Identifying areas of socio-ecological value for the translocation of perceived conflict cheetah (*A. jubatus*) and leopard (*P. pardus*) in Namibia

by

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May 2013

Masters project submitted in partial fulfillment of the
requirements for the Master of Environmental Management degree in
the Nicholas School of the Environment of
Duke University
2013

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Abstract

Human-wildlife conflict is an ever-present threat to large carnivores in Namibia due to their distribution across privately owned properties. Translocation techniques are one approach to solving this conservation challenge, but are often regarded as unsuccessful due to new sources of competition, stress, or human conflict for translocated animals. In attempt to mitigate some of these failures, I developed an ArcGIS- (v.10.1, ESRI 2012) based carnivore translocation suitability tool (CaTSuiT) that identifies habitat patches which meet the ecological requirements of leopard and cheetah and accounts for human-development parameters. CaTSuiT ranks potential habitat patches based on landowner tolerance of carnivores (determined by survey) and the uncertainty associated with a patch's designated tolerance due to the number of un-surveyed landowners. The model indicates a large number of available habitat patches for leopard; however, suitable cheetah habitat patches are limited by the amount of suitable areas farther from the recommended minimum homing distance away from a conflict animal's capture location. This tool should be used as a guide to inform conservation managers about where to focus their efforts to help landowners incorporate more tolerant farming practices and improve coexistence between local land-owners and large carnivores.

Introduction

Background

Humans and large carnivores have coexisted for thousands of years. Across Africa, Asia, and the Americas, humans and high-order predators have used similar resources, resulting in conflict and a general decline of these carnivores' abundance and distribution (Weber & Rabinowitz, 1996).

Many African countries experience human-wildlife conflict regularly, especially those with high levels of pastoral agriculture. In these areas, larger carnivores (e.g., hyenas and large felids) have been known to prey on local livestock and occasionally people (Woodroffe 2000). Unsurprisingly, landowners retaliate against these predators. Some landowners and livestock owners will even remove any large predator they encounter indiscriminately, as a way to minimize possible future conflict. This persecution can seriously threaten local carnivore viability. In Namibia, where it is estimated that approximately 2000 cheetah (*Acinonyx jubatus*) of an estimated 5000 total individuals throughout southern Africa

(Purchase et al, 2007) and approximately 7500 individuals worldwide (IUCN Cats Red List Workshop 2007), and a currently unknown number of leopards (*Panthera pardus*) occur (Henschel et al, 2008), the large carnivore population is subjected to this type of conflict on a regular basis – more so because much of the available landscape is considered suitable carnivore habitat, but used for livestock production.

As a result of predator competition [mostly by lion *(Panthera leo)*, and spotted hyena (Fam. Hyaenidae)], in the protected areas of Namibia, compounded with historic conflict between these top-order predators throughout the country, the majority of free-ranging cheetahs and leopards have thrived on privately owned property (Berry et al, 1996), thought to contribute to an increased rate of conflict between carnivores and humans. In the past Namibian landowners have killed or removed up to 900 cheetahs per year from their lands, especially during periods of drought. During a drought-stricken period in the 1980s, for example, a rabies epidemic killed close to 80% of the kudu in Namibia, forcing cheetah to subsidize their diet with livestock, in turn causing retaliation from livestock landowners (Marker et al 2007; Berry et al 1996).

Although various conservation strategies to protect large carnivore populations such as cheetah, lion, leopard, and hyena have been implemented for decades, which methods are most successful is still widely contested due to a lack of comprehensive monitoring studies. The translocation of perceived conflict predators is especially controversial; some studies state that translocation is costly and less effective than other alternatives such as compensation for best herding practices (Fonturbel & Simonetti 2011). Others support that for Namibian cheetahs specifically, translocations do not inhibit survivorship in almost all cases as long as population densities are at viable levels in the reintroduction site (Purchase 1998; Marker and Dickman 2003). However, many translocations of cheetah are not monitored after release, which results in a loss of valuable information concerning factors that affect translocation success such as prey capture rate, reproduction, survivorship, site fidelity, and homing instinct (Purchase and Vhurumuku 2005). Site fidelity and homing instinct are of great importance; knowing whether an individual

remains on the property to which it is released or if it homes back to its source site is important to evaluating the success of a translocation.

Some argue that not enough is known about the new habitat into which the animal is released; resident carnivores may cause displacement of the translocated individual, it may not be able to reproduce successfully, there is insufficient knowledge of the native prey-base, or the individual may seek out and continue to prey on the livestock of landowners in this new region (Cobb 1981, Norton 1986, Ebedes 1970). Additionally, it is believed that when a carnivore is removed from a population it creates empty habitat for which another individual from a neighboring territory may enter, effectively leaving a landowner with another potential conflict animal (Athreya 2006). Most importantly from a conservation-management perspective, translocation has been regarded as one of the least cost-effective methods for mitigating conflict, though this has only been evaluated on a circumstantial basis depending on available funding (Linnell et al, 1997).

To conserve cheetah, leopard, and other large carnivore species in Namibia, the N/a'an ku sê Foundation began the Carnivore Conservation Research Programme (CCRP) in 2008. This program works to document and analyze individual carnivore movements using GPS-satellite collar data, share the results with local landowners, and work with them to better manage their livestock without retaliatory killing. Through their efforts they have succeeded in fitting 60 large carnivores with radio-collars, 30 of which have been translocated to various private protected lands (Figure 1) [23 cheetahs, 6 leopards, and 1 brown hyena (*Hyaena brunnea*)]. By fostering relationships with local landowners and creating home-range maps using these data, N/a'an ku sê has ascertained which individuals inhabit home ranges on specific properties and mitigated the lethal removal of many animals which may not have been conflict animals in the first place.

Additionally, the Foundation has used translocation of "conflict animals" known to hunt livestock as a conservation technique. As an example, assume a landowner contacts N/a'an ku sê claiming to have a large carnivore on their land that is preying on their livestock. The CCRP will first assess that there is in fact a singular individual or group of individuals that are indeed depredating on the livestock, thus rendering them conflict

predator(s). Once alternative methods of prey prevention (e.g. fortifying enclosures with thornbush, implementing guard dogs, shepherds, etc.) have been attempted, N/a'an ku sê will proceed with a translocation study. The individual is then captured to assess its physical condition (whether it is fit for translocation) as well as to attach a GPS satellite collar. When the CCRP finds a suitable location for translocation, the individual is transported and released on-site and continuously monitored via the collar's software interface or VHF telemetry tracking.

It is important to distinguish that most of the animals translocated by N/a'an ku sê were selected because their post-release conflict potential was expected to be low, e.g. they were opportunistic conflict predators as opposed to habitual conflict predators. In addition to an individual's physical fitness, N/a'an ku sê also requires that they be within natural breeding age range, to ensure a higher probability of contributing to the gene pool. Source-site landowners were also required to agree that the animal is to be released into a free-ranging habitat, to change their farming practices as best as possible, and only carried out the translocation if the N/a'an ku sê thought that it would significantly improve the landowner's tolerance towards large carnivores on their property. The ultimate condition for a translocation is to avoid a repeat translocation on the same source property.

Through geospatial analyses, the CCRP is working to determine the likelihood of translocated predators to return to their original home ranges and whether they can successfully establish new home ranges in the relocation area. Translocation distances were chosen at longer intervals than in many previous translocation studies in an attempt to define minimum critical translocation distance for cheetah and leopard that prevent successful homing. Recipient areas are chosen based on their land use which must be tolerant of large carnivores, where prey is adequate and conspecific predator species densities are low. This information will be valuable in determining whether relocation techniques can permanently remove conflict animals from a livestock area and mitigate human-carnivore conflict. By improving farming practices and livestock protection, these research strategies have already helped shift many local landowners' attitudes towards large carnivore conservation (Weise, observation).

While N/a'an ku sê promotes the idea that translocation should be implemented only when other techniques have failed, its well-designed translocation studies have been largely successful in comparison with previous translocation accounts (Linell et al. 1997). Because N/a'an ku sê fastens GPS-satellite and/or VHF radio collars to each translocated animal, it is possible to track the movements, survivorship, reproductive success, site fidelity, and home range size of each individual. Reliable movement data such as these have led N/a'an ku sê to speculate that within Namibia, translocations should be available as a last-resort mitigation practice under circumstances where this will significantly increase the landowner's attitude towards free-ranging carnivores and on the condition that suitable recipient sites can be sourced in a timely manner.

The majority of translocated carnivores collared and released by N/a'an ku sê have been considered successful; there have nevertheless been several instances in which individual carnivores have been killed. Of the 29 large felids in the translocation study, 11 (38%) suffered fatalities. Of these fatalities, 10 (91%) were cheetahs. Fatalities resulted predominantly from hyena attack (30% of cheetah fatalities), road collisions (1 leopard and 1 hyena), and human conflict (50% of cheetah fatalities, 1 possible leopard fatality[1]).

Purpose

The statistics above are not evidence that the relocation sites chosen by N/a'an ku sê were inappropriate; indeed, all releases of conflict animals are typically on privately owned farms and conservation lands. Theoretically, these areas are almost ideal for relocation given their ecological suitability and the attitudes of landowners on and around the release sites. However, property-owner intolerance can only be determined after a carnivore kill occurs. Practical relocation sites are currently also limited by N/a'an ku sê's knowledge of ecologically suitable carnivore habitat and the relationships N/a'an ku sê maintains with property owners willing to accept a previously-labeled problem-animal. Additionally, areas which N/a'an ku sê has found to have successful carnivore survivorship, reproduction, prey base, etc. will eventually be less than ideal choices for translocation because the influx of

[1] The cause of death for this particular leopard was determined to be either conflict-related or due to a road collision; the exact cause was unknown.

additional carnivores to these regions would result in stress and exacerbated competitive pressure on previously established resident carnivores.

To better assess carnivore relocation to regions of Namibia for which data is limited, I developed an ESRI-based geospatial tool called the "Carnivore Translocation Suitability Tool," or CaTSuiT. This tool's primary purpose is determining which swaths of land in Namibia are suitable for the relocation of any 'problem' cheetah or leopard based on its capture location and habitat suitability. Once the tool identifies appropriate patches, N/a'an ku sê will be able to contact landowners in these identified areas to further determine their willingness to accept a carnivore on their property.

Methods

Data Acquisition

To determine which areas in Namibia are suitable for leopard and cheetah translocation, baseline knowledge of ecologically suitable areas must be established. This can be determined by analyzing areas that display appropriate characteristics for leopard or cheetah habitat. One of the best ways to determine this is to use presence/absence data of a species of interest coupled with several important ecological parameters such as elevation, precipitation, vegetation type, etc. Unfortunately, the database for presence/absence of most large carnivores in Africa is extremely limited, and unsuitable for this analysis. Further, the Namibian databases for geospatial datasets (shapefile/raster files), although fairly comprehensive in comparison with most other African countries, are still fairly limited in their content and accuracy. Limited by access to data, I performed a literature review to determine which parameters of my available datasets could be used to determine ecological suitability.

Geospatial data used for this analysis (Table 1, see Appendix) were acquired from the Environmental Information Service of Namibia (www.the-eis.com). A digital elevation model was acquired through the U.S. Geologic Survey's Earth Explorer (http://earthexplorer.usgs.gov/). Finally, a dataset from a previously conducted N/a'an ku sê survey discerning landowner's attitudes towards carnivores was spatially

joined to the respective farm plots from the EIS. This survey contains demographic data like registered farm name and number, size of farm properties in hectares, and source of income. Additionally the survey includes an estimation of each landowner's propensity to indiscriminately capture or kill carnivores found on their property, whether they have experienced livestock losses, the number of kills and kill type made on the property, and whether they practice farming measures to defend against livestock predation.

