Research Article

Distribution and abundance of lions in northwest Tete Province, Mozambique

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Abstract

The continued existence of large carnivores such as the lion (*Panthera leo* Linnaeus, 1758) outside of protected areas is uncertain. Such populations are the least studied and the most rapidly declining. Mozambique contains roughly 8% of Africa's lions, nearly half of which persist outside of protected areas. We estimated the distribution and abundance of lions in an unprotected section of northwest Tete Province and identified potential threats to the local persistence of lion populations. Structured interviews of local people indicated lion presence and human-lion conflict. We used interview results and anthropogenic land uses defined via Google Earth to delineate lion range digitally. We estimated population size using two methods of density estimation. We estimate that 185 lions inhabit roughly two thirds of the study area, including a likely transfrontier population with Zambia. Lion populations are resident and possibly recovering. Proper management of limiting factors, such as human-wildlife conflict, may stimulate and sustain lion population growth in the study area.

Keywords: human-lion conflict, wildlife management, *Panthera leo*, population size, Google Earth, Mozambique

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Introduction

The persistence of wide-ranging carnivores such as the African lion (*Panthera leo* Linnaeus, 1758) remains uncertain as anthropogenic impacts continue to increase across the globe. Lions once roamed across nearly all of Africa, and Myers [1] estimated 400,000 individuals in 1950. Lions now persist in only about 25% of African savannahs, and the most recent estimate of the African lion population suggests between 32,000-35,000 individuals [2]. The International Union for the Conservation of Nature (IUCN) classified the lion as Vulnerable when last assessed in 2008, and lion numbers have declined approximately 30% within the last 20 years [3]. Populations are decreasing particularly rapidly outside protected areas [3], where Riggio et al. [2] suggest that about a third of all lions reside. However, populations outside of protected areas are the least known and studied [4]. This uncertainty hinders effective conservation initiatives [5]. Therefore, monitoring of lion populations outside protected areas is critical, particularly in locations that could link isolated populations protected in national parks and game management areas.

For effective lion conservation, knowledge of the distribution and density of lions, the relative importance of various threats (i.e., human-lion conflict), and the density of prey is crucial. We surveyed lions in three northwestern districts of Tete Province, Mozambique, because of its intact natural land cover and proximity to protected areas in Zambia and Zimbabwe. Furthermore, Tete has major gaps in knowledge about the status of lions [6], and was recommended as a survey area [6,7].

In preparation for the Conservation Status and Action Plan for the African Lion in Mozambique, Chardonnet et al. [6] undertook the most detailed and comprehensive survey of lions in the country. They found well-studied lion populations in only two locations, Niassa National Reserve and Gorongosa National Park. For the remainder of Mozambique, they collated all available information and gathered new data on lion observations, frequencies and human-lion conflict. Based on this information, Chardonnet et al. [6] estimated 2,700 lions in Mozambique. Previous reports were less comprehensive and suggested no more than half this number [4,8,9]. While lions still roam throughout much of Mozambique, Niassa National Reserve hosts the largest single population of lions [6].

Lions likely have been resident in Tete Province, northwest Mozambique, since historical times. Smithers and Lobao Tello [10] found lions both north and south of the Zambezi River in the early 1970s. However, the status of lions in the area is not well known. The earliest known population estimate for the province was by Chardonnet in 2002 [4], who stated that there is a “substantial resident population” but did not have reliable numbers. He estimated lion range at 25,000 km^2 with a population of 125. As part of the nation-wide survey, Chardonnet et al. [6] estimated 507 lions distributed throughout the province. Other publications were less specific. Bauer and Van Der Merwe [8] do not indicate lion presence in Tete Province, and the IUCN [9] indicated that lions are likely present north of the Zambezi but gave no estimate.

The conservation of lions is of increasing national and international concern (see the Conservation Strategy and Action Plan for the Lion in Mozambique [11], the 2011 petition for the listing of the African lion on the United States Endangered Species List [12], and motions to upgrade the lion to CITES Appendix 1 [13]). This research identifies the current extent and abundance of lions in the study area with implications for the future management of the area.

Methods

Study area

Tete Province in northwestern Mozambique is roughly 100,724 km^2 in size and has an estimated human population of less than 1.8 million people. Zambia borders the province to the west and north. Zimbabwe is to the south and Malawi to the northeast of Tete. There are no formal protected areas in the province, although the Tchuma Tchato Community Project covers nearly a third of its land area (Fig. 1). Community programs divide Tchuma Tchato into different management units, most focused on trophy hunting and others on ecotourism [14]. Professional hunting of wildlife, including lions, is ongoing and controlled by an official quota system.

