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Abstract: Leopards are the most widely-distributed wild cat on earth. They are found throughout most of sub-Saharan Africa and in smaller populations within the Middle East, southwest Asia, southeast Asia and north to the Amur peninsula of the Russian Far-East. Throughout this distribution, leopards have persisted in hostile areas outside of protected areas due to their secretive nature and adaptable ability to live in a variety of habitats including sub-urban environments. Leopards in Namibia are thought to have healthy population numbers, distributed across most of the country, primarily located outside of protected areas where depredation on livestock have caused many farmers to have a negative attitude towards the presence of leopards on their farms unless they pay their way. The trophy hunting of leopards is thought to be a potential source of income for the country where healthy leopard populations can sustain a regulated off-take based on the recommended CITES export quota. In 1997, Namibia was granted an annual quota of 100 export permits, which were increased to 250 in 2004. This figure was considered conservative, yet there was little information available to estimate the national population. Further, this annual quota was not filled until 2010 when reports of improper hunting practices caused the Namibian government and the hunting industry to review the national leopard population and hunting management strategies. In December 2010, the plans for a national leopard survey were undertaken. A questionnaire was distributed to 1,500 farmers to assess the distribution and relative abundance of leopards throughout Namibia. Nearly, 400 replies were received and based on these responses; we created a contoured map of leopard relative abundance that contributed to a focused population survey. Over the course of 2011, three study areas were chosen and surveyed using camera trapping and spoor tracking. These locations were chosen based our understanding of the local leopard population density and the willingness of farmers to assist with our survey. The results from these surveys were categorized into three density categories high (3.1 leopards/ 100km2), medium (2.0 leopards/ 100km2) and low (1.2 leopards/ 100km2). These density estimates were extrapolated across the contours determined from farmer questionnaires to produce a national estimate of 14,154 leopards (range 13,356- 22,706). The annual leopard hunting quota stands at 250, representing 3-4% of the total adult male leopard population. We recommend that this quota remain at the current level, with the introduction of an intensive monitoring program to distribute permits evenly across the landscape according to leopard density, previous hunting practices and trophy quality. The permit distribution, trophy quality and permit allocation systems are outlined in detail within this report. In high density areas, 0.5 adult male leopards per 1,000 km2 can be removed annually. In medium density areas, 0.35 adult male leopards per 1,000 km2 can be harvested. Low density areas are able to harvest adult male leopard at the lower rate of 0.21 individuals per 1,000 km2. Where trophy quality male leopards are consistently harvested, regions will retain or increase their permit number, however, where low quality trophies or insufficient records returned to MET permits will be reduced. This report is designed to provide MET with a detailed understanding of the national leopard population and a strategy for objectively monitoring the harvest of trophy hunted leopards throughout the country.

Namibian National Leopard Survey- 2011

Final Report

Andrew Stein, Ph.D. Survey Consultant

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Amon Andreas was the primary field researcher on this project. He was my liaison with the farmers and sent weekly reports on the successes and challenges of the program. His efforts kept the project running through many of the challenges described in this report. Also the trackers and various assistants that helped Amon set cameras and conduct spoor surveys in the field.

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Executive Summary

Leopards are the most widely-distributed wild cat on earth. They are found throughout most of sub-Saharan Africa and in smaller populations within the Middle East, southwest Asia, southeast Asia and north to the Amur peninsula of the Russian Far-East. Throughout this distribution, leopards have persisted in hostile areas outside of protected areas due to their secretive nature and adaptable ability to live in a variety of habitats including sub-urban environments. Leopards in Namibia are thought to have healthy population numbers, distributed across most of the country, primarily located outside of protected areas where depredation on livestock have caused many farmers to have a negative attitude towards the presence of leopards on their farms unless they pay their way. The trophy hunting of leopards is thought to be a potential source of income for the country where healthy leopard populations can sustain a regulated off-take based on the recommended CITES export quota. In 1997, Namibia was granted an annual quota of 100 export permits, which were increased to 250 in 2004. This figure was considered conservative, yet there was little information available to estimate the national population. Further, this annual quota was not filled until 2010 when reports of improper hunting practices caused the Namibian government and the hunting industry to review the national leopard population and hunting management strategies.

In December 2010, the plans for a national leopard survey were undertaken. A questionnaire was distributed to 1,500 farmers to assess the distribution and relative abundance of leopards throughout Namibia. Nearly, 400 replies were received and based on these responses; we created a contoured map of leopard relative abundance that contributed to a focused population survey. Over the course of 2011, three study areas

were chosen and surveyed using camera-trapping and spoor tracking. These locations were chosen based our understanding of the local leopard population density and the willingness of farmers to assist with our survey.

The results from these surveys were categorized into three density categories- high (3.1 leopards/ 100km^2), medium (2.0 leopards/ 100km^2) and low (1.2 leopards/ 100km^2). These density estimates were extrapolated across the contours determined from farmer questionnaires to produce a national estimate of 14,154 leopards (range 13,356-22,706).

The annual leopard hunting quota stands at 250, representing 3-4% of the total adult male leopard population. We recommend that this quota remain at the current level, with the introduction of an intensive monitoring program to distribute permits evenly across the landscape according to leopard density, previous hunting practices and trophy quality. The permit distribution, trophy quality and permit allocation systems are outlined in detail within this report. In high density areas, 0.5 adult male leopards per 1,000 km^2 can be removed annually. In medium density areas, 0.35 adult male leopards per 1,000 km^2 can be harvested. Low density areas are able to harvest adult male leopards at the lower rate of 0.21 individuals per 1,000 km^2. Where trophy quality male leopards are consistently harvested, regions will retain or increase their permit number, however, where low quality trophies or insufficient records returned to MET permits will be reduced.

This report is designed to provide MET with a detailed understanding of the national leopard population and a strategy for objectively monitoring the harvest of trophy hunted leopards throughout the country.

INTRODUCTION

Leopards are the most widely distributed wild cat species on earth. The 9 documented sub-species are distributed from southern Africa through the Middle East, southeast Asia into the Russian Far-East inhabiting a variety of habitats (Bailey 1993, Nowell and Jackson 1994, Miththapala et al. 1996, Uphyrkina et al. 2001). Leopard populations in Asia are of particular conservation concern with many sub-species in need of conservation action (Nowell and Jackson 1994). In sub-Saharan Africa, leopard populations are generally thought to be healthy with the exception of populations in West and North Africa (Ray et al. 2005). Even within areas where leopards are thought to have healthy populations they are particularly difficult to count (Balme et al. 2009). The only continental estimate of 719,000 was the only previous attempt to assess sub-Saharan leopard populations and was based primarily on rainfall (Martin and de Melaneaur 1988). Many researchers contested these findings with region specific data that accounted for environmental impacts such as problem animal control and habitat fragmentation, known prey distributions and affects of sympatric competitors (Norton 1990). The result of this report was the early discussion of adjusting the African leopard from CITES Appendix I to Appendix II, allowing for a controlled harvest through trophy hunting. In 1997, 10 African countries were allocated permits from CITES for the export of leopard skins and products (CITES Notification Number 994). Though considered conservative, all of these permits were allocated without the benefit of scientific surveys, primarily due to a lack of reliable methods for surveying populations. Since the initial allocation, many countries have adjusted their permits with the benefit of more detailed information.

