH	GR	59	1	7%
Unknown	Unable to determine geographic location from logged info	UK	26	12	3%

These lower reported numbers and data gaps from 2005-2018 dramatically underrepresent the level of conflict at present based on media occurrences and conversations with MET staff/ local officials. HWC with lions and lion mortality incidences is believed to be increasing each year. Discussion with regional and national MET staff indicated that recent social, political and land use changes may explain the decline in reported HWC. In particular, the transition of farm type designations for commercial vs. resettled farms, game vs. livestock, and commercial hunting vs. "game reserves" of grouped commercial game farms is believed to be a complicating factor to HWC reporting today. Many policy changes related to land use designations coincide with decreased HWC reports particularly after 2010, and may explain the artificial decrease in ENP's documented HWC. [3]

Data for 1975-2010 HWC events is comprised of HWC documentation of confirmed lion mortalities only. Data sources from 2015-present consist of HWC problem reports, lion mortalities, and livestock lost reports indicating lion mortalities. However, many of the incident documentation reports indicate HWC but don't specify mortalities and location names cannot be matched to geography and available location datasets to follow up. Therefore, the data from 2015- present are not confirmed. Additional document review and through georeferencing of all locations surrounding ENP mentioned in HWC reports is necessary to confirm which HWC incidents ended in mortalities and what their actual locations were.

<u>Future Directions</u>

Additional home range analyses will be conducted for collar 1679 to determine if using a time Local convex Hull (tLoCoH) statistical method is suitable for hourly (method standard) vs 4 hour interval data (suggested setting for Etosha) in order to understand how the lions use an area both spatially and temporally. This method estimates the amount of time an animal spends within an area in its home range, which in turn shows which areas are visited less often but for long periods of time (i.e. feeding) and which areas are often visited but only for short periods of time (i.e. waterholes) (Lyons, Turner & Getz 2013). This will help to understand the space time use of lions in Etosha to understand where they visit frequently but also how long they are present in an area. This information will be useful for understanding lion movement outside the park in relation to HWC events.

Preliminary home range analyses indicate significant differences between seasonal subsets of location data. Further home range analyses will therefore examine lion UD across the landscape for both landscape level variables (proximity to waterholes, land cover, land use type, proximity to fencing) and temporal variables (season, rainfall, month).

Historical HWC data can be used to model historical occurrence of conflict hotspots and determine future, potential "risky" areas for HWC and resultant lion mortalities to occur. Further acquisition of historical conflict data, particularly after 2010 up till present, is necessary to determine an actual record of HWC in the last decade. Data sources have been identified via the permit office at MET national office in Windhoek. This will include examination and digitization of lion skin/bone sale permits, livestock compensation claims, poaching reports and illegal animal parts sales, problem animal reports and monthly summary reports per park region and for the country. Once this is obtained, data can be used to create risk maps that will highlight potential high conflict zones for further examination.

<u>Recommendations</u>

1. The lack of significant difference in home range size, shape, and UD for lion 1679's KDE between various sampling frequencies indicates that it would be in the project's best interest to set all collars to read at 4 hour intervals. This sampling frequency will provide the minimum number of fixes per day of all sampling intervals designated in literature, was found suitable for Home range estimations and will prolong collar battery life.
2. The 4 hour interval should be used on all future lion collar home range estimates in order to maintain cohesive methodology for eventual use in conflict hotspot prediction modeling.
3. Preliminary analyses of conflict locations and observations from literature suggest some population demographics, locations, and location types might be more prone to experience HWC(i.e. older females, young dispersing males, lions with home ranges overlapping commercial farms etc).. Identification of historic conflict locations, particularly within the last decade, should be used to collar new individuals close to the boundary fences near high conflict risk zones.
4. A further 4 lion collars are planned for being deployed over the next 3-6 months. It is recommended that these collars be deployed on old or dispersing male lions as well as lions in southern boundary locations. More collar location readings near those locations will be essential for future HWC monitoring and better understanding lion movement and space use in HWC zones.
5. The HWC data gaps make ENP records insufficient to accurately assess recent conflict hotspots, and subsequently inadequate for the originally proposed HWC risk model. It is necessary to obtain accurate and complete information related to HWC events via Nationally archived records available in the Windhoek MET office and permits logs.
6. There is a need for more current GPS data for surrounding boundary farms and villages, and document the status/ quality of fencing and landcover types around ENP. These

variables have historically proven integral to assessing future HWC via risk mapping, and it is critical that they be accurately document for risk mapping analyses (Miller 2015).