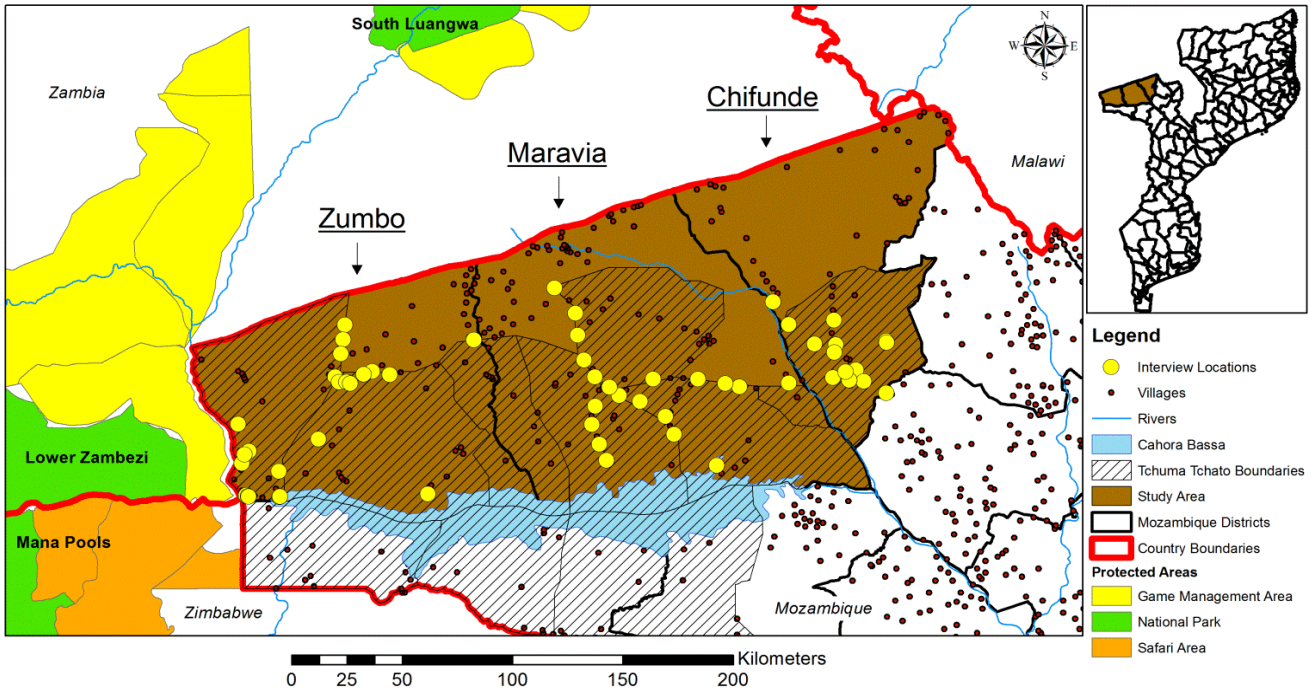

Fig. 1. Map of the study area in northwest Mozambique illustrating proximity to nearby protected areas. We conducted interviews throughout the study area except for the far northeast.

The Zambezi River and Lake Cahora Bassa divide Tete Province into north and south sections. Our study area was north of Lake Cahora Bassa in the three districts of Chifunde, Marávia and Zumbo, an area of roughly 38,000 km^2. Lake Cahora Bassa and the Luangwa River bound these three districts to the south and west, respectively. The terrain is hilly, with the altitude gradually increasing to a plateau around 900-1,100 m above mean sea level [15]. The uplands have thick miombo woodlands with mopane vegetation along the rivers and lake (Fig. 2). Climate is strongly seasonal with a long, dry season from May to November.

Since the end of the Civil War in 1993, economic development in the province has increased rapidly [16]. However, Tete Province remains sparsely populated apart from the cities of Tete and Moatize in the southeast, which serve as economic hubs for the region. Human settlement is confined along the limited

road network, the rivers and Cahora Bassa, and along the borders of Zambia and Malawi. The province's topography and lack of infrastructure have prevented rapid population growth, although sizable communities exist (e.g., Zumbo, Zambue, Fingoe). Small-scale agriculture is the predominant land use, but mining is expanding rapidly. Significant coal resources exist throughout the province, but the majority of resources are to the south or east of the study area [17].