Of the countries in sub-Saharan Africa, Namibia has the greatest potential for maintaining wildlife populations with its vast open landscapes, low human population and conservation ethic. Large areas of the country remain as wilderness with much of the historic assemblages of species still present. In Namibia, leopard populations are thought to be stable or increasing in many areas of the country even where other large mammal species have been extirpated (Stein 2008). Despite conflicts between livestock and leopards, many farmers believe that leopard populations are increasing due in part to the reduction of larger predators, increased surface water for livestock and game and the particularly secretive nature of leopards (Stein et al. 2010). In 1997, given a lack of detailed information, the initial CITES export quota was conservatively set at 100 individuals until 2004 when the quota was increased by 150% to 250 (CITES Resolution Conf. 10.14 (Rev. CoP13)). That same year, the Namibian Large Carnivore Atlas was produced, which was the first attempt to use available tourist sightings for a greater understanding of large carnivore distribution and density (Hanssen and Stander 2004). Though the Carnivore Atlas was a strong first step to understanding the national leopard population, a call was put forward in 2010 for a more scientific national survey after the CITES quota was filled for the first time since the 2004 increase. With advances in non-invasive survey techniques for secretive species, the Namibian government has undertaken the task of estimating the national leopard population (Karanth and Nichols 2002, Balme et al 2009).

The objectives of the national leopard survey are to categorize regions of the country into sections of high, medium and low density and ascribe density estimates to each. These densities will be used to extrapolate a national density estimate with statistically generated confidence limits. These estimates will be used to prescribe a national quota recommendation. Lastly, we will outline the challenges to the leopard population, the role of trophy hunting and present a system for hunting permit allocation and benefit distribution within regional farming sub-units based on regional leopard density, farm size and land use, previous trophy quality and reported conflicts.

Study Areas

Survey Area 1

Survey area one was situated in the central Namibia between Okahandja and Otjiwarongo in the Mount Etjo region. The survey area was demarcated across five farms (Otjikoko Sud, Okatherute, Okosombuka, Etjo South, Omaha) and Erindi Game Reserve and covers area of 934 km^2. The area has different land uses, such as cattle farming, a large game reserve and one hunting farm. The vegetation is categorized as thornbush savannah. The area is mostly dominated by *Acacia* species; however the vegetation close to the Mount Etjo escarpment is dominated by *Terminalia* species. Two most dominant grass species are *Stipagrostis* and *Eragrostis*. The central Namibia receives an average rainfall of 350mm, however for the past four years there have been increased rains. Thus the current average rainfall might surpass the long-term documented average. The temperature in the central region ranges from 6- 36 degree Celsius.

A wide range of ungulates are present in this area including oryx (*Oryx gazella*), red hartebeest (*Alcelaphus buselaphus*), plains zebra (*Equus burchelli*) and kudu (*Tragelaphus strepsiceros*). However, less common game species are also present, such as eland (*Taurotragus oryx*), mountain zebra (*Equus zebra*), common duiker (*Sylvicapra grimmia*), springbok (*Antidorcas marsupialis*), steenbok (*Raphicerus campestris*), damara dik dik (*Madoqua kirkii*), and warthog (*Phacochoerus aethiopicus*). Erindi Game Reserve introduced many species otherwise absent from the area including waterbuck (*Kobus ellipsiprymnus*), hippo (*Hippopotamus amphibius*), elephant (*Loxodonta africana*) and blue wildebeest (*Connochaetes taurinus*).

Survey Area 2

Survey area two is approximately 7 km south of Windhoek along the boundary of the Khomas Hochland Mountains. The area contains 6 livestock farms (Lichtenstein North, East, South and West, Krumhuk, and Haigamas) and two game reserves (Gocheganas and Auas) covering 741 km^2. The dominant vegetation type is thorn bush savannah. The dominant tree species are *Acacia* spp., complemented by sparsely distributed *Boscia albitrunca*. Other tree species are also represented in this area but in low numbers. The *Stipagrostis* and *Eragrostis* species are the dominant grass species in the area.

As in area one, the long term mean annual rainfall is approximately 350mm with higher rainfall in recent years. Temperatures range between 6- 36 degree Celsius. The dominant ungulate species found in this area are oryx and mountain zebra. The mountain zebras are mostly found in Khomas Hochland Mountain. There is, however, a population of mountain zebra present within Gocheganas Game Reserve along the eastern boundary of the Khomas Hochland Mountains. All other species present in study area one are also represented in survey area two except for the species that were introduced in Erindi GR.

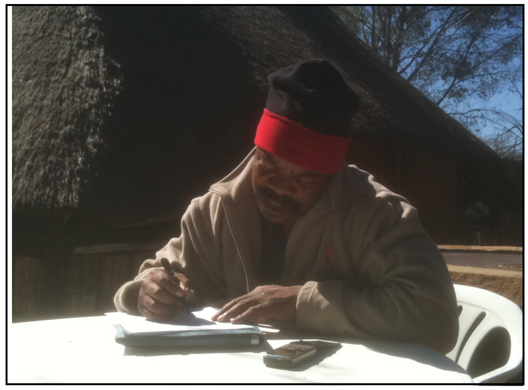
Survey Area 3

Survey area three is situated on the ecotone of desert and semi-desert habitats. The area is southwest of Maltahohe town and east of Namibrand Nature Reserve. The survey area was demarcated across 6 farms covering 517 km^2. All farms encompassing the survey area were converted from livestock production to tourism activities and wildlife conservation. However, farmers bordering the survey area on the east and southeast are still practicing livestock farming. The mean annual rainfall in this area is less than the previous areas (85mm), however, with increased rainfall in recent years, gravel plains have been converted to grassland. The average temperature ranges from 5-40 degree Celsius. The two most common ungulate species observed during the survey were oryx and springbok with ostriches (*Struthio camelus*) also present. The dominant tree species in this area are Camelthorn acacias (*Acacia erioloba*). Other species present in the area are *Salsola aphylla*, along dry rivers, *Boscia albitrunca* and *Boscia foetida*, *Commiphora* spp are sparsely distributed. Aloe (*Aloe dichotoma*) is present, but restricted to the mountains.

METHODS

Farmer Questionnaire and Leopard Relative Abundance Map

A national farmer questionnaire was mailed to 1,500 Namibian commercial farmers. The objective of this questionnaire was to gain information on leopard distribution and relative abundance as well as perceived conflicts with livestock and predator management. The locations of respondents were mapped using ArcGIS 9.0 and contours were developed according to farmers' perceptions of leopard relative abundance. Additionally, in areas with deficient data, we consulted wildlife researchers and the event-book for supplemental distribution information.



Camera-trapping Survey Design

We identified 3 study areas, based on previous data and farmer questionnaires for establishing our population surveys. We set between 20 and 30 camera-stations per study area. Each station had two cameras set at approximately 50 cm in height offset by 1 meter on opposite side of the roads, game paths and dry riverbeds commonly used by leopards. The cameras were set to medium/high sensitivity and the area between cameras was cleared of all debris to reduce the likelihood of false triggers. Each camera was set 1 to 2 m from the center of the path and took 3 photos each time the sensor is triggered. We did not set a delay between camera activation. No lure was used. Camera station spacing was based on the assumption that each station covers an area of 40 km^2 according to the minimum recorded home range size for Namibian leopards (Stein et al. 2011). Although based on this criterion the camera-stations could be spaced up to 3.55 km apart, due to constraints of farmer participation we decided to maximize the our efforts on farms that were willing to participate in the survey and placed stations at a higher density on those farms. The stations will be set for 60 days and checked once per week to download photos, check batteries and monitor the effectiveness of the location. After 2 weeks, if there were no photographs of leopards, we considered relocating the camera to an alternative location within 500m. If we determined that the cameras were taking suitable photographs, battery life is sufficient, we reduced our station visits to once every 2 weeks to minimize disturbance and fuel consumption. At the conclusion of the survey, we recalculated the buffer area (assumed area covered) for each station based on the half mean maximum distance moved (HMMDM) by individually identified leopards (Balme et al. 2009).

The leopard population estimates were generated in Program Capture using the heterogeneity model (Mh) within the capture-recapture analysis. These estimates were converted into densities from assumed home range size from previous research and HMMDM (Karanth 1995, Balme et al. 2009, Stein et al. 2011). Photos for all species will be entered into a database to assess relative abundance of species across the three survey areas at a later stage.