From these survey parameters, I assigned a 'tolerance' rating to each farm: tolerant, semi-tolerant, or intolerant (Figure 2, see Appendix). 'Intolerance' refers to landowners admitting to capturing and/or killing carnivores indiscriminately (i.e., the landowner was not able to produce proof that the captured or killed individual was indeed responsible for livestock loss). 'Semi-tolerant' landowners captured individuals only in selected situations with no indiscriminate captures or lethal removals and a maximum of 1-2 lethal removals. 'Tolerant' landowners had no indiscriminate captures and no lethal removals. In many countries home to large carnivores, landowners are unlikely to answer questions like this truthfully, due to many countries' laws forbidding killing protected species or requiring a permit. In Namibia; however, it is legal to kill a cheetah or leopard without a permit if in defense of one's self or one's livelihood, in this case livestock (Purchase et al, 2007). Therefore, the survey data collected by N/a'an ku sê were considered trustworthy for use in this analysis.

Analysis and Creation of Suitable Habitat Patches

Separate geospatial models were created for cheetah and leopard, to account for differences in habitat suitability. All analyses were performed using ArcGIS v. 10.1 (ESRI 2012). After assigning all datasets to the same geographic and projected coordinate system (Albers Bessel Namibia), I used a weighted overlay function to systematically rank ecological parameters by their relative importance to leopard or cheetah habitat. Each variable was given a percentage of overall influence to the model, and the values within each variable were scaled according to importance (i.e., values closer to a river were ranked higher than values further away). The scales for each parameter in any given cell was multiplied by its influence percentage, and then summed for an overall suitability

score, between 0-100 in increments of 10. For leopard, I used 15 parameters (Figure 3a-j, 3m-r, see Appendix) based on expert scientific opinion as determined through the literature review and collaboration with N/a'an ku sê:

Table 2: Ecological Parameters used in Weighted Overlay Function, with % overall influence for each.

Ecological Variables	Weight (100%)	
	Leopard	Cheetah
Elevation	15%	10%
Terrain Ruggedness	20%	15%
Distance from Rivers	15%	10%
Vegetation Type	15%	15%
Herbivore Densities	12% (Kudu, Mountain/Burchell's Zebra, Springbok, Red Haartebeest, Oryx, 2% each)	12% (Springbok (4%), Kudu (4%), Mountain/Burchell's Zebra (2%) Red Haartebeest (1%), Oryx (1%))
Herbivore Diversity	13%	13%
Carnivore Densities	5% (Spotted Hyena (1%), Leopard (2%), Lion (2%))	20% (Spotted Hyena, Leopard, Lion, Cheetah, 5% each)
Carnivore Diversity	5%	5%

Table 3: Parameters used in 2nd Weighted Overlay Function, with % overall influence for each. Ecological output from Table 2 is used as a parameter in Table 3.

Other Variables	Weight (Leopard/Cheetah)
Human Population/Urban Encroachment	20%
Distance to Major Roads	5%
Distance to Minor Roads	5%
Distance to Mining Sites	5%
Livestock Densities	25% (Karakul/Dorper sheep, Goat, Donkey, Cattle, 5% each)
Distance from Protected Areas	5%
Aggregate Livestock	15%
Ecological Model	20%

- ***Elevation*** – Using a DEM (USGS 2012) I ranked intervals of 100-2600m from sea level by where leopards and cheetahs are most likely to be present. For leopards, I

referenced a study by Hatten, et al. (2005) which documented the spatial patterns of jaguar in Arizona and found that 60% of all sightings occurred between 1200-1800m, with the remaining sightings between 1000-2700m. Because jaguars and leopards are considered ecologically equivalent in habitat preference and versatility on a biome level (Dasmann 1972) and the Southwestern US and Namibia are of similar desert/scrubland habitat, I deduced the most desirable habitat was between 1200-1800m while somewhat desirable habitat between 1000-1200m and 1800-2600m. Elevations below 1000m were scaled as accessible by leopards, albeit less desirable. Studies from other parts of the world, such as Armenia, support that leopard tend to utilize terrain which is roughly between 700-2500m above sea level in arid, mountainous landscapes (Khorozyan et al., 2010).

Because cheetahs have been documented as more widely spread across elevational gradients in Namibia, I assigned the highest preference to elevations between 200-1500m, with fairly high preference still given to elevations below and above this range as well.

- Terrain Ruggedness Index (TRI) – Using methods suggested by Riley et al. (1999), I constructed a TRI by which to measure the level of ruggedness in a landscape. I used a digital elevation model (DEM) of Namibia as the source elevation data for the recommended SQL equation:

$$\sqrt{|Focal\ Max^2 - Focal\ Min^2|}$$

This index uses a 'moving window' analysis for each cell in the DEM, which reassigns the cell's value to the minimum elevation value adjacent to it (focal minimum value). This analysis was performed again, assigning values to the maximum elevation value (focal maximum value). The squares of focal maximum values were subtracted from the focal minimum values to result in a measure of ruggedness per cell. In other words, a cell is classified as extremely rugged if a large difference in elevation is found between adjacent cells. Conversely, a cell is classified as level if there is no difference between the maximum and minimum adjacent cell

values. The resulting TRI was reclassified into seven intervals of ruggedness: Extremely Rugged (>959m), Highly Rugged (498-958m), Moderately Rugged (240-497m), Intermediately Rugged (162-239m), Slightly Rugged (117-161m), Nearly Level (81-116m), and Level (0-80m). According to Hatten et al. (2005) 96% of jaguar observations occur in intermediate to extremely rugged terrain (levels 4-7) and has been associated with leopard movement models as well (Gavashelishvili & Lukarevskiy 2007). In the leopard model, therefore, I scaled equally high preference to levels 4-7, with lower preference given to more level terrain.

Because cheetahs are able to cross extremely rugged terrain, but often prefer level to fairly rugged habitat for ease of hunting, the highest scaled preference is given in this model to categories between 'level' terrain and 'slightly rugged' terrain with a tapering decrease in preference with higher levels of 'intermediate', 'moderate', 'highly', and 'extremely' rugged terrain.

- ***Distance from rivers*** – Because many leopard sightings, both during physical surveys and camera trap surveys, are documented near permanent and seasonal riverbeds (N/a'an ku sê, observation), the highest scaled preference was given to any area less than 5km from a riverbed. Likewise, decreasing preference was given to areas less than 10, 20, 40, and greater than 40km from a riverbed.

  I assigned the same preference scale to distances to rivers in the cheetah model as the leopard, yet I only allocated 10% of the overall influence here, as cheetahs have been observed in semi-to-hyper-arid regions surviving on the water attained by their prey source (N/a'an ku sê 2010, Laurenson 1995).
- ***Vegetation Type*** – Leopards are extremely versatile in which types of vegetation they inhabit; (e.g., woodlands, standard shrubland, dwarf shrubland, highlands, etc.). Vegetation types other than those listed were not restricted from use however, as leopards tend to traverse through other habitat types (Gavashelishvili & Lukarevskiy 2008).

Cheetahs primarily hunt during the day and are fairly reliant on habitat (Muntifering et al, 2006). The most ideal vegetation types were preferred in this model, i.e. Kalahari ecosystems, floodplains, shrublands and dwarf shrublands, savannahs, and highland regions (Na'an ku se, 2013), while other vegetation types were given a smaller scale factor but not excluded from the model, since cheetahs could still utilize this habitat if necessary.

- ***Herbivore Densities & Diversity*** – Density and diversity scale factors were assigned based on studies which discuss prey preference of leopards (Hayward et al. 2006, Stander et al 1997), and the data available on prey densities through the EIS (kudu, mountain zebra, Burchell's zebra, springbok, red hartebeest, and Oryx). In each case, a higher density of livestock in an area was preferential to leopard habitat, with tapering influence in areas of lower densities. I also included an herbivore diversity dataset, assigning the greatest diversity of herbivores to the highest scale factor.

  The cheetah model differs only in the influence between species densities from the leopard model. Springbok (5%) and kudu (4%) comprised the most influence because springbok and kudu juveniles are observed to be the most common forms of prey for cheetah in Namibia, from the data used for this study. Densities of red hartebeest, Oryx, and zebra (mountain and Burchell's) each comprise 1% overall influence because cheetah still hunt juveniles of these species, but are not preyed upon as often once adults.
- ***Carnivore Densities & Diversity*** – leopards are thriving in many areas of Namibia due to the absence of lions and other top predators from hunting (Marker & Dickman 2004). Competition may be apparent or much more likely between species in areas which still contain these top predators. I included lion, spotted hyena (*Crocuta crocuta*), and leopard density datasets, with decreasing densities being most preferential with regards to lion and hyena. The carnivore diversity parameter was included because there has been evidence that higher carnivore diversity generally points to higher overall biodiversity in a region (Dalerum et al, 2008). I assigned the highest preference to the most diverse locations within this parameter.

I allocated more overall influence to carnivore densities in the cheetah model than the leopard model. Because intraspecific competition is more commonly observed between cheetahs, areas with lower densities of leopard, lion, and spotted hyenas are preferred (Caro & Laurenson, 1994). The cheetah density parameter is scaled to give greatest preference to areas with moderate densities of cheetah, but decreasing preference to areas where cheetah population are too sparse or too common. Translocated cheetahs would not be able to reproduce with too few or no other cheetahs in the vicinity, and would most likely move out of the released site to find a mate. If too many cheetahs exist in the area, the translocated individual runs the risk of being displaced by resident individuals, especially if they are males as part of a coalition. (Observations by N/a'an ku sê, 2009, 2010). Both of these scenarios may reduce the overall success of a translocation, specifically with regard to site fidelity.

I scaled each of these parameters in terms of preference on a 0-100 value system, in increments of 10. The output weighted suitability for leopard and cheetah habitat in Namibia produced combinations of these parameters that resulted in a scale from 20-90. This means that there are no completely perfect or completely imperfect locations in Namibia for leopards or cheetahs, according to the model (Figure 4, see Appendix). Using the output from the ecological model, I selected for areas within Namibia that earned a ranking of 60 or greater for leopards and 50 or greater for cheetahs, as the focal regions of subsequent weighted overlays involving human-induced parameters (Figures 3k-l, 3s-z, 3aa). Because the overall goal of successful translocation is the same for both cheetah and leopard, the threats from human-induced parameters were weighted according to the same scale.

- ***Urban encroachment and human population densities*** – Ideal translocations for both cheetah and leopard should take place as far away from potential urban encroachment and high population densities as possible, to avoid further conflict. Therefore, I allotted the highest scaled preference to areas with low urban

encroachment and population densities, with tapering scale factors as densities and encroachment increases.