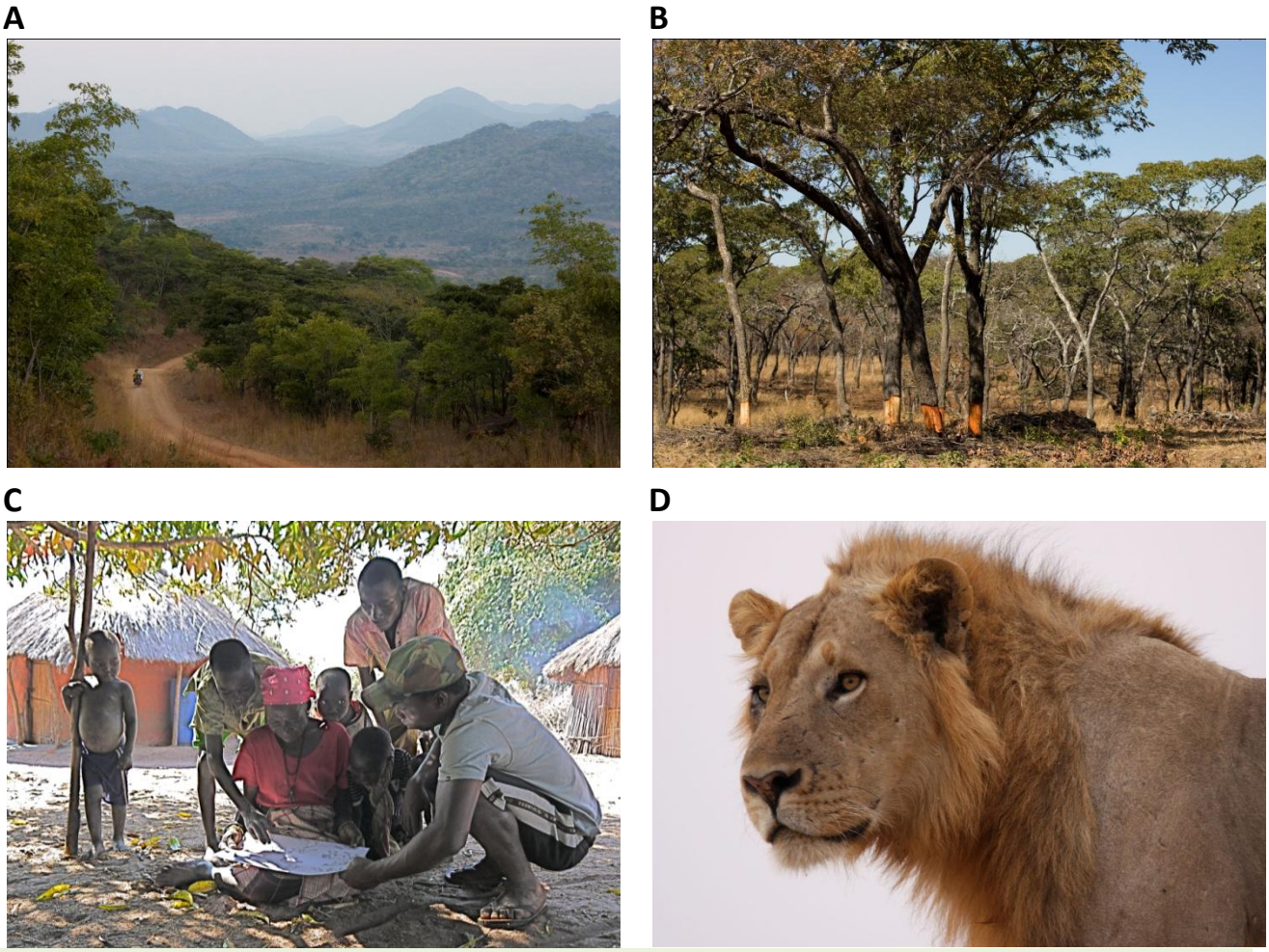

Fig. 2. The majority of the study area in Tete Province, Mozambique is miombo woodland and hilly (A); girdling trees at their base is a popular method of killing large trees before clearing land (B); a family studies the wildlife drawings during an interview (C); a male lion from Zambia (D). Photos A and B by Rudi van Aarde; photo C by Megan Cattau; photo D by Stuart Pimm.

Data collection

We assessed the presence of large carnivores and their potential prey, as well as the relative magnitude of livestock loss and human mortality due to lion attacks via structured interviews with local people. Interviews afford the most accurate indirect survey method for carnivores [18]. Interviews may be more cost and time-efficient than other survey methods, such as line transects, especially when the target

species is sparsely distributed and difficult to detect. Our questionnaire contained questions about the presence and locations of several mammal species, including lions, and human-animal conflict.

We conducted 61 interviews throughout 49 villages in the Chifunde, Marávia, and Zumbo Districts of Tete Province in July and August 2010 (Fig. 1). We selected villages along roads, ideally at a minimum distance of 10 km apart. At each village, we approached the local chief for permission to survey a member of the village and to see if he recommended someone with good knowledge of the local wildlife. A single researcher conducted the interview with the assistance of a translator who knew both Portuguese and the local Bantu dialect. Each interview lasted approximately 45 minutes. Typically, small groups of people would gather around the interview, and we recorded multiple answers or the consensus answer from these groups for questions related to wildlife sightings. In smaller villages, these groups consisted of the majority of people living there. We primarily conducted one interview per village but conducted two to four interviews in larger villages to achieve a more representative sample of the community.

The interview began with general information about the interviewee and then we inquired about the location and frequency of 14 wildlife species of interest (Appendix A). In order to minimize biased responses, we did not tell the interviewee our purpose. Positive species presence could include directly observing an individual, observing animal tracks, or hearing vocalizations either within or outside the village. The 14 species fell into the following categories: (1) lion; (2) other large carnivores (e.g., leopard and spotted hyena); (3) potential prey species of the lion (e.g., kudu, bushpig, and common duiker); (4) other species that may be present in the area (e.g., baboon); and (5) species that are not present in the area (e.g., brown bear and Cape fur seal). We included these absentee species to confirm the interviewee's credibility. We showed the interviewee a black-and-white line drawing of each species in order to clarify the species of interest (Appendix B). The final section of the interview pertained to livestock loss from disease and depredation as well as human death from disease, animal attack, and childbirth. Results from this section indicated the impacts of lion conflict, both directly (via animal attack) and indirectly (via livestock loss), and the relative magnitude of this conflict compared to others that result in loss of life (i.e., disease, childbirth).

Lion distribution

We identified anthropogenic land uses in the region using high-resolution imagery available on Google Earth (© 2012 Google; © 2012 CNES/Spot Image; © 2012 GeoEye; © 2012 DigitalGlobe; © US Dept of State Geographer). The goal was to incorporate all anthropogenic land uses, where lions were least likely to be present due to human occupation, into a single digital layer called user-identified land conversion (UILC). Google Earth provides an estimate of the altitude of the viewer. We visually inspected the imagery at roughly 6-8 km in altitude and at least 50 km in all directions from the study area. We hand-drew polygons around anthropogenic land uses, such as croplands, mines, and urban areas. There are several qualifications to this product. We did not include land conversion smaller than approximately a half square kilometer. In large areas blanketed by croplands or urbanization, we did not differentiate embedded natural areas smaller than a few square kilometers. Areas affected by trophy hunting, poaching, or pollution could not be visually identified in Google Earth and were not included. Another important qualification of this product is the temporal aspect of the images Google Earth displays. Dates vary between images and thus some may be more recent than others. For our study area, all images were newer than 2002, and images from 2006 or newer cover greater than 90% of the area. We used this methodology after conducting an unsupervised classification of Landsat imagery that did a poor job discriminating agriculture from natural habitats. Small-scale agricultural fields intermixed with forest or

shrub land can be highly spectrally variable [19], and thus can appear similar to natural vegetation in land-use classifications of moderate-resolution satellite imagery (e.g., Landsat). In the absence of extensive sampling of ground truth points, our method is likely to produce higher resolution and more accurate identification of anthropogenic land use in the study area.