Spoor Tracking Design

We conducted spoor tracking surveys in each study area concurrent with our camera-trapping survey. The tracking began at first light and ran until 11 am. Two trackers and one driver conducted the spoor tracking (Stander 1998). One tracker sat on the bonnet of the vehicle and the driver maintained a speed of less than 20 km/ hr. When a spoor is encountered, the two trackers investigated the spoor to determine the species and collected demographic information. The driver recorded the species, demographics, location, odometer, and dominant vegetation. After the data was recorded, the tracker returned to his position on the bonnet and the survey continued. When the identified spoor left the road, the distance of road use was recorded. In cases where a spoor of the same species was encountered within 500 m of the last observation and the trackers could not determine whether this was a new individual, observation was recorded but removed from the analysis.

The information was entered into a database that generated spoor density (spoor/km) and spoor frequency (km/spoor). Using the spoor frequency, we calculated and plotted the coefficient of variation. A logarithmic regression line was fitted to the data to determine when an asymptote was reached and our tracking concluded. Based on previous studies, we used 35 observations as a guideline for generating population estimates from the spoor density once the coefficient of variation was reached in sandy substrates (Stander 1998, Balme et al. 2009, Funston et al. 2010).

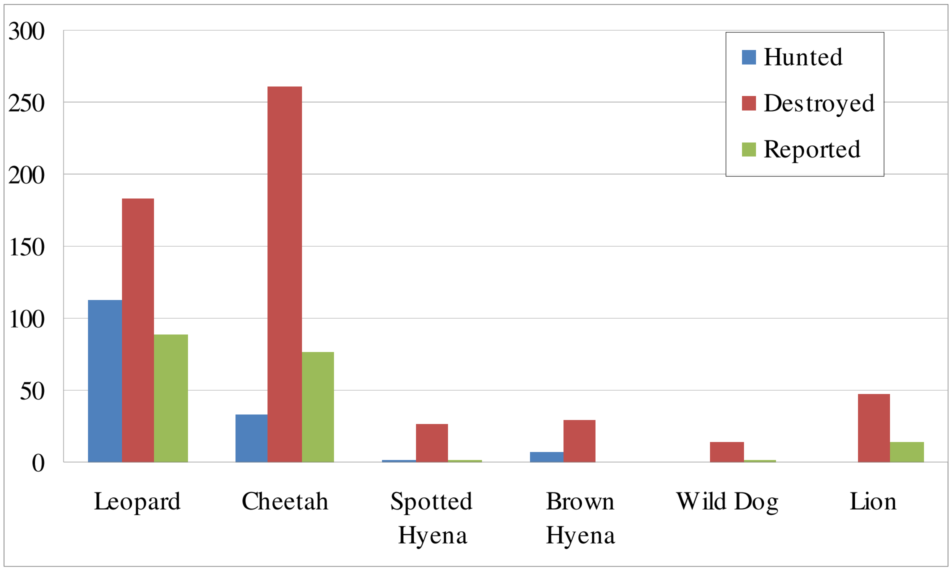
We calibrated spoor density to our camera-trap density estimates. Lastly, our spoor frequencies will be compared across study areas to compare relative abundance.

RESULTS

Farmer Questionnaires

A total of 398 questionnaires (27%) were received and entered from respondent farmers. Many farmers stated that they raised cattle (58.9%, n= 235), smallstock (35%, n = 139) and game (29%, n = 115). Most farmers stated that they frequently see signs of leopards (55%, n = 222), while 15% stated that they only seldom see sign (n = 61) and 27% (n = 110) state that they never see sign. Leopards were reported to be the carnivore with the highest rate of killing cattle followed by cheetahs. The mean number of cattle reported killed leopards annually was 726, ranging from 805 in 2008 to 646 in 2010. Cheetahs, however, were reported to kill smallstock more frequently, though leopards were reported to kill approximately 389 per year between 2008 and 2010. Leopards were reported to annually kill on average 1,926 head of game increasing the reported number from 1,795 in 2008 to 2,043 in 2010, whereas cheetahs were reported to kill approximately 2,976 head of game per year during the same period. Leopards were reported to be the most commonly trophy hunted large carnivore in the country (126- cheetah was the second highest at 34) and the second most commonly destroyed because of conflicts (183- cheetahs were the highest with 261; Figure 1). Less than 50% of these destroyed leopards were reported to MET (n = 89).

Figure 1. Leopards were the frequently killed of all large carnivores in Namibia as reported by 399 farmers.



The respondents represent a wide distribution from areas throughout the country including many within our three proposed study areas (Figure 2, 4). Most respondents were located in the area between Etosha in the north and Rehoboth in the south with fewer points along the boundaries of the country and the southern portion of the country. Secondary data from Namibian researchers supplemented our farmer questionnaire covering large areas of the country (Figure 3). Dr. Ortwin Aschenborn engaged a GIS expert (Sylvia Thompson from WWF) to assist us in creating maps of relative abundance contours from these questionnaires that assisted us in designing our population survey (Figure 2).

Figure 2. The location of respondent farmers.

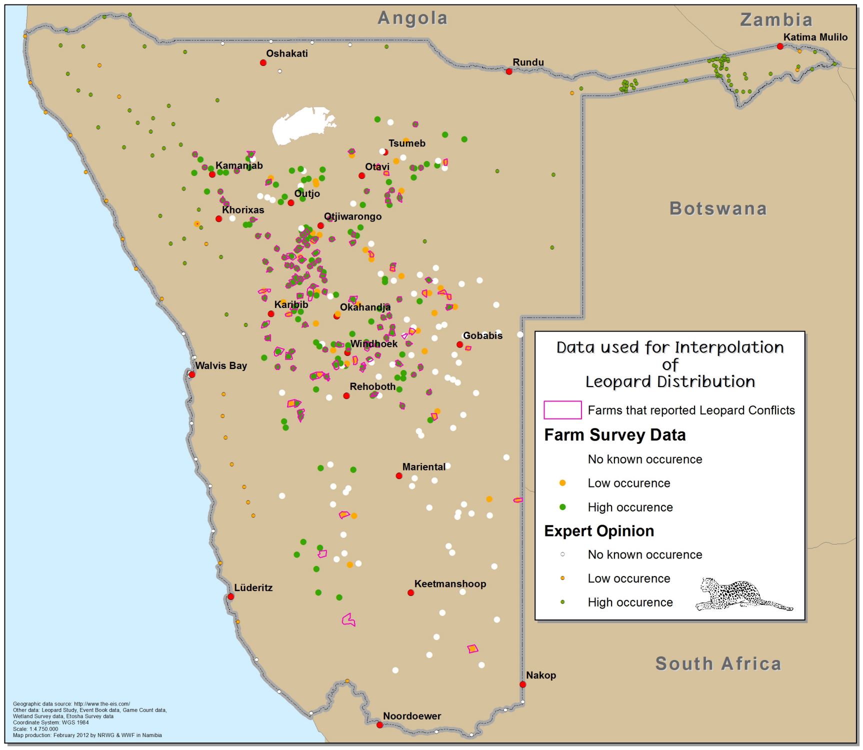


Figure 3. The location of various research studies that supplied relative abundance information for our contour map.