Future Project Timeline

Given funding opportunities and permits, the timeline below is suggested for continuation of lion and HWC monitoring/analyses to complete analyses for MSc dissertation project and beyond:

July 2018 –

1. Monitor previously collared individuals to follow various lion prides and assess population dynamics/demographics.
2. Use tourist sighting books and lion collar location data from the last 6 months to determine where lions are since last collaring/monitoring operations →observe and record pride demographics

August 2018 – September 2018 –

1. Conduct population call up survey across the park.
2. Plan deployment operations for remaining 4 lion collars
3. Conduct GPS survey to obtain location data for towns/ farms along park boundary for use in HWC mapping/analyses
4. Examine historical archived records/permits in Windhoek MET office for HWC events 2010- present (i.e. lion skin/bone sale permits, livestock compensation claims, monthly summary reports per region, problem animal reports)

October 2018

1. Digitize historical conflict data obtained from 2010 to present.
2. Conduct further Home range KDE and T-LoCoH analyses to confirm ideal/significant collar reading interval and HR estimation methodology for all collars moving forward.

November 2018 – July 2019 –

1. Ongoing monitoring of lions.
2. Produce home range analysis maps for all full dataset collars
3. Conduct HWC risk mapping analyses

End Notes

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[1] Various environmental factors influence the satellite signals received by a GPS collar, potentially deteriorating accuracy of position. Therefore, all GPS-Sat collars placed on lion subjects also record a dilution of precision (DOP) value indicating the range (in meters) that a recorded point is expected to fall within of the animal's actual location at the time of the reading. In order to increase the accuracy of calculations based on animal location data, all collar fixes were filtered to exclude data points under the following conditions: (1) the first 48 hours after collaring (demonstrated in literature to have high levels of inaccuracy while collar is calibrated to locale), (2) DOP values ≥ 20 m (Pebsworth et al. 2012, XX) and (3) duplicate times recorded ≤ 120 seconds from each other. Inaccurate location fixes were removed prior to all analyses. Of the removed datapoints, most points were fixed during nighttime hours, when animals were frequently moving at higher speeds and high DOP values. It is notable that **<5 %** of collar fixes were removed for DOP exclusion, indicating a relatively high level of collar reading accuracy compared to other lion collaring studies in the literature (Abade et al. 2014).

[2] Examination of records 2004- present showed huge data gaps and inconsistencies, particularly when compared to park officials' knowledge of events as well as the number of HWC recorded in the media since 2015. HWC numbers since 2004 should therefore to be viewed as potentially incomplete, and numbers since 2010 are completely unreliable and incomplete, requiring additional data collection sources in order to accurately assess HWC locations and patterns.

[3] Historically, Namibia did not provide compensation for damages or losses caused by HWC but allowed individuals to report "problem animals" to investigate, monitor, and potentially relocate problem lions. Recent changes in land use designations and wildlife management policies now also allow "communal" farmers to apply for HWC compensation from MET for livestock losses (Stander 2005). Commercial livestock farmers cannot claim any compensation but can legally kill a lion and apply for a permit to sell the skin and bones instead, if the animal was "presenting a threat to [their] life or livelihood" (ibid.). Compensation applications and skin/bone sale permits can be filed directly with national MET offices whereas traditional "problem animal complaints" often went through local/regional MET staff. This potentially explains why documentation of HWC on the local/regional level shows a decrease in numbers.

References

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