The locations and frequency of lion encounters were mapped as reported by the interviewees. Arrows indicate the distance and direction of the interviewees' lion encounters. These arrows are approximate rather than exact distances and directions. Additionally, we included buffers of five km around all towns where interviewees indicated there was no lion presence.

We constructed lion range maps digitally from UILC, interview data, and incidental information (such as lion spoor). We began by considering the entire study area as lion range. We hand drew lion habitat boundaries by constraining their range against the UILC. To apply the UILC layer, we merged all polygons into a single layer of anthropogenic land use (Appendix C). Small patches of natural habitat surrounded by anthropogenic land uses are not considered lion habitat. In some cases, we included larger areas of land conversion (up to ~60 km^2) as habitat if they were isolated by extensive lion range. We used interviewee encounters and incidental information secondarily to expand or contract lion habitat.

Population size

We used two methods to estimate the size of the lion population in the study area. Method A used the most recent lion densities for the area, estimated for each community program area (see [6]). To deduce the population size, we applied these density estimates and restricted the analysis to our predicted lion distribution. In Method B, we compiled lion density estimates for various ecosystems from several reports (Appendix D). The estimates varied from 0.12 to 2.5 lions per 100 km^2. We then selected lion density estimates of ecologically similar, geographically proximal habitats, which constrained the density range to 0.6 to 1.0 lions per 100 km^2. Finally, we applied the minimum and maximum density numbers to the predicted lion distribution to estimate population size. Neither method relies on the frequency with which interviewees reported lion encounters.

Results

Interview data

The interviews yielded data concerning the presence of several mammal species and human-carnivore conflict (Appendix E).

Of the interviewees that owned domestic animals in the past year (n=57, 93% of interviewees), a much higher percentage reported losing livestock to disease (n=47, 82.5%) than to depredation (n=24, 42.1%) (Table 1). Overall, seven livestock owners (12.3%) reported losing livestock to lions. Of those owners who suffered depredation events of any kind, lions were the most common killer(s) (implicated by 29.2% of these owners). Other major predators include spotted hyena and snake (both identified by 25% of those who had lost livestock to depredation). Interviewees that owned goats suffered the highest relative cost from predation, with 15 owners suffering depredation (40.5%) and also the highest proportion of lion attacks, with 16.2% losing a goat due to lion depredation. Interviewees reported no cattle killed by lions.

About a third (n=20, 32.8%) of interviewees reported that a wild animal had killed someone in their village within the last year. None of these reports involved lions. Of the reported human deaths by animal attack, roughly two-thirds were by crocodiles and a third resulted from snakes. The interviews gave distributional data indicating how often there was lion presence, at what distance, and in what direction from town. Half

(n=31) of the interviews indicated lion presence since the start of 2009. A third (n = 9) of the reports indicated more than one animal, and two interviewees observed cubs.

Table 1. Livestock ownership and causes of livestock mortality based on interviews.

Percentage of interviewees that own…		Percentage of interviewees that owned livestock lost livestock to…			
		Disease	Predation		
			Lions	Other Animals	Total*
Chickens	80.3	77.6	2	22.4	22.4
Goats	60.7	40.5	16.2	29.7	40.5
Pigs	39.3	66.7	8.3	16.7	16.7
Cattle	24.6	33.3	0	6.7	6.7
Pigeons, ducks, guinea fowl	8.2	40	0	0	0
Any livestock	93.4	82.5	12.3	38.6	42.1

* Some interviewees who suffered livestock losses from predation reported takings by both lions and other carnivores

Lion distribution

We created a lion distribution map incorporating the UILC, interviewee lion observations and incidental information (Fig. 3). Our derived lion range is roughly 23,000 km^2, or just under two-thirds of the study area. Nearly 75% of lion range overlaps with the Tchuma Tchato Community Project (Fig. 4).

Table 2. Lion population estimates in three northwest Tete districts: Zumbo, Marávia, and Chifunde.

	Chardonnet et al. 2009			This Study: Method A	
Location	Density (lions/100 km^2)	Area (km^2)	Population Estimate	Area (km^2)	Population Estimate
Chifunde community program	1.37	3683	51	3052	42
Chipera community program	0.69	3200	22	1565	11
Chiputu community program	0.69	2969	20	2277	16
Nhenda community program	1.70	2933	50	961	16
Extension community program	1.01	2477	25	1790	18
Muze community program	0.32	4640	15	4031	13
Chawalo community program	1.70	3632	62	3099	53
Chifunde district (outside of CP's)	0.34	6135	21	3654	12
Marávia district (outside of CP's)	0.34	5789	20	1761	6
Zumbo district (outside of CP's)	0.34	2638	9	0	0
Overall NW Tete province	0.34 to 1.7	38096	295	22687	187

Population size

The population of lions in the study area using Method A is 187 individuals (Table 2). Using Method B, with density varying from 0.6 to 1.0 lions per 100 km^2, the population estimate is between 136 and 227 individuals, the average of which is 181 lions.