- ***Distance to major and minor roads*** – From personal accounts at N/a'an ku sê and several studies documenting road/vehicle fatalities to carnivores (Gubbi 2004; Gloyne & Clevenger 2000), I attributed major roadways to be an integral parameter when determining suitable areas for large carnivores. Areas within a 5km (leopards) or 10km (cheetahs) distance of any major roadway were completely excluded from the analysis, while the highest preference was weighted towards any area further than 40km from major roads. Minor roads were weighted with the opposite standards of major roads; i.e., the highest preference was given to areas closest to side roads. A cost is still associated with being in an area with a roadway, but often carnivores will utilize roadways as a least-cost path in movements throughout their territory, and have been known to facilitate dispersal from a group (Bailey 1993).
- ***Distance to known mining sites*** –GPS collar data (N/a'an ku sê 2009-2011) has shown that the introduction of mining development within an established leopard home range will instigate a shift in territory. Therefore I assigned the highest preference to areas further than 90km away from a known mining site, with decreasing preference closer to mines.
- ***Livestock densities*** – The occurrence of livestock in or around a translocation site is one of the most important aspects to consider when releasing a conflict animal. Areas without livestock and areas with extremely sparse livestock densities were given the highest preference/scale factor, tapering in preference as densities increase.
- ***Distance from known protected areas and conservation lands*** – Though not required for a successful translocation, if a carnivore is released in or around a government-regulated protected area or private conservation land, the conflict animal will inherently come into contact with fewer livestock and human population in general, apart from tourists. I scaled preference to areas within or less than 5km

from a protected area, scaling down in preference as the distance away from a protected area increases.

The resulting output after overlaying weights from all said parameters are again ranked on a 0-100 scale in increments of 10. Values range from 0-70 (i.e. there are no areas within ecologically suitable areas that are 100% poor for leopard or cheetah habitat.) Another difference is that rather than thinking of a score of 100 as 'perfect' for habitat, 0 is now 'perfect;' in other words, the higher the value, the higher the cost for the leopard to inhabit or traverse this area (Figure 5, see Appendix). For the purposes of a translocation study, the resulting areas were restricted to locations that ranked a 20 or lower in value for leopards and 30 or lower for cheetahs. The remaining cells, which in theory should account for the highest suitability for either leopards or cheetahs, were then grouped together to form contiguous habitat patches for further suitability analysis.

Developing a Final Translocation Identification Tool

General conservation biology dictates that larger areas of suitable habitat for a given species are more ideal than smaller areas. CaTSuiT calculates the area of each patch, and selects for patches that are at least 450km^2 in size for leopards, or 1700km^2 for cheetahs, as shown in Figure 6 (see Appendix). I selected these minimum areas because they are the documented average range size for male leopards (Marker & Dickman 2004) and cheetahs in Namibia (Marker et al. 2008). I incorporated male range sizes in the model for a more conservative analysis, as female ranges tend to be smaller in size (Marker & Dickman 2004).

I incorporated the landowner survey data into the model, based on the area of tolerant farms within each patch with respect to how much area was surveyed compared with the area of the patch. Due to the opportunistic and geographically biased nature of sampling (Figure 7, Ripley K Test, see Appendix), it is important to account for farmland within each patch that has an unknown/unsurveyed tolerance level. Therefore, I developed an easily interpretable equation that produces values which represent tolerance with respect to uncertainty:

$$\frac{Tolerant\ Farm\ Area\ in\ Patch}{Total\ Surveyed\ Area\ in\ Patch} \times \frac{Tolerant\ Farm\ Area\ in\ Patch}{Total\ Area\ of\ Patch}$$

This equation produces an output that accounts for both the level of tolerance within the patch and, more importantly, for the confidence that a patch can be considered tolerant or intolerant due to a lack of survey responses in the patch. To determine if this equation produces the desired results depending on survey adjustments, I performed a simple sensitivity analysis by which various farms' responses were altered from tolerant to intolerant or unknown to a given tolerance ranking. Based on this analysis, a patch with many farms ranked as 'tolerant' (as opposed to semi-tolerant or intolerant) while also having a large proportion of surveyed *and* tolerant farms is given the highest ranking. Conversely, if a patch has relatively few farms surveyed in a patch, its tolerance ranking becomes greatly depreciated due to its high amount of uncertainty throughout the patch, regardless of the surveyed farms' tolerance level. Figure 8 (see Appendix) shows a hypothetical output from using this equation on a given patch.

Adjusting Output for Homing and Contact Farms

To refine the output of the model further, I adjusted the CaTSuiT to account for potential homing, as well as a useful output that lists the names of farms that should be contacted to discuss the translocation process. First, the tool is equipped such that a user can place a point on the map that represents the relative location where a problem carnivore was captured. The tool will then create a buffer of a desired radius (again input by the user), and then run the analysis for remaining available patches of an appropriate area (Figure 9, see Appendix). In the case of leopard translocation, studies have shown (N/a'an ku sê) that this species will typically adjust relatively quickly after release (N/a'an ku sê, observation), not requiring conservation managers to travel long distances from a capture site. Still, I recommend that leopards be displaced at least 100km from its capture site, to be sure that the individual does not successfully home to the farm where it was captured. In the case of a cheetah translocation, I recommend that individuals be displaced at least 300km from the capture site, since cheetahs have been documented to roam much further distances upon release (N/a'an ku sê, observation).

CaTSuiT then selects for the farms (from a shapefile consisting of all freehold farms, conservation lands, and protected government land) that overlap with any of the produced habitat patches (Figure 10, see Appendix). From this output, conservation managers can contact the farms on a desired translocation patch to discuss the landowner's current attitude and potential willingness to accept a large carnivore on his/her property.

Figure 11 (see Appendix) depicts a box-and-arrow representation showing the step-by-step approach within the models of CaTSuiT.

Discussion

Model Results

Basic patch statistics are shown in Table 5 (see Appendix). Both leopard and cheetah models produced potential translocation patches with areas totaling roughly 300,000 km^2. The leopard model produced 19 more suitable patches than the cheetah model (52 compared with 33 patches, respectively), but the average patch size produced from the leopard model was smaller than that from the cheetah model (~6300km2 vs. ~8700km2, respectively). Roughly 50% of patches had at least one surveyed property within or intersecting it for both cheetah and leopard models, while both models produced an average proportional tolerance per patch of less than 10% (~5% for *P. pardus*, ~7% for *A. jubatus*). The inclusion of an example homing buffer zone from a hypothetical capture location produces causes relatively little change to these statistics for the leopard model. However, when the leopard model includes a buffer zone at the suggested distance of 300km, over 100,000km2 of potential habitat is lost, along with half of surveyed patches. Interestingly, of the patches remaining from the cheetah model, the proportional tolerance is higher, raising the average to ~15%.

From a conservation standpoint, the models show that there is still quite an extensive network of patches to which both cheetah and leopard can be translocated. These vast swaths of intact leopard and cheetah habitat are present most likely because of the opportunistic and adaptive nature of large carnivores, but also likely because there simply isn't a large human population in the majority of Namibia (2.54 people/km2, National

Planning Commission of Namibia, 2011). For leopards, there are still a large amount of patches remaining after a 100-kilometer capture area exclusion zone is introduced (Figure 9, 50 patches of 52 remaining, see Appendix). This further emphasizes the relative ease by which a conservation manager can translocate a leopard, due to their small home range sizes and ability to settle into a released area fairly quickly (N/a'an ku sê).

Conversely, the model predicts that cheetah translocations may become more difficult to carry out. If a cheetah is captured in northern Namibia, for example, options become extremely limited by the recommended 300-kilometer exclusion zone around the capture site, as well as the limited patch options found in southern Namibia for translocation (Figure 9, 20 of 33 patches available, see Appendix). Only 25% of these available patches (4 of 20) currently have an assigned tolerance ranking, which introduces more uncertainty. The cheetahs' need for large home range territory combined with a restricted ecological suitability confined mostly to the northern half of Namibia greatly reduces the number of potential relocation sites, if the capture site is in northern Namibia. Indeed, the likelihood of conflict cheetahs originating from Northern Namibia is quite high, considering that the majority of the country's population (~66%, National Planning Commission of Namibia, 2011) resides in legislative regions north of the capital region of Khomas, in central Namibia. The current space restrictions paired with the unknown tolerance levels of many patches demonstrates the great need for conservation managers to continue surveying Namibian landowners to a) determine their level of tolerance and b) work with potentially intolerant landowners to reduce their livestock losses, potentially improving tolerance.

It is important to note that many of the locations chosen by N/a'an ku sê as translocation sites up until now are within habitat patches predicted as suitable by the model (Figure 12, see Appendix). Disregarding any known levels of tolerance, suitable patches are produced that overlap or are nearby to N/a'an ku sê's properties and affiliates, such as NamibRand and Sandfontein Nature Reserves. Indeed, NamibRand virtually surrounds an entire patch, which, despite being one of the smaller patches suitable for cheetah, has the highest proportional tolerance ranking per area (over 40%). The high level of carnivore tolerance

and presence could be attributed to a higher income from wildlife and wildlife tourism and lower livestock biomass in these areas (Lindsey et al., 2013).

Current Limitations

The development of CaTSuiT, although applicable in its current state, is still limited by the data that can be used to create its initial ecological and human-factor models, as well as what is known about leopards and cheetah as far as how suitable a habitat can be. It is important to consider the following limitations before carrying out a translocation based the model's output.

The models used for this analysis are only as good as the data used to run the analyses. Although Namibia has one of the more complete geospatial datasets throughout the African continent in their Environmental Information Service system, the most recent surveys for any of the datasets used were performed in 2002, rendering the 11-year-old data more than likely outdated. It stands to reason, then, that many datasets such as population, livestock and herbivore densities, roads, and protected area boundaries have changed enough to alter the areas that are currently predicted to be suitable for translocation. Additional datasets not used in the current version of CaTSuiT, such as density distributions of other, smaller prey species like duiker or steenbok would add strength to the ecological suitability model. Until more reliable data is available, performing intensive on-site pre-release surveys is highly recommended to avoid allocating resources to transport a carnivore to an area only to find that it is no longer or was never suitable. This 'ground-truthing' would involve visiting the prospective translocation patch to assess whether the current data holds up to what would be considered suitable for translocation. For example, a team could document the addition of any new roads, the expanse of human population, and perform surveys to determine current densities of livestock and native herbivores. Once an initial accuracy assessment such as this is performed and shown to produce minimal error, CaTSuiT can then be used as a tool for which to base future translocations, or at least to improve predicted success of translocation in an area.

One major obstruction to any study incorporating large carnivore densities is the limited knowledge of species ranges and densities on a macro-scale. Presence/absence data is

extremely difficult to obtain if it even exists, due to the reclusive nature and expansive territories of many large carnivores, especially cheetah and leopard. If more reliable presence data existed, perhaps through the use of novel approaches like the Footprint Identification Technique (FIT) developed by WildTrack (2008), we could perform more robust analyses with statistical models. Maximum Entropy modeling (MAXENT), Generalized Linear Modeling, and Random Forest modeling (via BIOMOD, R), rather than solely relying on expert opinion based on individual studies and collective knowledge, could produce altered habitat patches that reflect the reality of current landscape features.

Another issue surrounding the current state of the CaTSuiT involves the reliability of the tolerance ranking assigned to each habitat patch. The survey results attached to each respective farm is administered on an opportunistic basis; i.e., as N/a'an ku sê happens to encounter each landowner, usually by the circumstance of translocating a conflict animal or understanding why there is/was a conflict in the first place. As a result, many interviewed farms tend to be clustered around the properties that N/a'an ku sê either owns or works closely with for conservation purposes (Figure 1), and are very blatantly geographically biased, as shown through a Ripley-K test for clustering (Figure 7, see Appendix). This bias is somewhat circumvented via the application of the tolerance calculation, so that areas with more knowledge of tolerance levels are ranked higher than ones with limited data. However, tolerance levels are also limited by the fact that each property is assigned a static tolerance ranking regardless of species. Lindsey et al. (2013) has found that in general, landowners are more tolerant of leopards than cheetah, for example, but this information is not included in our tolerance calculations. It is important to note that this ranking should not be used as a static number per patch; rather it is a roadmap that points conservation managers to where tolerance and attitude data is needed to better improve the chances of releasing an animal in an ecologically suitable *and* socially tolerant area, regardless of species. Only by successfully surveying every farm within a given patch will we be able to compare the tolerance rankings between patches with acceptable confidence.