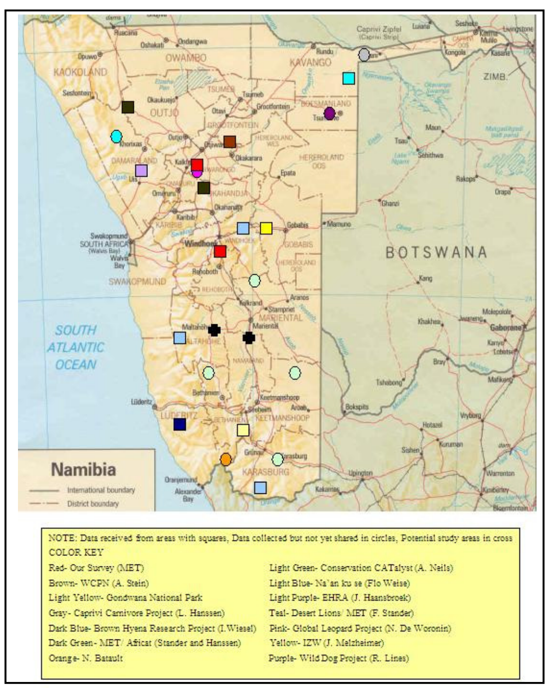
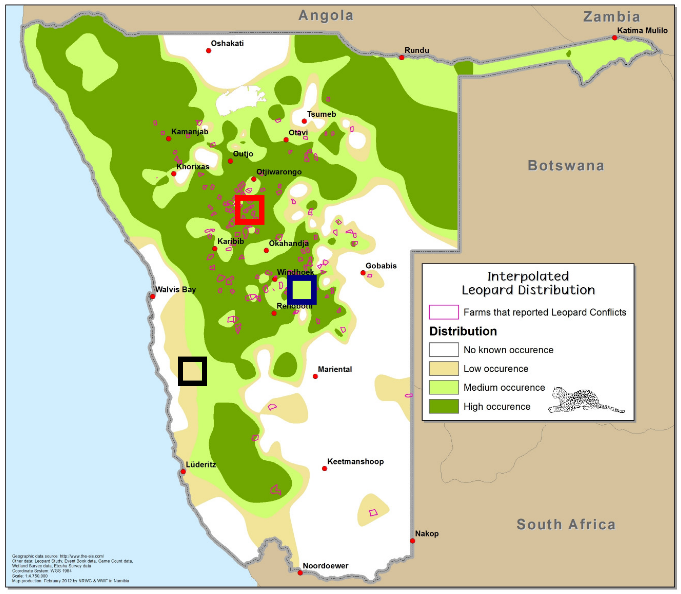


Figure 4. The contoured map of high, medium and low leopard density areas. Additionally, the location of our three study areas are demarcated here with red (study area 1), blue (study area 2) and black (study area 3).



Density Estimates

We calculated leopard density estimates for each of our 3 study areas based on our camera-trapping survey and spoor tracking (Figure 4).

Study Area 1

Camera-trapping

From March 27 to May 31, 2011, we set up 25 camera-station locations on 12 farms in study area one. At the completion of our camera-trapping survey for study area one, we have acquired 849 photos, reduced to 50 capture events of 21 individual adult/subadult leopards at 11 of the 25 stations over 60 days (Table 1). Of these leopards we have recorded 7 males, 11 females and 3 unidentified sex with recaptures of 13 individuals. We recorded 17 adults, 4 subadults and 1 cub.

We conducted a second round of identification in order to assess observer bias. Our initial analysis within Program CAPTURE yielded an estimate of 26 individuals (standard error= 4 and 95% Confidence Intervals of 23-34). The high rate of recapture provided a reasonable standard error and relatively narrow confidence intervals. We calculated density using two techniques for determining assumed area covered by our camera stations. First, with the assumed average home range size of 71 km^2 around each camera station (based on leopard home range size recorded near Waterberg), we have calculated an area of 934 km^2 (Figure 5) and a density of 2.8 leopards/ 100km^2 (Table 2). The second method we will use will be the Half Mean Maximum Distance Moved (HMMDM), which is determined by calculating the average largest distance recorded for individual leopards that were photographed in two stations or more. This mean maximum distance moved was determined to be 6 km from the 5 leopards that were recorded at 2 different stations. The HMMDM value therefore is 3 km, which was added as a buffer area surrounding the minimum convex polygon drawn around the outer edge of the station locations (Figure 6). then creating a minimum convex polygon around the stations with a buffer zone of this distance.

Table1. The total results of leopard camera and spoor surveys for each study area.

Study Area	Total Leopard Photo	Number Individual Leopards	Number of Stations	Leopard Photo Rate (/ 100 trapnights)	Leopard Estimate (/ 100 km^2)	Leopard Spoor Number	Km Driven	Leopard Spoor Density (/ 100 km)	Leopard Estimate (/100 km^2)
1	50	21	25	3.3	3.1	57	642	8.8	4.8
2	31	13	26	1.99	2.0	27	502	5.4	3.7
3	23	7	23	1.67	1.2	14	1525	1.0	??

Table 2. The density estimates for the three study areas with the calculated confidence intervals and extrapolated numbers based on estimated area for each density category.

Study	Density Estimate	95% Confidence Limits		Estimated Area	Extrapolated	95% Confidence Limits	
Area	#/ 100 km2	Low	High	100 km2	Number	Low	High
High	3.1	2.9	4.1	308,091	9,551	8,935	12,632
Medium	2.0	1.9	4.3	181,928	3,639	3,457	7,823
Low	1.2	1.2	2.8	80,393	965	965	2,251
Absent	0			238,091			
Total				808,503	14,154	13,356	22,706

Figure 5. The camera trapping survey design for study area one in the Mount Etjo region, using the circular home range buffer technique. The camera-stations (dots) and buffer area (circles) are demarcated over the farm boundaries.

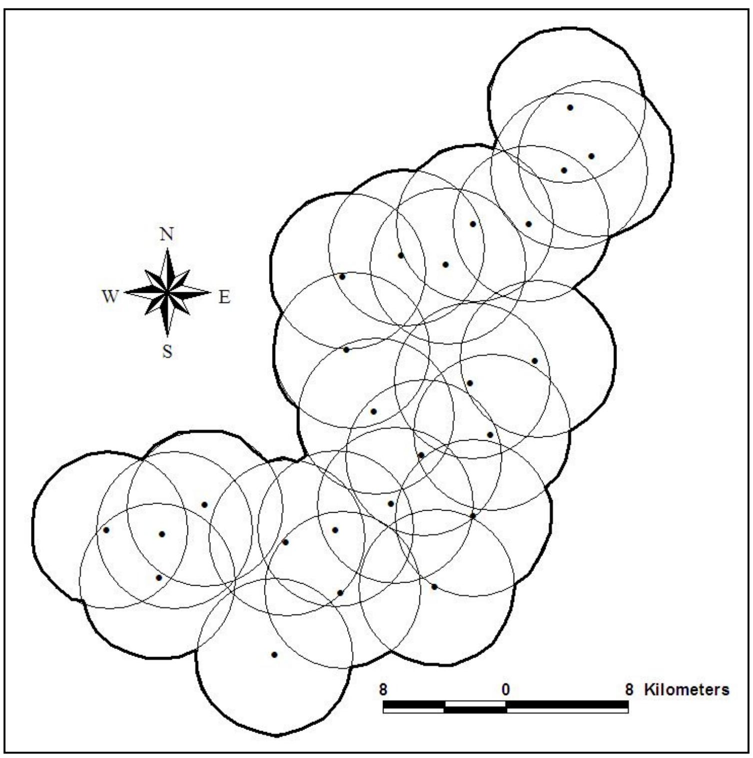
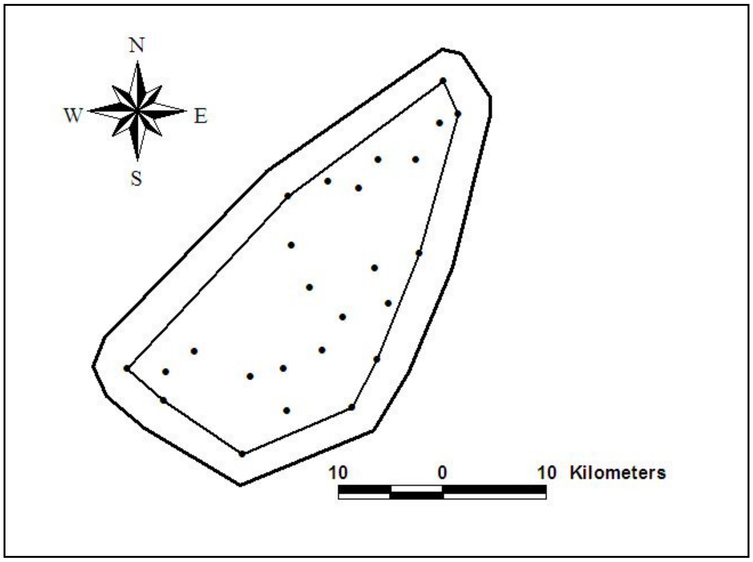