Discussion

Data suggest roughly two-thirds (23,000 km^2) of the study area contains lions. In the west, lion range is continuous with Zambia along much of the Luangwa River. Range extends along most of Lake Cahora Bassa and expands northwards into pockets of Marávia and Chifunde districts. We suspect the lion range extends eastward into the neighboring Macanga and Chiuta districts as it is contiguous with habitat in Chifunde. Distribution should be viewed with caution, as presence was not confirmed in all locations. Interviews, particularly in northern Zumbo, northeast and southeast Chifunde, and northern Marávia, would increase confidence of the lion distribution in these areas. It is possible that lion range in these areas is over-predicted and the true amount of habitat is smaller.

Lion populations in Tete Province are likely isolated except in the west where they connect with lions in Zambia. Several villages on the western border with Zambia noted weekly lion presence, suggesting that a transfrontier lion population may exist. Lions may also disperse from our study area to/from Zimbabwe when they cross the Zambezi River (Gianetta Purchase 2011, pers. comm., Nov 22). However, it is unlikely that lion range connects to the rest of Mozambique (e.g., to Gorongosa National Park) because of extensive human populations and disturbance to the southeast of the study area.

Lions in Tete Province are likely remnants of a low-density population once continuous with and ecologically part of neighboring protected areas. Although it is possible that the population is composed entirely of nomads, or dispersers, from abutting protected areas (e.g., Lower Zambezi and Luangwa Valley National Parks) or the Zambezi valley floodplains, interviewees from two separate villages indicated seeing more than one lion and cubs. This suggests that the area has a resident lion population.

We estimate 185 lions in the study area with a range from 136 – 227. Our estimate of 185 lions is greater than previous estimates from more geographically comprehensive reports [4,8,9]. However, it is less than the most recent estimate by Chardonnet et al. [6], which suggested 507 lions for all of Tete Province with the majority, 295, concentrated in the study area. Any estimate of lion numbers relying on density extrapolations to suspected habitat must be viewed with an appropriate amount of caution. While we feel this number is the best estimate possible given the available data, we also recognize that our results may overestimate lion range, and in turn population size.

A variety of evidence supports our claim of a relatively small lion population and low lion density. Most importantly, prey densities are low in the study area. Two aerial surveys, completed in 2003 and 2008, included portions of the study area, and both indicated low prey densities in our study area relative to other surveyed areas [20,21].

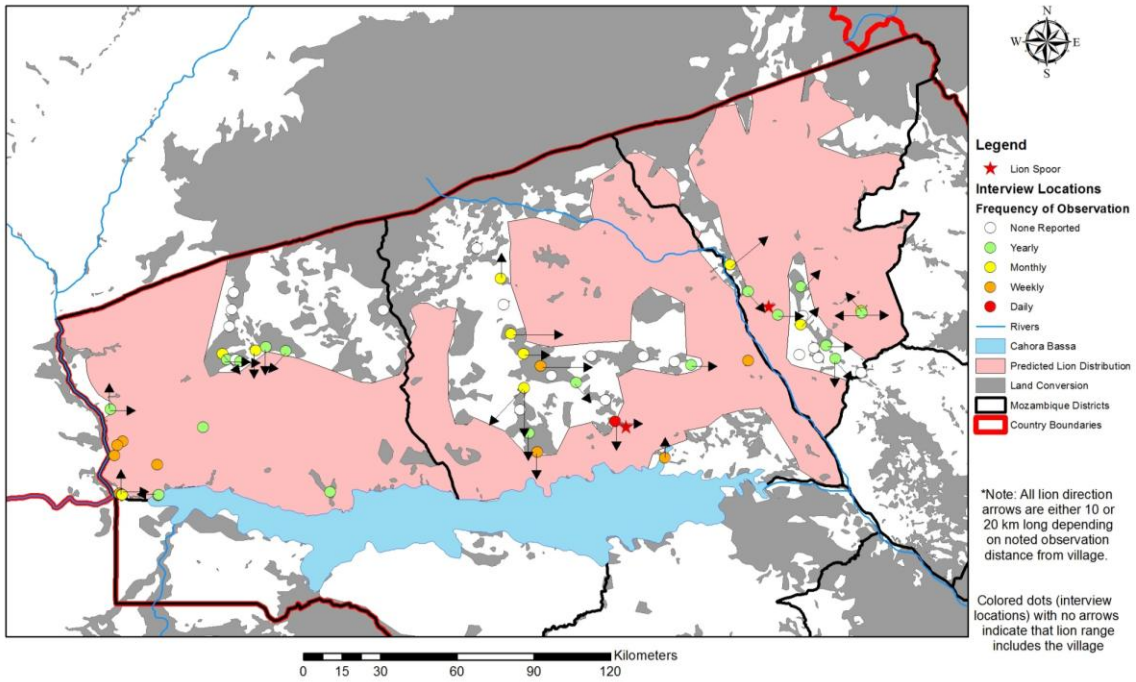

Fig. 3. Distribution of lion habitat resulting from land use conversion, interview data and lion spoor. Lion habitat comprises roughly two-thirds of the study area.