Future Research and Improvements

Translocation-suitability models such as this could prove to be an extremely useful aid to conservation managers in other locations, focusing on other conflict species, especially in regions where a species has been for the most part eradicated, such as the Asiatic cheetah (*A. j. venaticus*) in Iran. Barring that an adequate amount of reliable data is collected on ecological and human-related parameters for the region, and that a reliable amount of specific information is known about the life history and ecology of a given large carnivore, the latest format of CaTSuiT allows for substitution of current variables for parameters that fit the context of the study. Theoretically, conservation managers from Central or South America, for example, could perform translocations of problem jaguars (*Panthera onca*) and pumas (*Puma concolor*) based on a similar model pending a survivorship study is performed to determine the success of translocation as a viable conservation technique. For a more direct comparison, CaTSuiT could be utilized with relatively few adjustments for the translocation of native jaguar along the US-Mexican border, because the ecosystems in this region are comparable to those in Namibia. In this particular comparison, I would speculate that one of the major factors contributing to available habitat would be human populations and fragmentation of the landscape. Namibia's population is sparse enough for CaTSuiT to predict an extremely optimistic number of large habitat patches – this may not be the case in areas which are much more impacted by human development.

An important aspect of successful translocation is monitoring the influx of carnivores that a conservation organization places into an ecosystem, and the existing carnivore densities of a patch. If a habitat patch is identified as being suitable for translocation, it may be tempting to release several individuals of the same or other species, into that system. Some property owners happily allow translocated individuals onto their land, because they believe it will add value to their property as an ecotourism destination (N/a'an ku sê, observation), and may be more willing to accept individuals in the future. However, once the release of individuals in an area reaches perceived carrying capacity, competition between individuals and among species may increase, resulting in the emigration of individuals out of intended locations and into areas of either more (with less competition) or less (with more livestock/humans) habitat (N/a'an ku sê, observation). Determining the

appropriate number of carnivores per patch can become difficult, since one has to account for the differences in home range sizes between sexes and species, whether any previously released females have cubs, calculating a carrying capacity based on herbivore densities and area, etc. Therefore, to improve upon this tool, I recommend implementing a component that creates and adds to a record of previously released carnivores, with data on the species, sex, and estimated home range sizes to be used to alter the suitability rating of a patch.

Conclusion

Using Namibia as a case study, CaTSuiT is seemingly able to identify an extremely optimistic amount of available land for the translocation of both cheetahs and leopards, lending to the idea that translocations can be performed quite easily once suitable patches are recognized. However, it is imperative to keep in mind that translocations should still only be performed with a specific conservation goal in mind (such as saving an extremely small or rare population), and should not be a standard conservation tool if other methods of mitigating conflict can be reached. As generational shifts occur and conservation organizations reach out to landowners to help improve their farming practices, attitudes can and have been known to shift (N/a'an ku sê, 2013), reducing the perceived need to remove a carnivore from its native territory. Still, CaTSuiT serves as a basis to monitor and improve translocation success, and with future extensions to allow for a user to input newly surveyed farms (and which species they are intolerant of), while also being able to edit previously surveyed farms which have shifted tolerance, will be a valuable feature to improving the accuracy of the tool and its continued effective use in mitigating human-wildlife conflict.

Appendix

Figure 1: General Map of Namibia and locations of N/a'an ku sê properties/affiliates

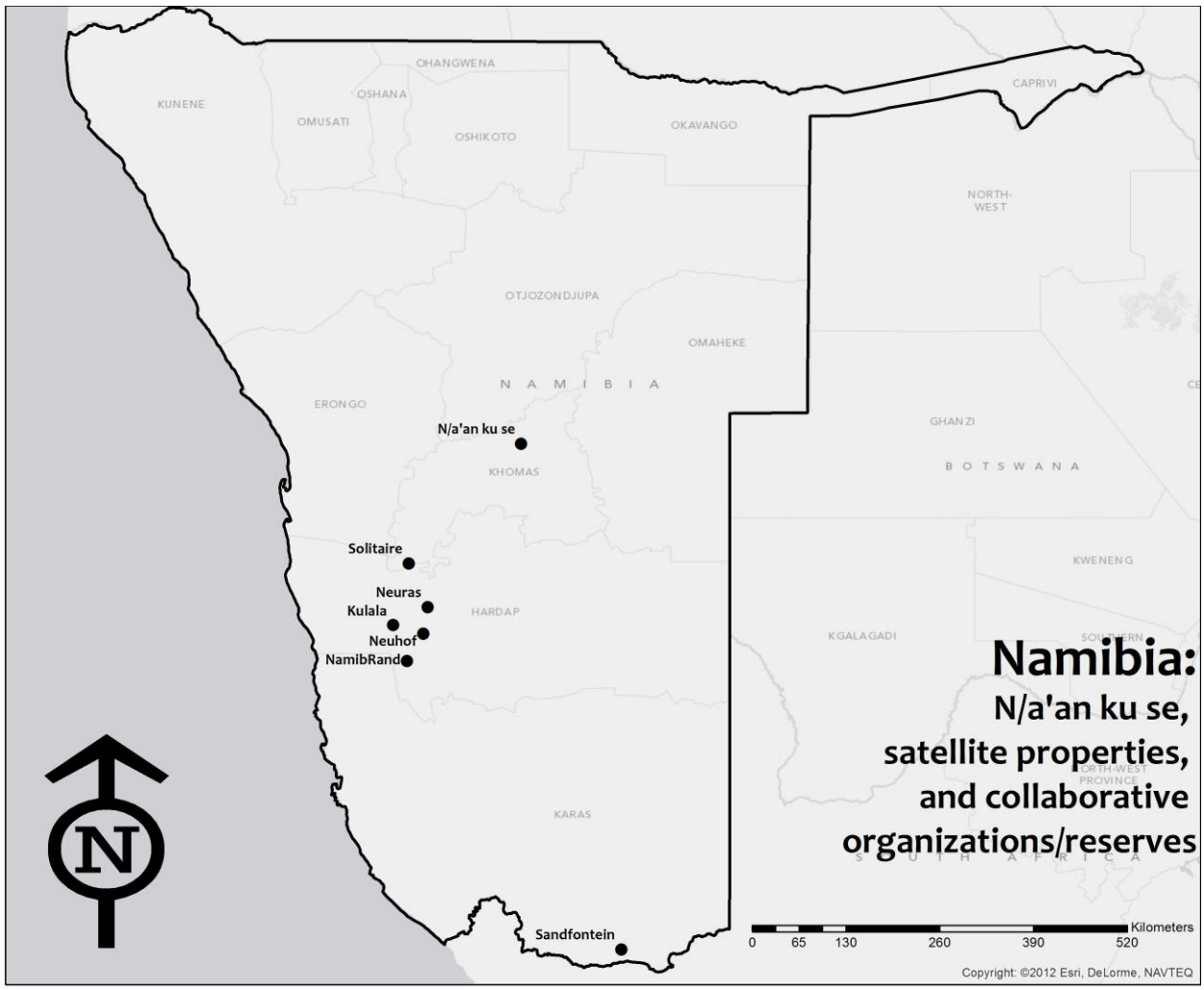


Table 1: List of original geospatial data used, data type, and source.

Initial Ecological Datasets			Other Datasets		
Name	**Type**	**Source**	**Name**	**Type**	**Source**
Rivers	Shapefile, Line	Namibian EIS	**Overall Livestock Density**	Raster	Namibian EIS
Vegetation Type	Shapefile, Polygon	Namibian EIS	**Karakul Sheep Density**	Raster	Namibian EIS
Herbivore Diversity	Raster	Namibian EIS	**Cattle Density**	Raster	Namibian EIS
Kudu Density	Raster	Namibian EIS	**Dorper Sheep Density**	Raster	Namibian EIS
Burchell's Zebra Density	Raster	Namibian EIS	**Goat Density**	Raster	Namibian EIS
Mountain Zebra Density	Raster	Namibian EIS	**Donkey Density**	Raster	Namibian EIS
Springbok Density	Raster	Namibian EIS	**Roads**	Shapefile, Line	Namibian EIS
Red Haartebeest Density	Raster	Namibian EIS	**Protected Conservation Lands**	Shapefile, Polygon	Namibian EIS
Oryx Density	Raster	Namibian EIS	**Mines**	Shapefile, Point	Namibian EIS
Carnivore Diversity	Raster	Namibian EIS	**Population Density**	Raster	Namibian EIS
Spotted Hyena Density	Raster	Namibian EIS	**Urban Encroachment**	Raster	Namibian EIS
Leopard Density	Raster	Namibian EIS	**Freehold Farms**	Shapefile, Polygon	Namibian EIS
Lion Density	Raster	Namibian EIS			
Elevation	Raster	Namibian EIS			
Digital Elevation Model	Raster	USGS Earth Explorer			

Figure 2: Surveyed Farmland sorted by Landowner Tolerance. All maps use the spatial reference information presented here:

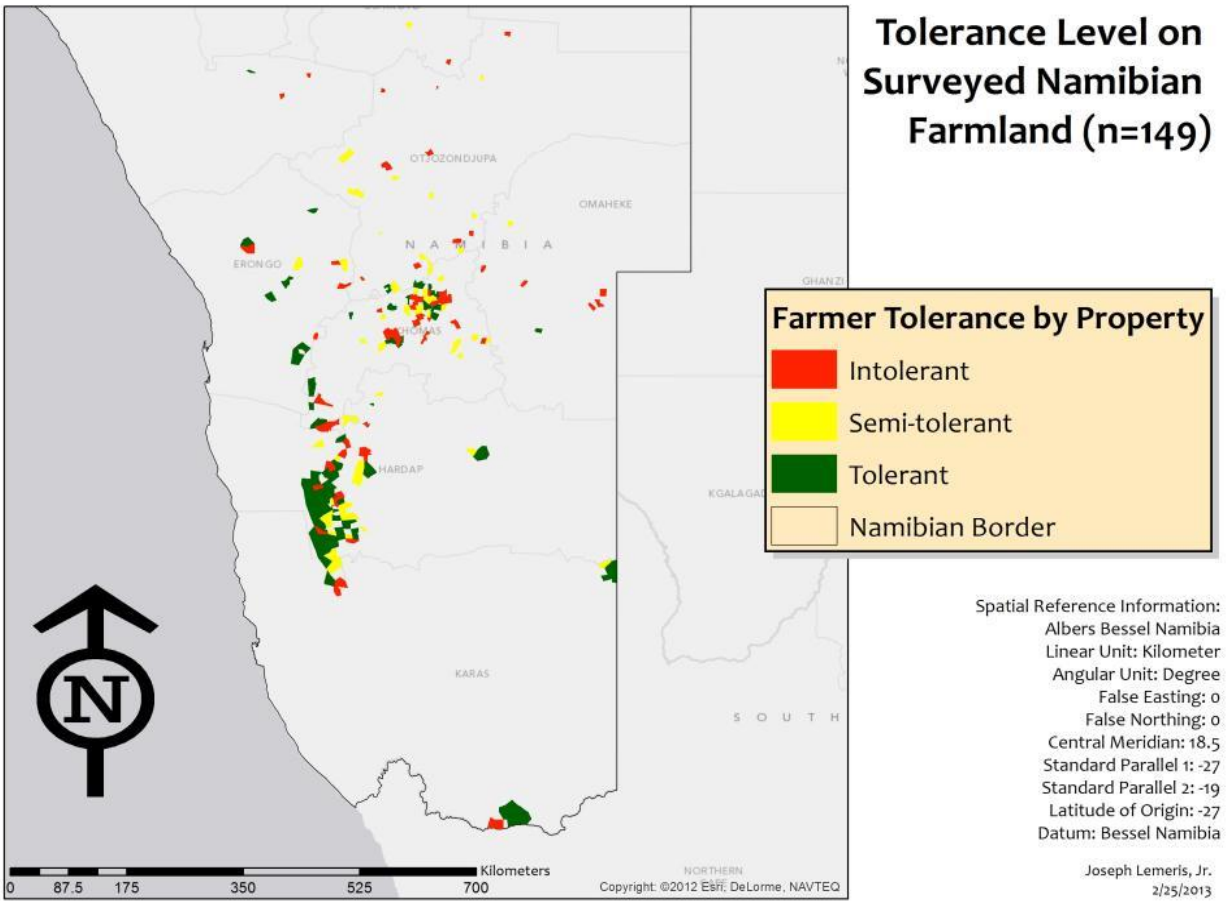
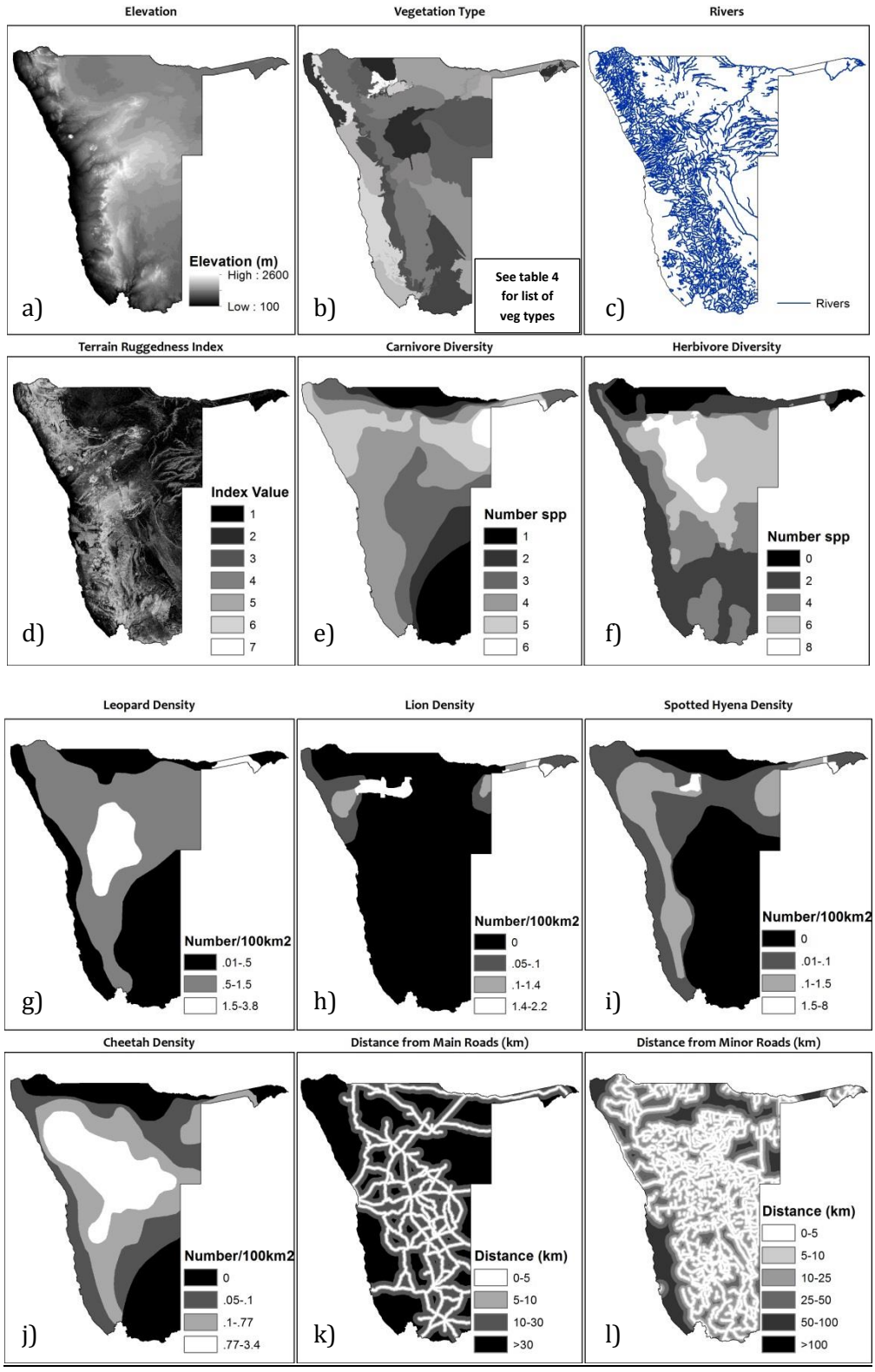
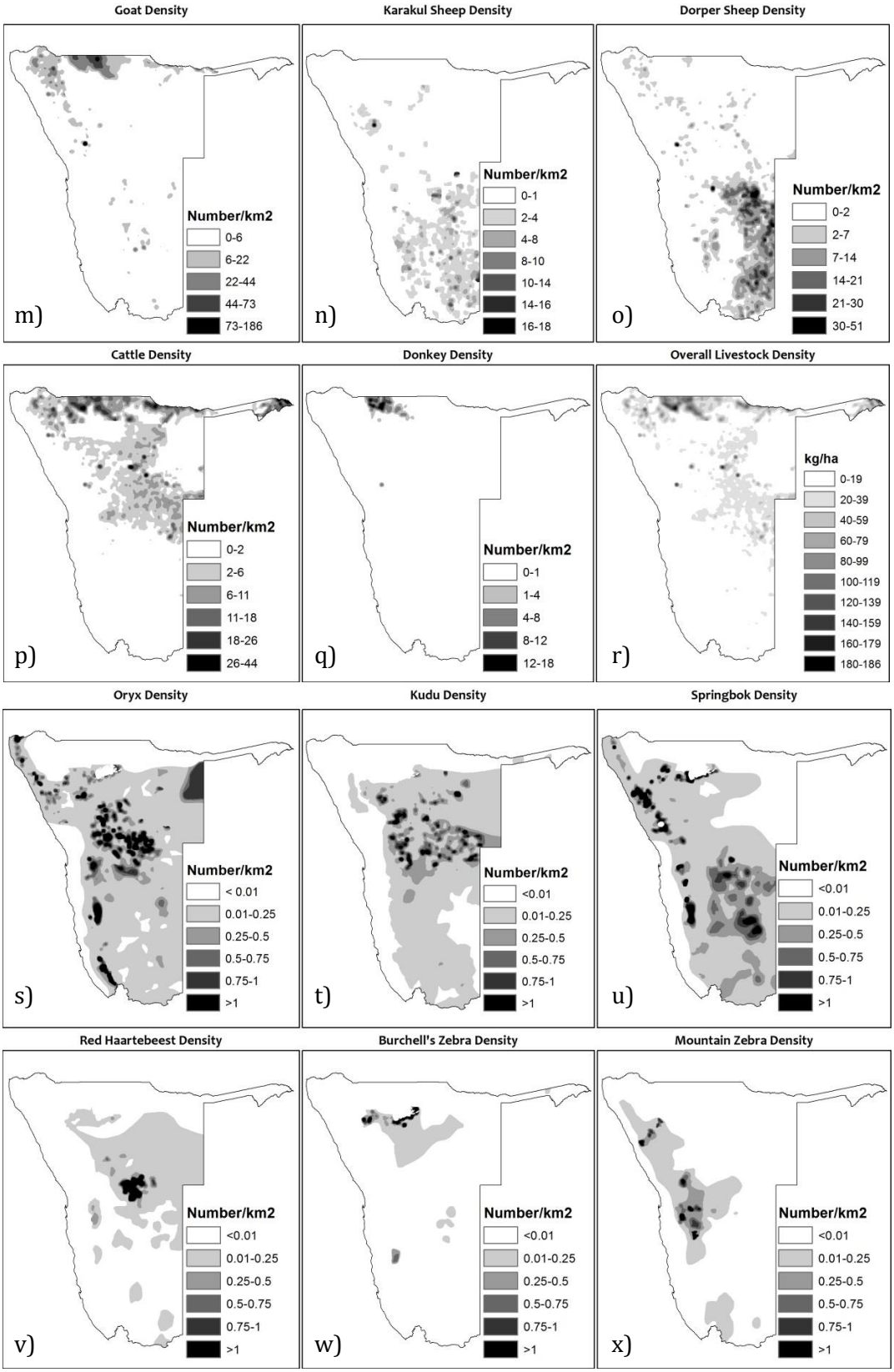


Figure 3 (a-aa): Input data derived from original geospatial data




Goat Density
Number/km2
0-6
6-22
22-44
44-73
73-186
m)
Karakul Sheep Density
Number/km2
0-1
2-4
4-8
8-10
10-14
14-16
16-18
n)
Dorper Sheep Density
Number/km2
0-2
2-7
7-14
14-21
21-30
30-51
o)
Cattle Density
Number/km2
0-2
2-6
6-11
11-18
18-26
26-44
p)
Donkey Density
Number/km2
0-1
1-4
4-8
8-12
12-18
q)
Overall Livestock Density
kg/ha
0-19
20-39
40-59
60-79
80-99
100-119
120-139
140-159
160-179
180-186
r)
Oryx Density
Number/km2
< 0.01
0.01-0.25
0.25-0.5
0.5-0.75
0.75-1
>1
s)
Kudu Density
Number/km2
<0.01
0.01-0.25
0.25-0.5
0.5-0.75
0.75-1
>1
t)
Springbok Density
Number/km2
<0.01
0.01-0.25
0.25-0.5
0.5-0.75
0.75-1
>1
u)
Red Haartebeest Density
Number/km2
<0.01
0.01-0.25
0.25-0.5
0.5-0.75
0.75-1
>1
v)
Burchell's Zebra Density
Number/km2
<0.01
0.01-0.25
0.25-0.5
0.5-0.75
0.75-1
>1
w)
Mountain Zebra Density
Number/km2
<0.01
0.01-0.25
0.25-0.5
0.5-0.75
0.75-1
>1
x)