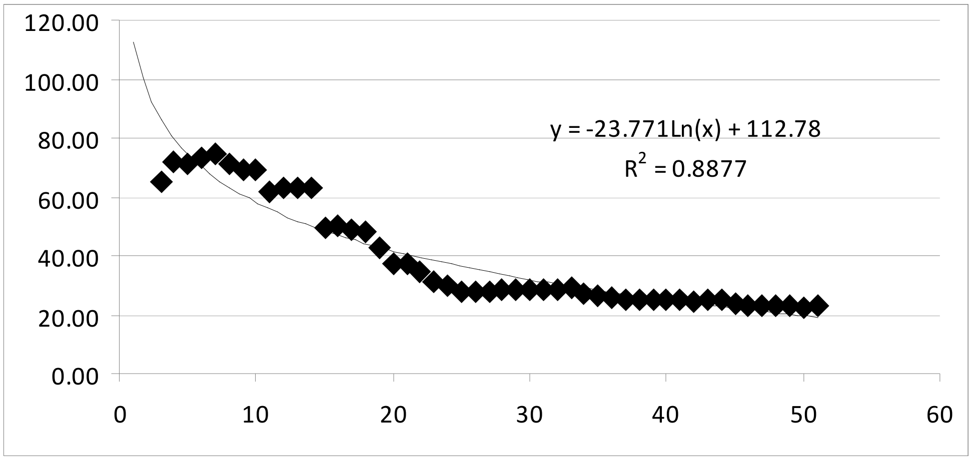
Figure 6. The camera-stations (dots) and buffer area (HMMDM- thick line) demarcated for study area 1 in northcentral Namibia.



Spoor Tracking

We recorded 57 spoor incidences while driving over 12 transects for 642 km. The average transect length of 27.9 km per transect (n = 23, range 6- 54 km; Table 1). There were 26 adult males, 8 females, 6 dependent cubs and 17 unknown recorded. We recorded an average distance between spoor at 8.9 km and spoor density is 8.8 spoor per 100 km- high estimates compared to other studies. Our coefficient of variation (the statistic which determines the precision of variation) reached an asymptote at approximately 30 observations at which point the average distance between spoor at 11.3 km and spoor density is 9.1 spoor per 100 km (Confidence Limits- 6.5; Figure 7). The logarithmic trend line fits the data reasonably well with an R^2 value of 0.89, showing that our model is appropriate. According to our spoor density and confidence limits, our population density was calculated to be 4.75 leopards per 100 km^2 (95% CI = 1.2- 8.3 leopards per 100 km^2, Funston et al. 2010).

Figure 7. The Coefficient of Variation (Y axis) for study area 1 calculated from randomly selected, recalculated spoor frequencies over the course of the survey. We determined that the coefficient of variation stabilized at 30 spoor samples.



Spoor Samples

Table 3. Population estimates calculated from spoor density in each study area based on the formula presented in Funston et al. (2010). For the upper and lower confidence intervals, the spoor density and population density estimate are stated. The estimates for study area 3 were calculated from preliminary data from a shortened survey (see study area 3- spoor tracking).

Study Area	Spoor Density	Mean Density	Upper 95% CI		Lower 95% CI	
			Spoor	Density	Spoor	Density
1	9.14	4.75	15.66	8.33	2.62	1.16
2	7.25	3.71	8.97	4.65	5.53	2.76
3	1.20	0.38	12.50	6.60	-10.10	-5.84

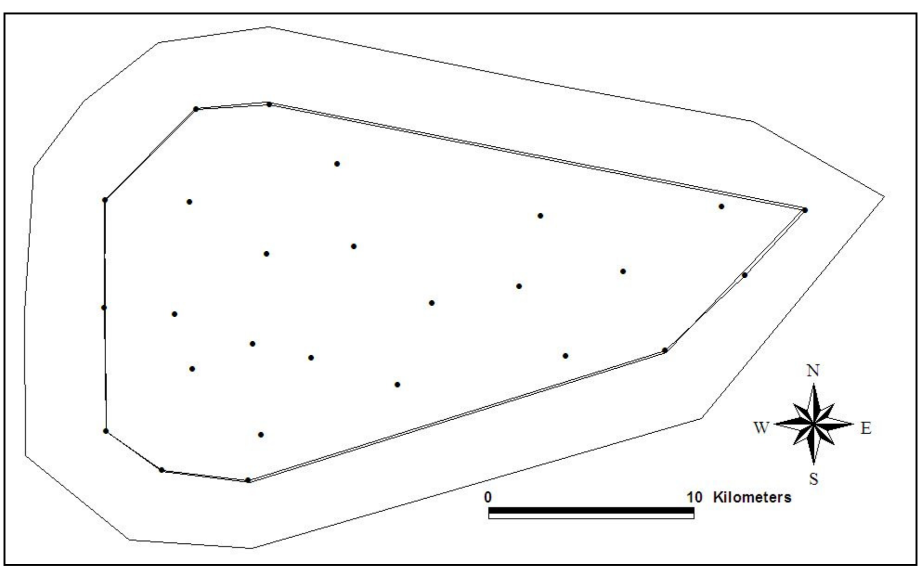
Study Area 2

<u>Camera-trapping</u>

From July 16 to September 13, 2011, we set 26 camera stations across 9 farms extending from the Khomas Hochland region in the west to the flat savannas to the southeast (Figure 3). Since our goal was to sample in an area of assumed medium density, we focused most of our stations to the savanna areas instead of the mountains where leopard density was expected to be higher. We captured 31 total leopard photo events of 13 individuals. Of these 13 individuals 8 were recaptured (range 1-6 recaptures). We collected photos of 6 males, 7 females total with 2 females having cubs. We recorded photographs of 2 cubs for one female and 1 cub for the other.

Of the 8 recaptured individuals with only 4 of them located in multiple stations (2 males and 2 females). We measured the mean maximum distance moved as 7.2 km (range 4.1-20 km) and the half mean maximum distance moved buffer calculated to 3.6 km. This buffer was created around the Minimum Convex Polygon for our camera-stations and covered an estimated 741 km^2 (Figure 8). Our analysis yielded an estimate of 15 leopards (SE= 4.0 and confidence interval of 14-32) and a density estimate of 2.02 leopards/100 km^2 (range 1.9- 4.3). This result is in line with our expected estimate for a medium population density for the country.

Figure 8. The camera-stations (dots) and buffer area (HMMDM- thick line) demarcated for study area 2 south of Windhoek.



Spoor Tracking

In study area two, we drove for 502.3 km recording 27 track incidences and 35 individuals. Of the 35 recorded individuals, 18 were adult males, 10 were females, 6 were dependent cubs and one unknown. Our coefficient of variation reached an asymptote at 27 observations. Our calculated leopard density and confidence limits for the Aris region was 3.7 leopards per 100km^2 (95% CI = 2.8- 4.7 leopards per 100 km^2, Funston et al. 2010).