It is useful to contrast Tete Province with Niassa National Reserve, an area of similar habitat, but where lion densities are better known [6]. Niassa contains 1-3 lions per 100 km^2 [6]. In our study area, cultivation and settlements are more extensive, herbivore diversity is lower, and there is less abundant wildlife of almost all varieties than in Niassa [21]. This suggests that lion densities, like herbivore densities, are lower in Tete than in Niassa.

Some accounts indicate depleted wildlife numbers caused by the Mozambican Civil War [11,22]. These reports suggest that the hostilities negatively impacted wildlife. Other reports suggest low wildlife numbers due to continued snaring and hunting for bushmeat both locally [23] and in nearby parts of Mozambique [24]. However, we cannot report on the true extent of snaring, poisoning or bushmeat hunting in this area.

Human-lion conflict can be a primary factor causing low lion numbers where villagers kill carnivores in retaliation for depredation of livestock [25]. Conflict between lions and humans is common in parts of Mozambique and Tete [6,26] and, while minimal locally, we believe it could worsen if lion or human populations increase. Interviews revealed no human deaths attributable to lions and one non-fatal attack. There were two reports of retaliatory lion killings. In terms of livestock, predation from all carnivores was a smaller threat than disease. Twice as many livestock owners suffered losses from disease than from predation (80% vs. 40%). Yet, the lion was the most common predator of livestock, with nearly 15% of livestock owners suffering lion depredation. We were unable to record detailed counts of livestock lost to depredation using interviews.

Implications for conservation

Mozambique recently completed a Conservation Strategy and Action Plan for the African lion [11]. The Plan was developed in two steps: a survey determining the status of the lion [6] and a national workshop held in Maputo in July of 2009. The Action Plan lays out a vision, goal, objectives and timeline with defined roles and responsibilities. The crux of the goal statement is "to secure, and where possible, restore viable lion populations in Mozambique [11]."

Sustaining or enlarging a viable local lion population may erode living conditions for rural people unless human-lion conflict is addressed. There are many options to mitigate conflict, but they require a locally appropriate approach and resources to plan and execute these actions. At least one of the safari operators and a partner in Tchuma Tchato help the community deal with problem animals (Carel Maartens 2010, pers. comm., July). However, more proactive approaches to dealing with conflict should be developed and implemented. The Human-Lion Conflict Toolkit, which details a variety of intervention strategies, could guide these approaches [27].

A local concession owner suggested that there are small resident lion populations in the study area that may be increasing as prey densities rebound (Carel Maartens 2012, pers. comm., June 11). Interviewee observations support this, with a third of observations consisting of more than one lion and some including cubs. One interviewee claimed seeing a pride of eight lions. Proper management of limiting factors, such as snaring, trophy hunting, and prey availability, may stimulate and sustain a recovery of the lion population in this area. A recovering lion population would support the goal adopted in the Conservation Strategy and Action Plan [11]. Importantly, our findings suggest a transfrontier lion population with connections to Zambia and possibly Zimbabwe. To identify trends, we recommend regular monitoring of lion and prey populations.

However, politics and land use decisions will dictate conservation in Tete. The land is valuable for many different uses (e.g. logging, mining, agriculture, trophy hunting and conservation) which traditionally have limited compatibility. The study area contains nearly 10% of the lions in Mozambique [6], and some sections have important biological value, particularly along the western border with Zambia [16]. Yet vast coal deposits exist throughout Tete, leading to claims that by 2025, Tete could be producing 25% of the world's coking coal [28]. With a tremendous amount of natural resources and rapidly accelerating investments to develop them [17], Tete will change rapidly and possibly drastically. Political choices and resultant land use policies will ultimately decide the size and extent of future lion populations in Tete.

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References

[1] Myers N. 1975. The silent savannahs. *International Wildlife* 5: 5-10.

[2] Riggio J., Jacobson A., Dollar L., *et al.* 2013. The size of savannah Africa: a lion's view. *Biodiversity and Conservation* 22: 17-35. DOI: 10.1007/s10531-012-0381-4.

[3] Bauer H., Nowell K. and Packer C. Panthera leo. 2012. IUCN Red List of Threatened Species. http://www.iucnredlist.org/apps/redlist/details/15951/0. Cited 3 January 2013.

[4] Chardonnet P. 2002. Conservation of the African lion: Contribution to a status survey. International Foundation for the Conservation of Wildlife, France and Conservation Force, USA. http://conservationforce.org/pdf/conservationoftheafricanlion.pdf. Cited 13 June 2012.

[5] Purchase G., Mateke C. and Purchase D. 2007. A review of the status and distribution of carnivores, and levels of human-carnivore conflict, in the protected areas and surrounds of the Zambezi Basin. The Zambezi Society. http://zamsoc.david.co.zw/wp-content/uploads/2012/02/Review-of-Carnivore-data-in-the-Zambezi-Basin..pdf. Cited 13 June 2012.

[6] Chardonnet P., Mesochina P., Renaud P.C., *et al*. 2009. Conservation status of the lion (*Panthera leo* Linnaeus 1758) in Mozambique. Maputo. http://www.shakariconnection.com/support-files/mozambique-lion-final-report.pdf. Cited 13 June 2012.

[7] Hunter L. 2006. The vanishing lion. *Wildlife Conservation*: 34-38.

[8] Bauer H. and Van Der Merwe S. 2004. Inventory of free-ranging lions (*Panthera leo*) in Africa. *Oryx* 38: 26-31.

[9] IUCN SSC Cat Specialist Group. 2006. Regional conservation strategy for the lion (*Panthera leo*) in Eastern and Southern Africa. http://www.catsg.org/catsgportal/bulletin-board/05_strategies/Lion%20Conserv%20Strat%20E&S%20Africa%202006.pdf. Cited 13 June 2012.