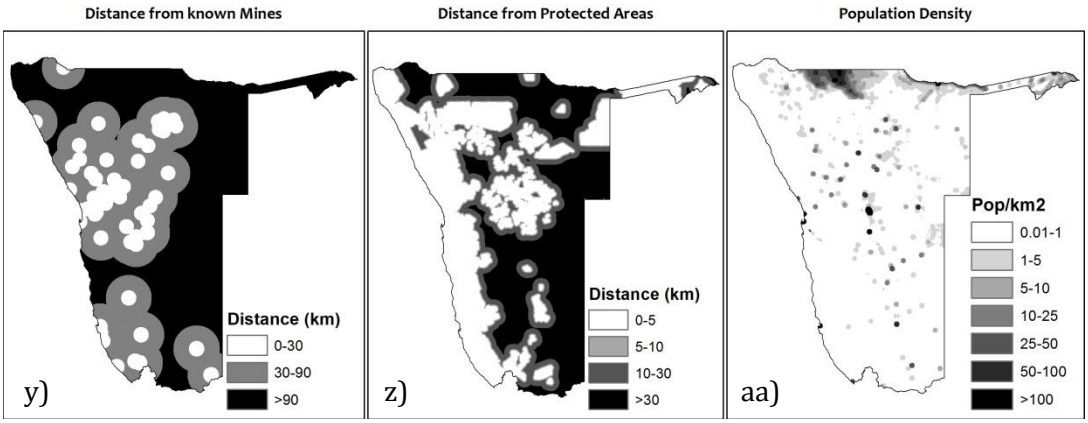
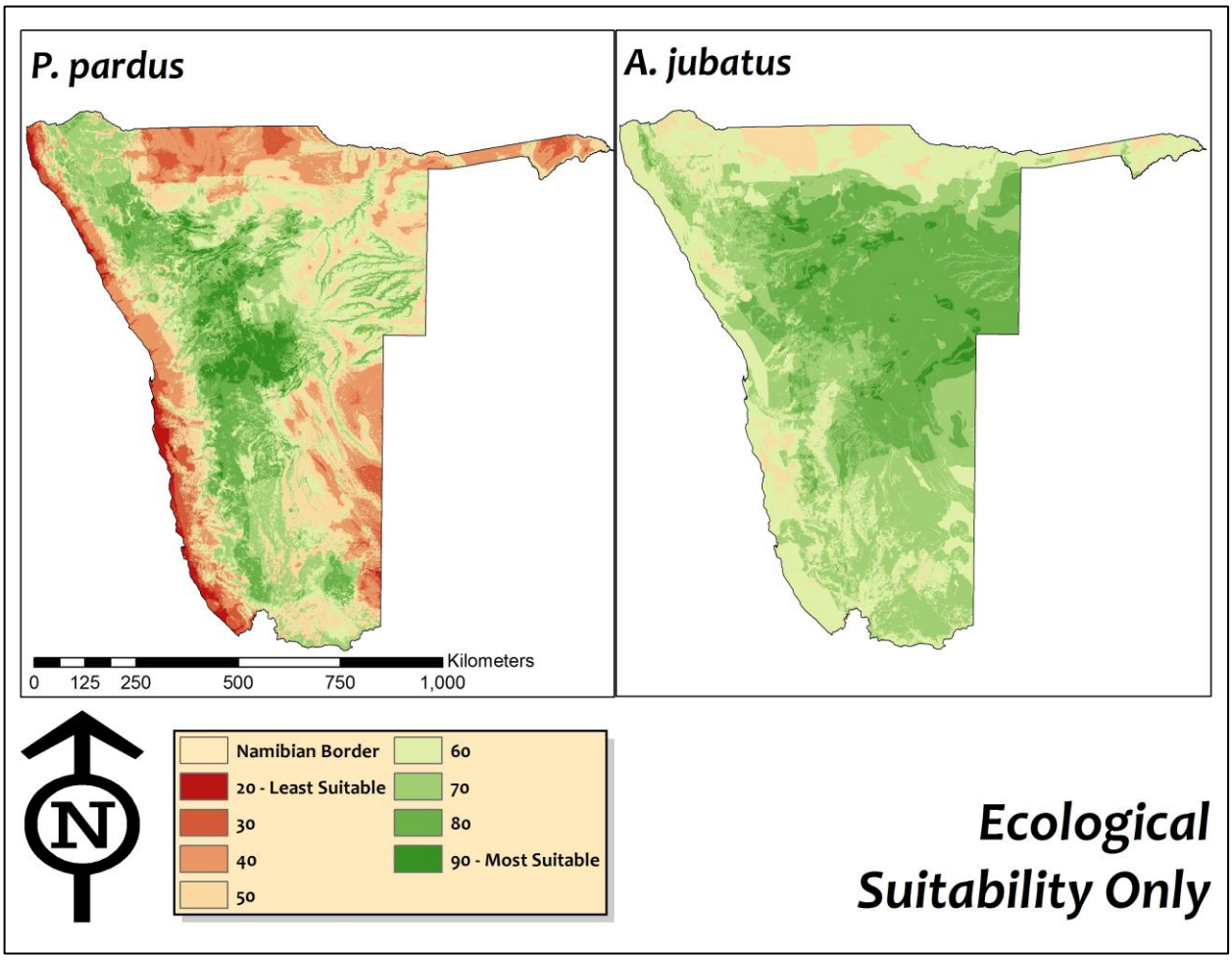


Table 4: Vegetation Type Codes & Names, used in Weighted Overlay models

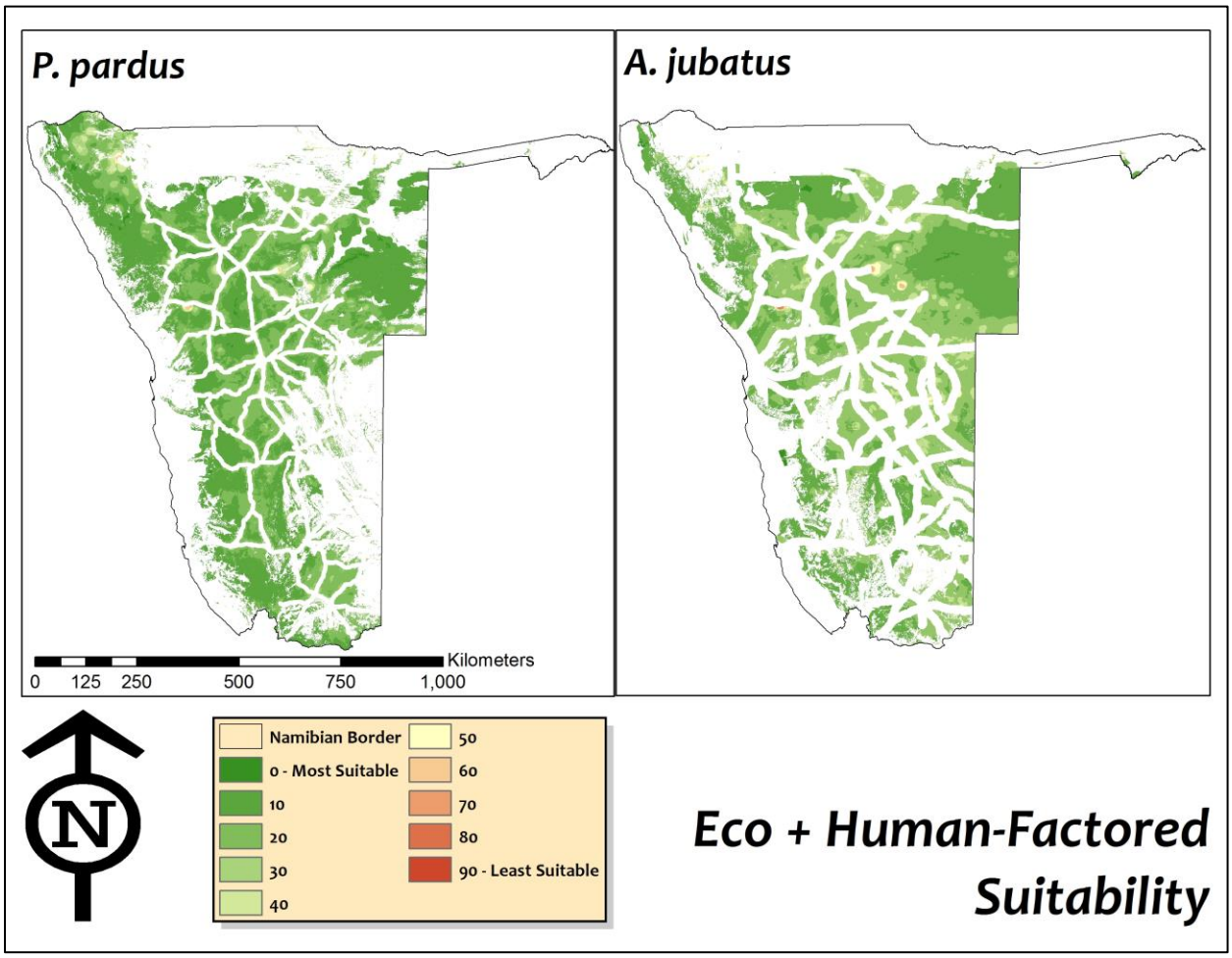
Code	Area (km^2)	Vegetation Type	Code	Area (km^2)	Vegetation Type
1	73831	North-eastern Kalahari woodlands	**17**	66163	Karas dwarf shrubland
2	14772	Cuvelai drainage	**18**	47226	Southern desert
4	6794	Mopane shrubland	**19**	24950	Desert/dwarf shrub transition
5	15978	Western Kalahari	**20**	20208	Succulent steppe
6	5381	Pans	**21**	57760	Southern Kalahari
7	2285	Etosha grass and dwarf shrubland	**22**	65551	Dwarf shrub savanna
8	43391	Karstveld	**23**	8817	Eastern drainage
9	70501	Western highlands	**24**	10477	Dwarf shrub/southern Kalahari transition
10	12979	North-western escarpment and inselbergs	**25**	60813	Central Kalahari
11	18413	Central-western escarpment and inselbergs	**26**	66361	Northern Kalahari
12	32002	Central desert	**27**	42380	Thornbush shrubland
13	20819	Northern desert	**28**	1817	Omatako drainage
14	3812	Caprivi Floodplains	**29**	1502	Okavango valley
15	4594	Caprivi mopane woodland	**30**	23744	Highland shrubland
16	355	Riverine woodlands and islands			

Figure 4: Ecological Habitat Suitability for Leopard[a] and Cheetah[b]