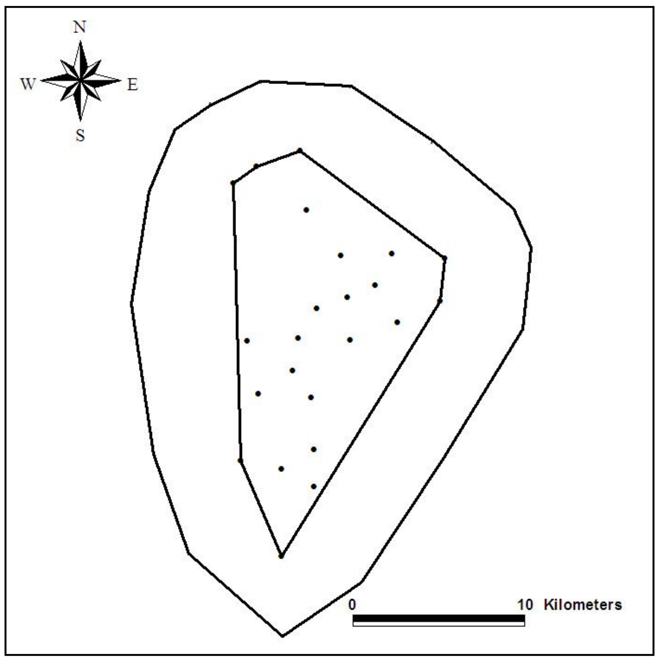
Study Area 3

Camera-trapping

From October 28- December 26, 2011, we set 23 camera stations across 5 farms in the Maltahohe region of southern Namibia (Figure 1). Based on farmer surveys and researcher input, we sampled this area expecting a low population density. We captured 7 total individual leopards out of 343 total leopard photos in only 5 stations. Of these 7 individuals, 2 were adult male leopards, 3 individuals were identified as females and 2 individuals were not identifiable as either sex. Four individuals were recaptured (range 2-5 recaptures).

Of the 4 recaptured individuals with only 3 of them located in multiple stations (2 males and 1 female). We measured the mean maximum distance moved as 9.1 km (range 5.4-13.1 km) and the half mean maximum distance moved buffer calculated to 4.55 km. This buffer was created around the Minimum Convex Polygon for our camera-stations and covered an estimated 517 km^2 (Figure 9). Our analysis yielded an estimate of 6 leopards (SE= 1.6 and confidence interval of 6- 14) and a density estimate of 1.2 leopards/ 100 km^2 (range 1.2- 2.8). This result is in line with our expected estimate for a population at low density for the country.

Figure 9. The camera-stations (dots) and buffer area (HMMDM- thick line) demarcated for study area 2 in the Maltahohe region.



Spoor Tracking

We have recorded 14 leopard spoors over 1525.5 km driven. Our 4 transects differ in length between 24 and 51 km. All transects traversed both mountainous and plains habitats though spoor were primarily located on transects 1 and 3 with only one spoor recorded on transect 4 and none recorded on transect 2. Due to limited resources and time, we have decided to discontinue the spoor tracking for study area three. Although typically we would continue the survey until we reach an asymptote with the coefficient of variation, since it is clear from our preliminary results that this area should be characterized as a low-density area.

National Estimate

We extrapolated out estimates for high, medium and low leopard population densities across our contoured map for the country (Figure 3, Table 2). The total extrapolated estimate for Namibia was 14,154 (95% CI= 13,356- 24,706). The total land area considered high leopard density was 308,586 km^2, or 38% of the country's landmass, primarily located in the mountainous regions of the Khomas Hochland, Mount Etjo and Waterberg regions. The medium density areas, representing 22.5% of the Namibia (181,928 km^2), are typically adjacent to these mountainous regions and the ecotones between thick forest or mountainous areas and the flat, more arid region. The low density areas, covering 9.9% of the country (80,928 km^2), were typically the more arid regions and southeastern portion of the country. The remaining 29% of the country includes portions of the skeleton coast and southeastern farmlands (238,091 km^2) where leopards are thought to be entirely absent.

Quota Distribution

Leopard trophy hunting permits should be distributed according to percentage of area determined for high, medium and low density (Table 4). The high density area was calculated to be 54% of the total area in which leopards are present and should therefore receive 54% of the trophy permits (n = 135). The medium density area should receive 32% of the permits (n = 80) with the low density areas on receiving 35 permits at 14% of the total area where leopards were reported.

Table 4. The proposed distribution of leopard hunting permits by area.

Density	Estimated Number	Percentage of Area	Permits per Area	Total Area (km2)	Permits per 10,000 km^2	Permits per 10,000 ha
High	9,551	67.5	169	308,586	5.5	0.055
Medium	3,639	25.7	64	181,928	3.5	0.035
Low	965	6.8	17	80,393	2.1	0.02

DISCUSSION

Our national leopard estimates are higher than previously reported possibly due to the differences in survey techniques or increases in the leopard population. In the mid-1990's, Namibia was thought to maintain a medium-sized leopard population between 1,000- 10,000 (Nowell and Jackson 1994). Ten years later, the Namibian Large Carnivore Atlas estimated leopard populations were between 5,469- 10,610 based primarily on reported sightings (Hanssen and Stander 2004). My current estimate is between 1.5 to 2.8 times the estimate presented in the Atlas. Neither of the previous surveys employed scientifically described nor widely accepted techniques for population surveys, rather, they employed the best information available including expert opinion and tourist sighting information. With advances in population survey techniques, I feel that our surveys address the criticisms of these previous surveys by removing perceived biases in density calculations. Interestingly, I found that our density estimates were remarkably close to those presented within the Carnivore Atlas (Hanssen and Stander 2004); yet, the density map was substantially different.

There are large areas of the country where information is limited or farmers' perceptions have skewed the results of our contour map. Many farmers stated that signs of leopards were frequently seen on their farm, but this is a relative assessment and different farmers may state that the same frequency of leopard sign was perceived to be 'frequent' or 'seldom'. Farmers may have stated that leopard density was high in order to increase the potential hunting quota. Lastly, farmers in the Waterberg region have previously stated that leopard populations have increased in the country in recent years (Stein et al. 2010). I discuss further challenges in the Limitations section below.

The population estimates derived here are necessary for guiding national species management. As in most leopard range countries, estimates of the leopard population were lacking and therefore management decisions are based on conjecture and guesswork (Purchase et al 2008, Packer et al. 2010). Management decisions without baseline information and strong monitoring systems can lead to disastrous declines even in populations within protected areas (Woodroffe and Ginsberg 1998, Balme et al. 2010). Predator populations are subject to conflicts with farmers due to conflicts with livestock. Problem animal control is a substantial cause of predator mortality (Stein et al. 2010). The underreporting of lethal problem animal control makes population management difficult. As well, poorly managed trophy hunting systems based on arbitrary quota setting can have detrimental impacts on large carnivore populations, in particular in species where infanticide is known (Whitman et al. 2004, Packer et al. 2010). In areas where adaptive management strategies are employed, the impacts of removals can be limited or severely curtailed (Balme et al. 2009b). With these newly calculated population estimates, I have acquired a population baseline from which to assess our current management systems, particularly related to setting a trophy-hunting quota.

<u>Quota Setting</u>

There are no clear guidelines for setting national quotas for leopards in the literature. Until recently, leopard population surveys were difficult to conduct due to their secretive nature (Balme et al. 2009a). In the absence of population estimates, countries have begun monitoring trophy quality as barometer for population health (Engen et al. 1997, Begg and Begg 2006, Funston et al. 2008, Purchase 2009, Balme pers. comm.). In populations where high quality trophies are consistently being harvested, the population health is assumed to be good since only a healthy population could consistently produce prime healthy males (Begg and Begg 2006). Where hunters are harvesting subadult males or females, the population health is assumed to be poor since hunters are assumed to be targeting prime males wherever available (Begg and Begg 2006).