[10] Smithers R.H.N. and Lobao Tello J.L.P. 1976. Checklist and atlas of the mammals of Mocambique. Museum Memoir No. 8, National Museums and Monuments of Rhodesia.

[11] Fusari A., Cumbi .R, Chardonnet P. and Begg C. 2010. Conservation strategy and action plan for the African lion (*Panthera leo leo*) in Mozambique. Ministry of Tourism and Ministry of Agriculture, Maputo, Mozambique. http://www.rateltrust.org/library_files/2010%20Mozambique%20Lion%20Conservation%20Strategy.pdf. Cited 13 June 2012.

[12] Place J., Flocken J., Travers W., *et al*. 2011. Petition to list the African lion (Panthera leo leo) as endangered pursuant to the U.S. Endangered Species Act. http://www.bornfreeusa.org/downloads/pdf/African_Lion_Petition.pdf. Cited November 28 2012.

[13] CITES. 2004. Consideration of proposals for amendment of Appendices I and II. http://www.cites.org/common/cop/13/raw_props/KE-Lion.pdf. Cited 28 November 2012.

[14] Filmao E., Mansur E. and Namanha L. 1999. Tchuma Tchato: an evolving experience of community-based natural resource management in Mozambique. Proceedings of the International Workshop on Community Forestry in Africa; Participatory forest management: a strategy for sustainable forest management in Africa. Banjul, the Gambia 1999.

[15] Timberlake J. 2000. Biodiversity of the Zambezi Basin. Occasional Publications in Biodiversity No. 9. Biodiversity Foundation for Africa, Bulawayo, Zimbabwe. http://www.biodiversityfoundation.org/documents/BFA%20No.9_Zambezi%20Basin%20Biodiversity.pdf. Cited 13 June 2012.

[16] Cunliffe R. 2000. Biodiversity and wilderness evaluation of the Tchuma Tchato project area surrounding Lake Cabora Bassa, Tete Province, Mozambique (2 vols). Bulawayo, Zimbabwe. http://www.biodiversityfoundation.org/documents/BFA%20No.11_Cabora%20Bassa_Synthesis.pdf. Cited 13 July 2012.
[17] Hatton W. and Fardell A. 2012. New discoveries of coal in Mozambique – development of the coal resource estimation methodology for International Resource Reporting Standards. *International Journal of Coal Geology* 89: 2-12.
[18] Gros P., Kelly M. and Caro T.M. 1984. Estimating carnivore densities for conservation purposes: indirect methods compared to baseline demographic data. *Oikos* 77: 197-206.
[19] DeGloria S.D. 1984. Spectral variability of LANDSAT-4 Thematic Mapper and multispectral scanner data for selected crop and forest cover types. *IEEE Transactions on Geoscience and Remote Sensing* 22: 303-11.
[20] Dunham K.M. 2004. Aerial survey of elephants and other large herbivores in the Zambezi Heartland (Zimbabwe, Mozambique and Zambia): 2003. A report for the African Wildlife Foundation.
[21] AGRECO. 2008. National census of wildlife in Mozambique. Ministry of Agriculture, Mozambique. http://www.rhinoresourcecenter.com/pdf_files/129/1290817769.pdf. Cited 28 November 2012.
[22] Hatton J., Couto M. and Oglethorpe J. 2001. Biodiversity and war: a case study of Mozambique. Washington D.C., Biodiversity Support Program. http://files.gorongosa.net/filestore/337-hatton%20et%20al%202001%20mozambique%20biodiversity%20war.pdf. Cited 28 November 2012.
[23] Cunliffe R. 2008. Estudo de viabilidade da area de conservacao comunitaria de Chawalo no Distrito de Zumbo, Provincia de Tete, Mocambique. African Wildlife Foundation Zambezi Heartland.
[24] Lindsey P. and Bento C. 2011. Illegal hunting and the bushmeat trade in central Mozambique. A case-study from Coutada-9, Manica Province. TRAFFIC East/Southern Africa, Harare, Zimbabwe.
[25] Frank L., Hemson, G., Kushnir, H. and Packer C. 2006. Lions, conflict and conservation in Eastern and Southern Africa. http://www.lionconservation.org/ScientificPapers/Lions-conflict-and-conservation,Frank-et-al.pdf. Cited 3 January 2013.
[26] Anderson J. and Pariela F. 2005. Strategies to mitigate human-wildlife conflict in Mozambique. Mozambique National Directorate of Forests and Wildlife.
[27] Begg C. and Kushnir H. 2010. Human-lion conflict toolkit. Projecto Carnivoros do Niassa and the Wildlife Conservation Network. http://www.rateltrust.org/library_files/Human-Lion%20Conflict%20Toolkit.pdf. Cited 13 June 2012.
[28] 2011. Talking Tete – Mozambique's new mining epicenter. The International Resource Journal. http://www.internationalresourcejournal.com/mining/mining_july_11/mozambique_s_new_mining_epicentre.html. Cited 13 June 2012.
[29] Apps P. 2000. *Smither's Mammals of Southern Africa: A Field Guide*. Struik Publishers, Cape Town, South Africa.
[30] Kingdon J. 1997. *The Kingdon Field Guide to African Mammals*. Academic Press, London, UK.