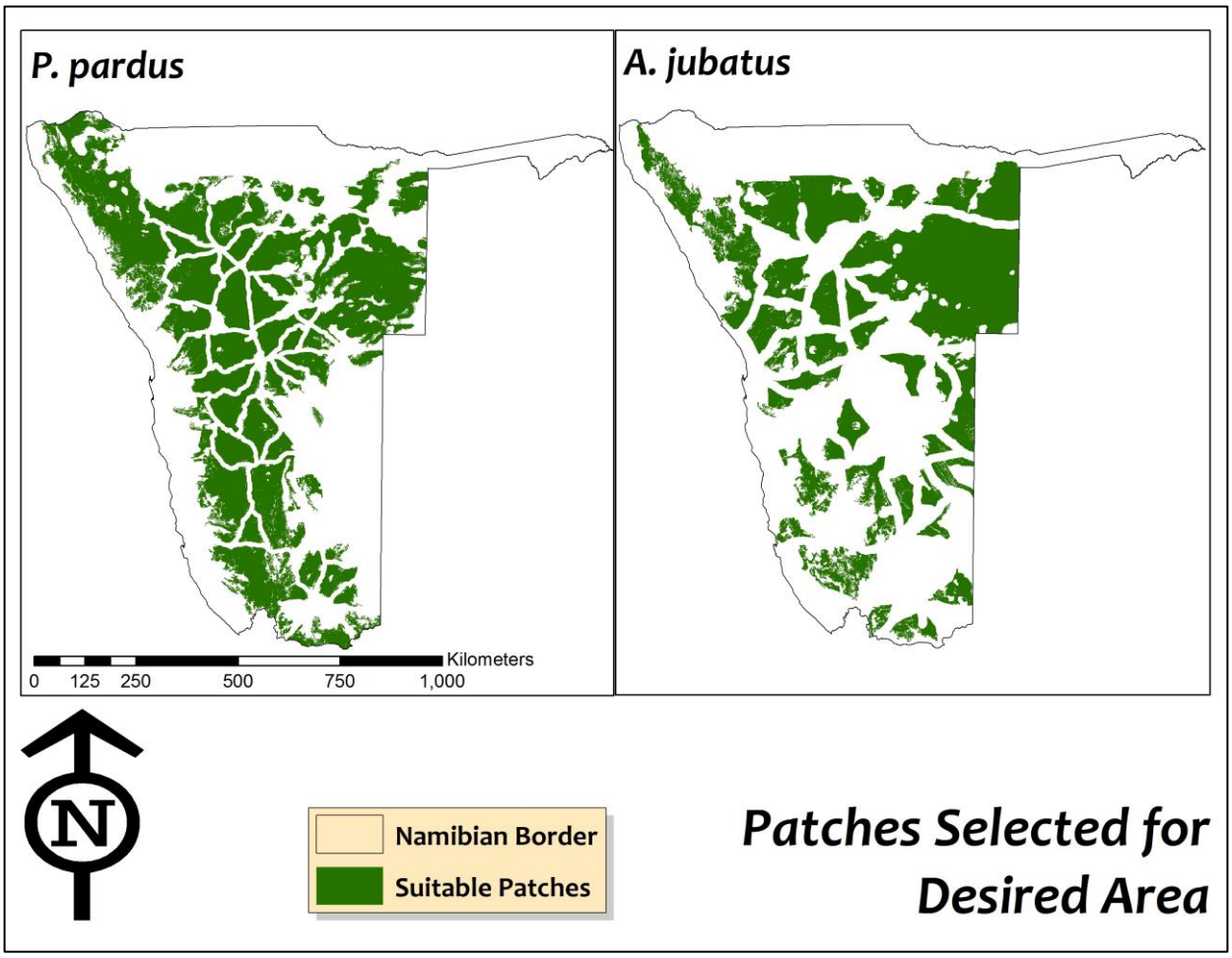
[a]*P. pardus*
[b]*A. jubatus*

Figure 5: Ecological and Human-Factored Habitat Suitability for Leopard[a] and Cheetah[b]



[a]*P. pardus*
[b]*A. jubatus*

Figure 6: Suitable Habitat Patches of Appropriate Area for Leopard[a] and Cheetah[b]

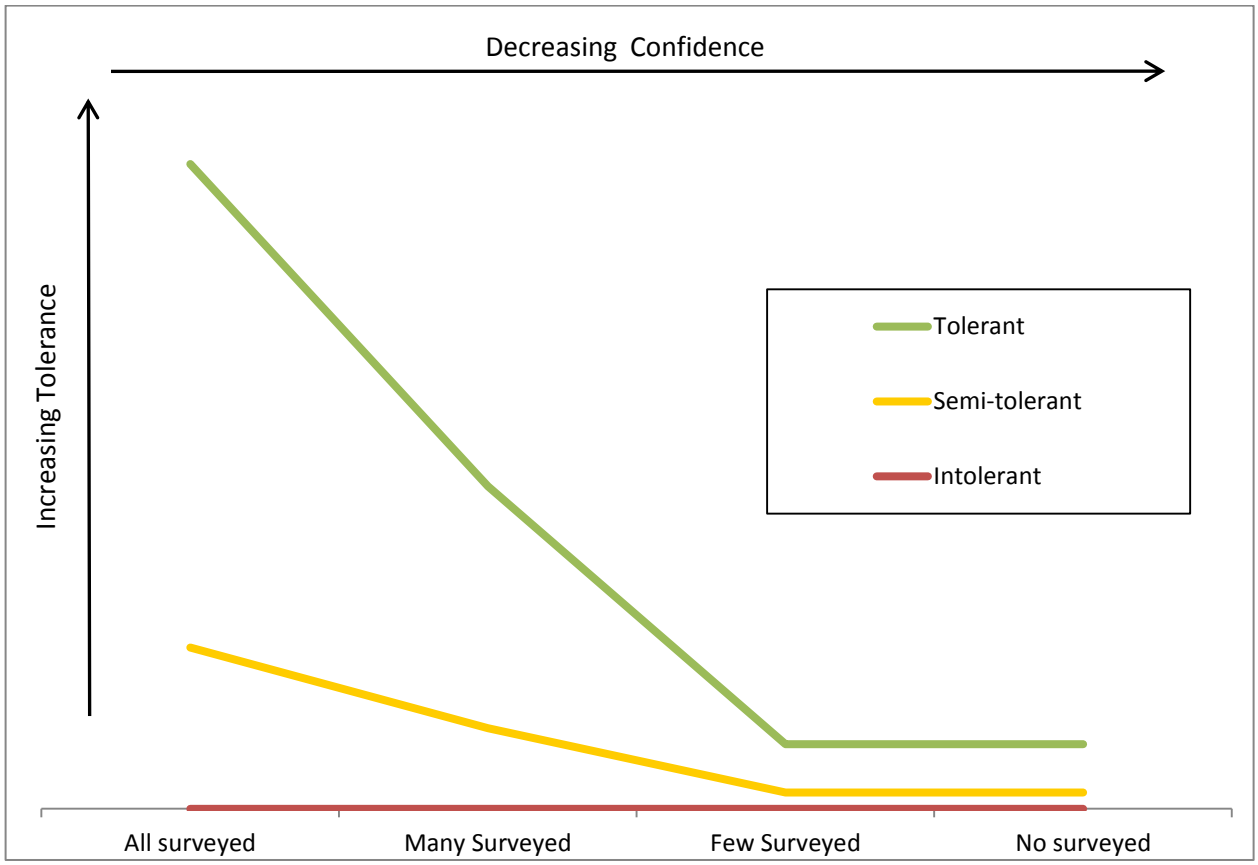


[a]*P. pardus*
[b]*A. jubatus*

Figure 7: Ripley K Test of Sampling Bias

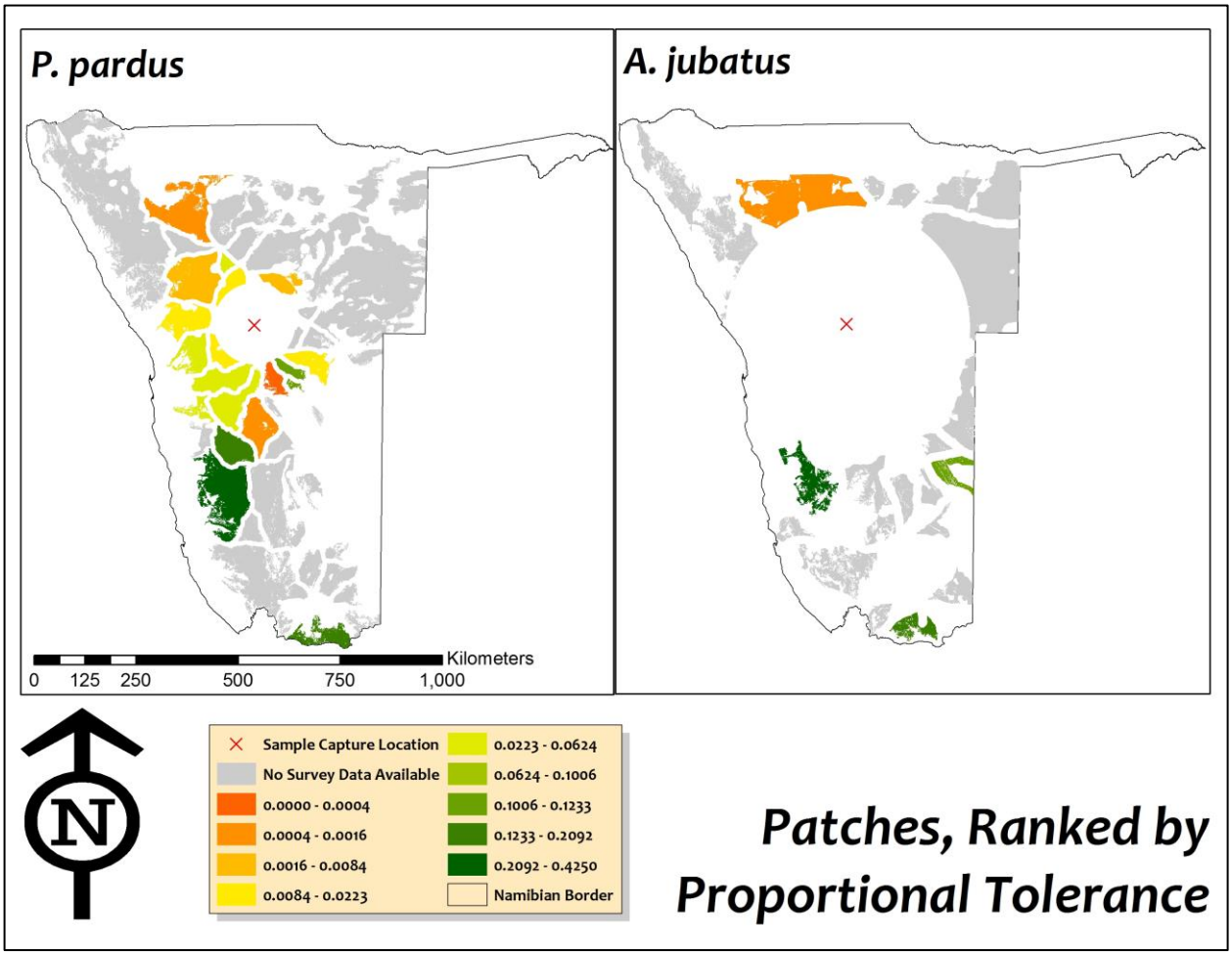
Note: The curved nature of the observed k-function implies clustering within the sample.

Figure 8: Simulation of Tolerance Model



Note: Areas with high tolerance and confidence are ranked exponentially higher than areas with less confidence and/or tolerance.

Figure 9: Example of Model Output of Suitable Habitat Patches for Leopard[a] and Cheetah[b] Given an Original Capture Location



[a]*P. pardus*

[b]*A. jubatus*

Note: Areas in green represent patches with abundant tolerant area with respect to patch area; areas in orange represent a higher uncertainty due to a lack of survey data (farms in orange patches may be tolerant or intolerant, but not enough is known about the entire patch; gray patches have no survey data.