The current, annual CITES quota for Namibia is set at 250 individuals (or 1.8% of the estimated total population). Assuming an adult sex ratio of 1:1 (adult male: adult female; Bailey 1993), we estimate that the current off-take rate is between 3-4% of male leopards. By comparison, several sources suggest a quota level of approximately 2-4% of the total male population for lions (Creel and Creel 1997, Begg and Begg 2006). I support the current quota for leopard hunting with the addition of an intensive trophy monitoring program. I caution the government against increasing the quota until a thorough assessment of trophy quality has been conducted. Trophy hunting is most sustainable when older, reproductively inactive individuals are removed (Balme unpublished data.), however, the removal of individuals is not necessarily compensatory for other sources of mortality and often in fact have additive affects, removing individuals that would not necessarily have died from other causes (Sandercock et al. 2011, Engen et al. 1997). As well, in areas of high persecution, such as farmlands, leopard densities are lower than otherwise expected (Marker and Dickman 2005).

Recommendations for Trophy Hunting Regulations

Leopard hunting in Namibia could be managed more efficiently with the addition of a few regulations to manage the leopard population and protect the hunting industry in Namibia. First, hunters should be rewarded for harvesting older, reproductively inactive individuals (Balme unpublished data., Figure 10). These individuals (age >7 years) are identified by their extended 'dew lap' extending from their chin to the chest. Often these are the largest individuals and make the most suitable trophies from a hunting and ecological perspective. However, the removal of these individuals is not necessarily compensatory for other sources of mortality and often in fact has an additive affect, removing individuals that would not necessarily have died from other causes (Sandercock et al. 2011, Engen et al. 1997). Second, trophy-hunting permits should be tied to a farming property, not a trophy-hunting operator and therefore the benefits of maintaining healthy leopard populations will be enjoyed by the farmer. Farmers may enter partnerships with hunting operators that will hunt exclusively on their property during the permitted hunt. Typically farmers receive between 50-60% of trophy fees from professional hunting operators for hosting a hunt (Stein et al. 2010). Farmers and trophy operators are prohibited from translocating leopards to the property without permission of MET. Third, only professional hunters licensed in Namibia should be allowed to hunt in country, not in conjunction with hunters from foreign operators from adjacent countries. Namibian hunters will be more motivated to maintain sustainable resource harvesting. As well Namibian hunters will have greater accountability to government and citizenry of Namibia. Next, hunters should maintain a Big Five license when hunting leopards, thereby creating an elite group of hunters that are highly knowledgeable and easily identified. Big Five licenses are given for the most dangerous species to hunt, leopards are considered part of the 'big five' for this reason and it stands to reason that you would need a Big Five license to hunt them. A moratorium should be maintained on hunting leopards with dogs. Although hunters argue that hunting with dogs is more efficient in targeting prime adult males, there have been some reported abuses within this system and until these abuses can be addressed, this technique should be made illegal.

Figure 10. Adult male leopard with a 'dew lap' photographed during the cameratrapping survey.

<u>Permit Distribution and Adaptive Management</u>

Leopard hunting permits should be distributed in an equitable way, based on our understanding of leopard density, prey base, conflicts with farmers (problem animal removal), farm characteristics (i.e. size) and measures of trophy quality. We recommend that permits are portioned out by region, administered by the central MET office, but monitored within farming units such as commercial conservancies or farmers associations. The national quota should be divided up into units related to relative size of the areas based on different leopard densities. For example, if all high, medium, and low-density areas had the same total land mass, high density areas would receive higher numbers of permits than low density areas. Within these density characterizations, individual farming communities (conservancies or farmers associations) would receive a proportion of the permits. These permits would then be assigned by a lottery system in which farmers with larger properties and higher density would receive a greater chance of receiving a hunting permit. If a region of interest was 100,000 ha and was assigned 3 permits per year and there were 10 properties of different size, each 10,000 ha, the farmer would receive one lottery ticket. If the farmer owned a property of 40,000 ha, he would receive 4 lottery tickets. If two farmers joined their adjacent farms together to create an area of 10,000 ha, then they would receive one ticket for both properties. An annual drawing would occur to assign the hunting permits to a property. Once that lottery ticket is picked, it will not be placed back into the lottery until all potential tickets are picked, ensuring a rotational system. As years pass, all farmers will receive an opportunity to host a hunt before all of the lottery tickets are returned to the drawing.

Once the permits are assigned there will be a point system in place that will grade the farm and region for future permit assignments. For example, a large farm that managed to shoot an adult male leopard (>4 years old) would receive a higher point total than a farm of the same size shooting a subadult male or even a female leopard. At the conclusion of the hunting season, the total points for the region will be tallied and divided by 3 to determine to the total number of permits available for the next hunting season (See Appendix 1 for more details regarding the calculations). As well farmers are required to fill in the trophy hunting datasheet within 2 weeks of the successful hunt and provide the specified photographs of 300 kb or larger for quality purposes (Appendix 2). Farmers that are conduct an unsuccessful hunt must also notify MET within 2 weeks in order to assess hunting effort. The point structure as described below is taken from the lion hunting system of the Niassa Carnivore Program in Mozambique and adapted in Botswana specifically for leopard hunting (Table 5; Begg and Begg 2006, Funston 2008).

Table 5. The annual regional leopard hunting quota will be determined by the point values accrued from the trophy quality from the previous hunting season

Quota	Adult Male	No trophy	Subadult male	Female	Incomplete Information
For quotas of 3 or more	4	3	-2	-4	0
For quotas of 2	4	3	0	0	0
For quotas of 1	6	3	0	0	0

The benefits of this system are that the quota assignments are transparent; the point system is created ahead of time so farmers can plan accordingly. This system, however is based on regional results and therefore while some farmers earn few points for poor practices and others are rewarded for good practices the regional quota will fluctuate based on communal results. In some cases regional quotas are increased where trophy quality is continuously high. As well, if farmers shoot a young individual, then the quota will be reduced in the following year. It is a self-regulating system and the quota will be adjusted on an annual basis. If a leopard is NOT shot during the hunt, then there is no penalty. The government should encourage hunters to shoot only trophy quality animals, and therefore not penalize hunters for passing on animals that are not trophy-worthy. There are several models for regulating trophy hunting currently being applied in South Africa, however, these models do not have a standardized point system for assigning future quotas, though they are based on the same premise of assessing trophy quality (Balme pers. comm.).

At that conclusion of the hunting season, prior to the assignment of new permits, a trophy quality assessment board will convene to review the datasheets and photographs from the previous hunting season. This board must contain a minimum of 3 experts for trophy quality assessment. Age of the leopard will be assessed by this panel based on size, toothware, visible scarring, relative distance of ears and the presence of a dew-lap (Stander 1997).