Figure 10: Farms Intersecting Potential Habitat Patches (leopard)

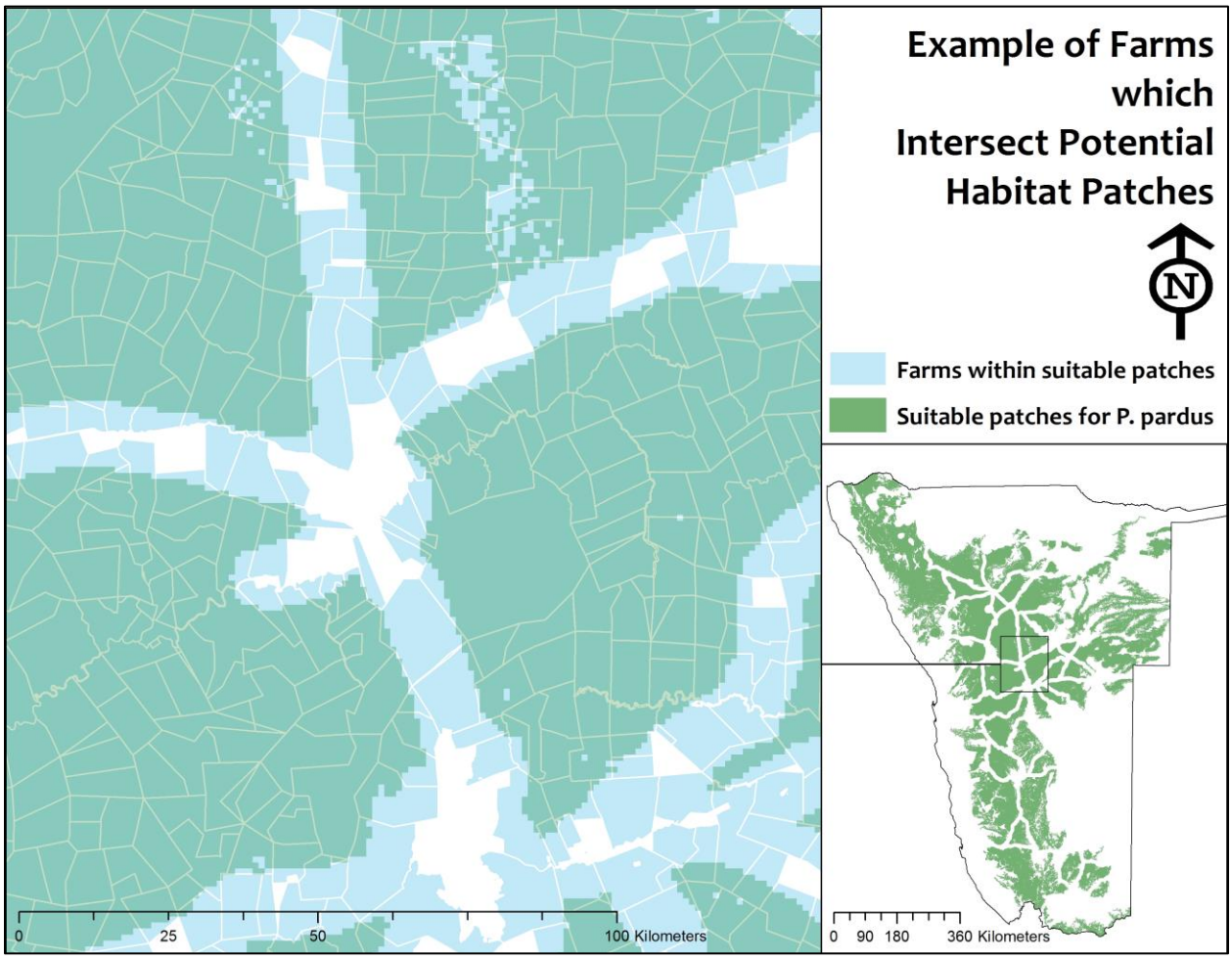


Figure 11: box-and-arrow flow chart of the full modeling processes in CaTSuiT

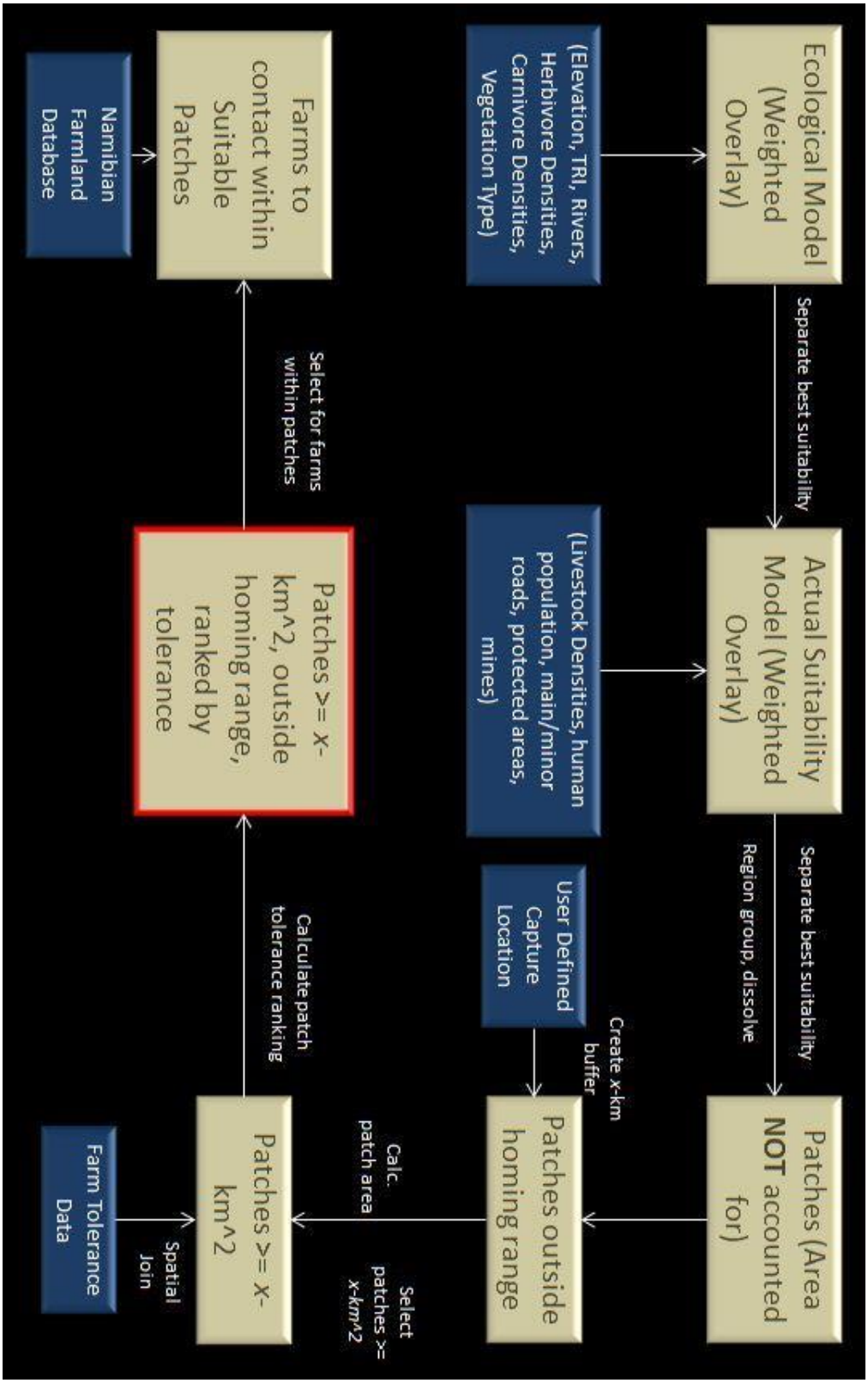


Figure 12: Overlay of Release Properties, Habitat Suitable for Cheetah, Habitat Suitable for Leopard, and Habitat Suitable for Cheetah and Leopard

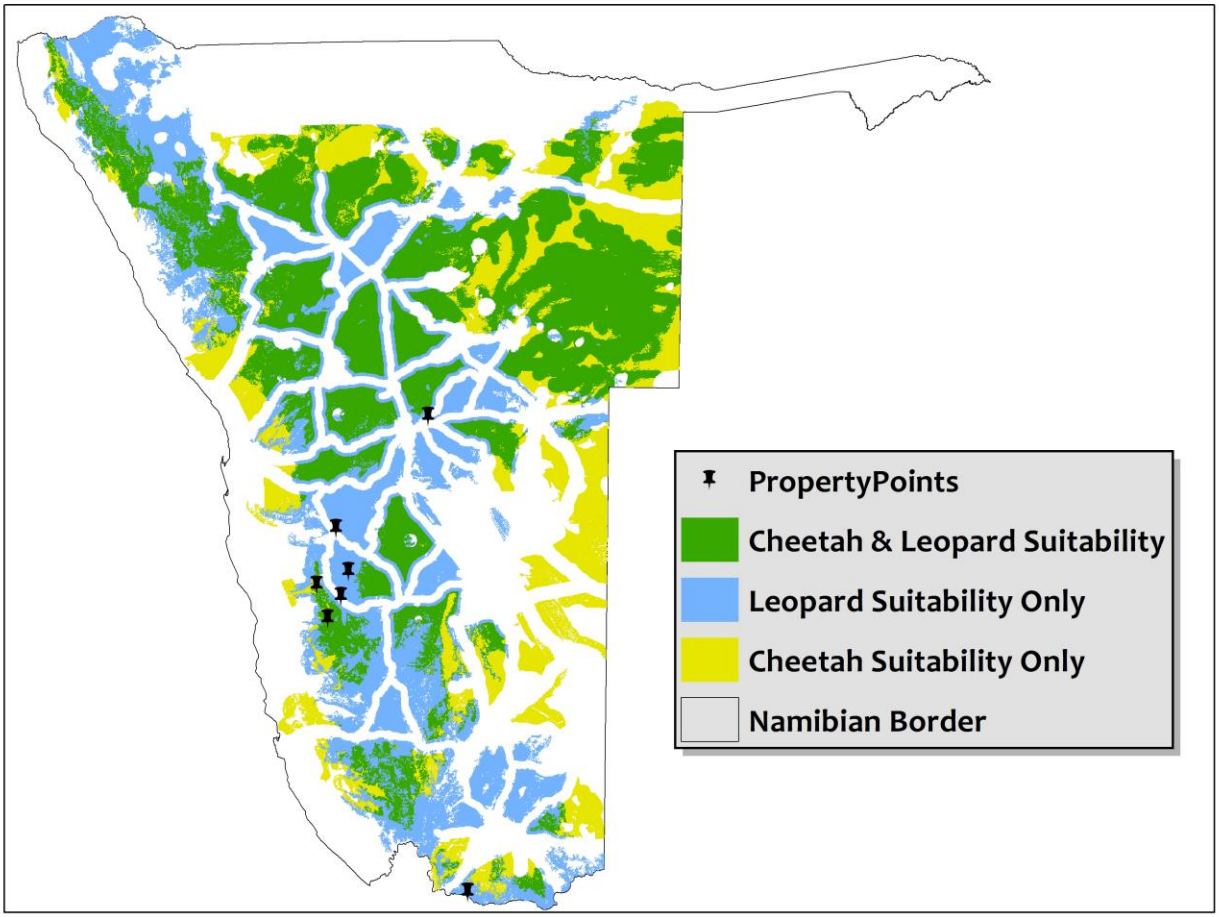


Table 5: Basic Model Output Patch Statistics

Patch Statistics	Leopard		Cheetah	
	Total	w/ Example Homing Buffer	Total	w/ Example Homing Buffer
Total Suitable Area (Ha)	336,561	314,707	288,971	171292
Number Patches	52	50	33	20
% Patches with any surveyed farms	55.8%	54.0%	48.5%	25.0%
% Proportional Tolerance	4.4%	4.2%	7.7%	15.2%

Acknowledgements

I would like to thank the faculty at the Nicholas School of Environment at Duke University who showed excellent guidance during the process of writing my Master's Project: Dr. Stuart Pimm (Masters Project adviser), John Fay (GIS technical adviser) and Andrew Jacobson (development). I would also like to give a huge thank you to Florian Weise at N/a'an ku sê, who provided me with data sources and the ideas necessary to initiate this project, and provided support throughout the process.

Funding Sources:

Thank you to the Kuzmier-Lee-Nikitine Fund, Student International Discussion Group-Lazar Internship Fund, and N/a'an ku sê Foundation for providing funding support for travel to and research in Namibia.

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