Limitations

There are several key limitations to our analysis that must be considered. First, these extrapolations are based on the results of only three population surveys across a large country. I chose these areas as representative of large portions of the country, yet there are large differences between habitat types, management strategies, rainfall, and prey base even within the broadly characterized density contours. With limited means, I present these results as a guide, not a steadfast rule for the current dynamics. Added to our own surveys were those conducted from various projects throughout the country that often confirmed our output and steadied our confidence (Stander et al. 1997, Hanssen and

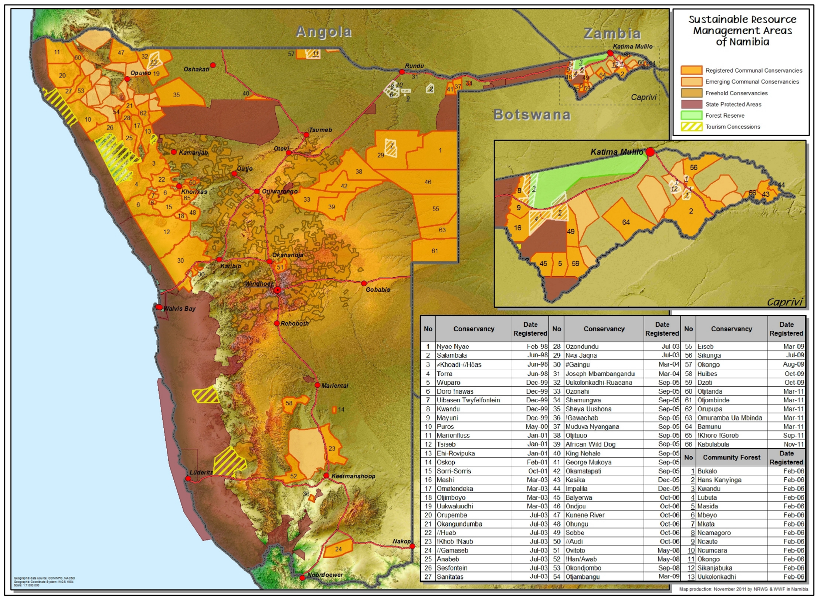
Stander 2004, Stein et al. 2011). The population surveys themselves had a host of challenges including unusually high rains in study area one that filled previously dry riverbeds and made certain areas inaccessible for changing batteries. In study area two and three, large sections of road were required for spoor tracking and many sections were covered in gravel making tracking increasingly difficult even with our experienced trackers. Farm access was also a challenge. Although many farmers were extraordinarily generous with farm access, others were unwilling to participate, creating spacing issues for our camera survey. In most cases, our team was able to adjust and maintain the required coverage, but in other cases, the spacing was extended further than desired. Lastly, as mentioned in previous sections, I propose a highly conservative off-take rate in the absence of reliable problem animal control estimates.

NEXT STEP

Population Surveys

Though our survey is complete, there is much to be done to confirm and further refine the results presented here for sustainable management of the leopard population. I propose several initiatives that can build upon the work done in this initial survey. The purposes of this survey were to assess the commercial farmland areas, where the majority of hunting permits are distributed, however, there is a paucity of information available for secretive species with in the communal conservancies where hunting permits are also disseminated (Figure 11). Similar camera-trapping and spoor surveys should be carried out in target communal conservancies where results should be incorporated much like our commercial farmland surveys.

Figure 11. The map of all commercial conservancies in Namibia



Trophy Quality Assessment

The historic trophy quality for leopards hunted within Namibia must be assessed. Namibia has a relatively comprehensive database on leopard trophies dating back several years that must be analyzed and built upon to guide hunting policy and permit distribution. Though MET can determine whether to use this information directly for current permit distribution, in the short term, these records should be used as a guide for designing the permit allocation point system and when presenting the desired and undesirable practices of the past.

Regional Pilot Study of New Hunting System

For the upcoming hunting season, MET should select a region for conducting a pilot study for assessing the described hunting system. I suggest the Khomas District as the target area. The Khomas District is almost uniformly high density area, close to Windhoek. The area is approximately 37,000 km2 and would therefore provide enough area for 20 hunting permits to be distributed amongst the farmers. Within each area, data for previous leopard hunts should be assessed for trophy quality and hunt location. A regional meeting should be planned to describe the pilot program and a lottery conducted with the same number of regional permits as the previous year. The guidelines for the point system must be clearly expressed and farmers allowed to ask questions and revise the system if necessary. In the following year, another meeting should be planned to discuss the results from the first year and the new quota will be assigned and the lottery conducted. The following year a second district should be added (potentially Caprivi at 14,000 km2 and 5 permits in medium density area or the western half of Otjozondjupa with nearly 80,000 km2 and 40 leopard permits in primarily high density area). After 3 years, this system should be expanded to additional regions potentially including communal conservancies.

Benefit Distribution Option

In Namibia, leopards are thought to be a considerable threat to calves, sheep and goats, yet many farmers are tolerant of their presence if conflicts remain low (Stein et al. 2010). Often the benefits of maintaining leopards are enjoyed by those that trophy hunt leopards on their property or have small tourist operations, while livestock farmers bear the costs (Stein et al. 2010). I propose a pilot program in which 10% of the trophy fee for each regional leopard hunt is placed in a community fund for distribution to farmers that have incurred the greatest losses, as in the self insurance programs administered by in the communal conservancies. These farmers must employ a minimum of husbandry practices with their livestock including kraaling of their livestock at night and employing effective herders that stay with their livestock during the day to qualify. Farmers must not remove conflict animals without assistance from regional MET officials. This program can be administered as part of the new leopard hunting system in selected pilot areas.

Information Dissemination

Also, more data was collected during this survey then could have been analyzed for this initial report. Literally thousands of photos were acquired during the population survey of many non-target species. These photos should be used for assessing relative abundance of a variety of species. In this vein, Amon Andreas is beginning his M.Sc. program at Free State University studying Environmental Management in Conservation and Biodiversity from the results of this study. Amon and I will work together on preparing manuscripts not only for his thesis, but also for submission to peer reviewed scientific journals

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Appendix 1. Example of quotas calculated from the previous season's point totals adapted from Begg and Begg 2006 and Funston 2008.

Current Quota	Adult Male	Subadult	No Info	Not Taken	Sum	Total Points	Points/3	Next Quota
	4 point	_0 points	0 points	3 points				
1 Leopards	1	0	0	0	4	4	1.3	2 Leopards
1 Leopards	0	1	0	0	0	0	0	0 Leopards
1 Leopards	0	0	0	1	3	3	1	1 Leopards
	4 points	-3 points	0 points	3 points				
2 Leopards	0	0	0	2	3+3	6	2	2 Leopards
2 Leopards	0	0	1	1	0+3	3	1	1 Leopards
2 Leopards	1	1	0	0	4-3	1	0.3	0 Leopards
2 Leopards	2	0	0	0	4+4	8	2.3	4 Leopards
	4 points	-3 points	0 points	3 points				
3 Leopards	1	0	1	1	4+0+3	7	2.3	2 Leopards
3 Leopards	2	1	0	0	4+4-3	5	1.6	2 Leopards
3 Leopards	3	0	0	0	4+4+4	12	4	4 Leopards

Appendix 2. Table of information necessary for trophy quality assessment adapted from Funston 2010. All submitted photographs should be larger than 300 kb in size for quality purposes.

Farm owner	
E-mail address of farm owners or hunter	
Farm name	
GPS Coordinates (Decimal Degrees preferred, specify otherwise)	
Was a leopard successfully hunted (yes/no)	
Date when the leopard was shot	
Sex of the leopard	
Body weight	
Total body length – ***measured from the tip of the nose to the tip of the tail in cm***	
Neck circumference ***– measured in cm around the middle of the neck***	
Length of the front paw – ***measured in cm from the back of the pad to the front of the longest toe pad***	
Skull measurement – ***total length and width of the skull in cm after it has been cleaned***	
Photograph of the face – from the front – ***not to zoomed in – we need to see the ears and nose clearly***	
Photograph of the face – side	
Photograph of the teeth – mouth held open – ***we need to be able to see the colour and length of the teeth***	
Photograph of the whole body – side on lying on the ground **–with a meter stick**	
Photograph of the leopard from the side in a typical trophy position with the hunter sitting just behind the leopard	
PHOTOGRAPH OF THE HUNTER HOLDING THE LEOPARD UP	
Photograph of the tail and hind quarters	
Photograph of the right front paw with a recognizable size reference object placed **ON TOP OF IT**, e.g. match box, ruler, etc.	