Appendix A: Survey questionnaire

Questionnaire

Interviewee Information

Interview #: _____

Name of Closest Village: _____

GPS Point Number: _____

Introduction

1. What is your year of birth? _____
2. How long have you been living here? _____
3. What is your way of living? _____
4. Do you travel away from this village? Y N
    a. If yes, how do you travel? (ex: by car, by bicycle, on foot)

        _____

        If no, skip to Question 6

    b. How far do you travel? _____
    c. How often? (ex: every day, week, month, or year)

        _____

Wildlife Information

	Do you see this animal around here?	If no, has anyone in your family seen this animal? (If yes, skip to Column A)	**A** When was the last time it was seen?	**B** In what direction and how far from here?	**C** How often do you see it?
1. Kudu	Y N	Y N			
2. Hyena	Y N	Y N			
3. Lion (male)	Y N	Y N			
4. Bushpig	Y N	Y N			
5. Lioness	Y N	Y N			
6. Buffalo	Y N	Y N			
7. Vervet Monkey	Y N	Y N			
8. Bear	Y N	Y N			
9. Leopard	Y N	Y N			
10. Cape Fur Seal	Y N	Y N			
11. Baboon	Y N	Y N			
12. Beaver	Y N	Y N			
13. Grey Duiker	Y N	Y N			
14. Elephant	Y N	Y N			

Well-Being

5. Do you have children? Y N
6. Are you married? Y N
7. Do you buy or grow your crops? B G

   If you buy, where do you buy it?

   _____

   If you grow, what crops do you grow?

   _____
8. Do you use cash or do you trade? C T
9. At your home, do you use/have:

a. Sugar?	Y	N
b. Cola?	Y	N
c. A mirror?	Y	N
d. A radio?	Y	N
e. A bicycle?	Y	N
f. Livestock?	Y	N

If you own livestock, what animals do you own and how many?

Livestock Information

10. Do you know of any livestock that have died from disease in the last year?

    Y N

    a. If yes, what kind of livestock and how many?

       _____

       If no, skip to Question 12

    b. What disease was it?

       _____

    c. Was it your livestock or someone else's?

       _____

11. Do you know of any livestock that have been killed by another animal within the past year?

    Y N

    a. If yes, what kind of livestock and how many?

_____

If no, skip to Question 13

b. Was it your livestock or someone else's?

_____

c. What animal killed it?

_____

d. Why do you think that?

_____

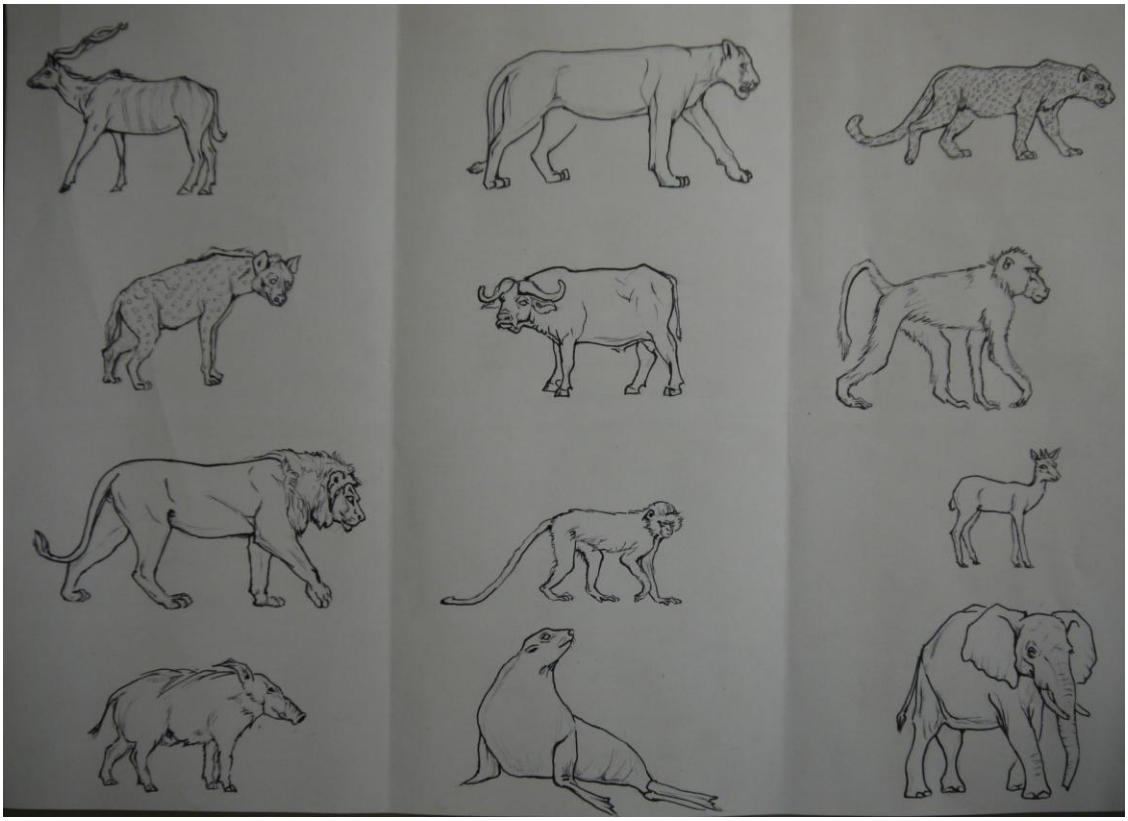
Human Health

12. Do you know of any people who have died <u>in the last year</u> from

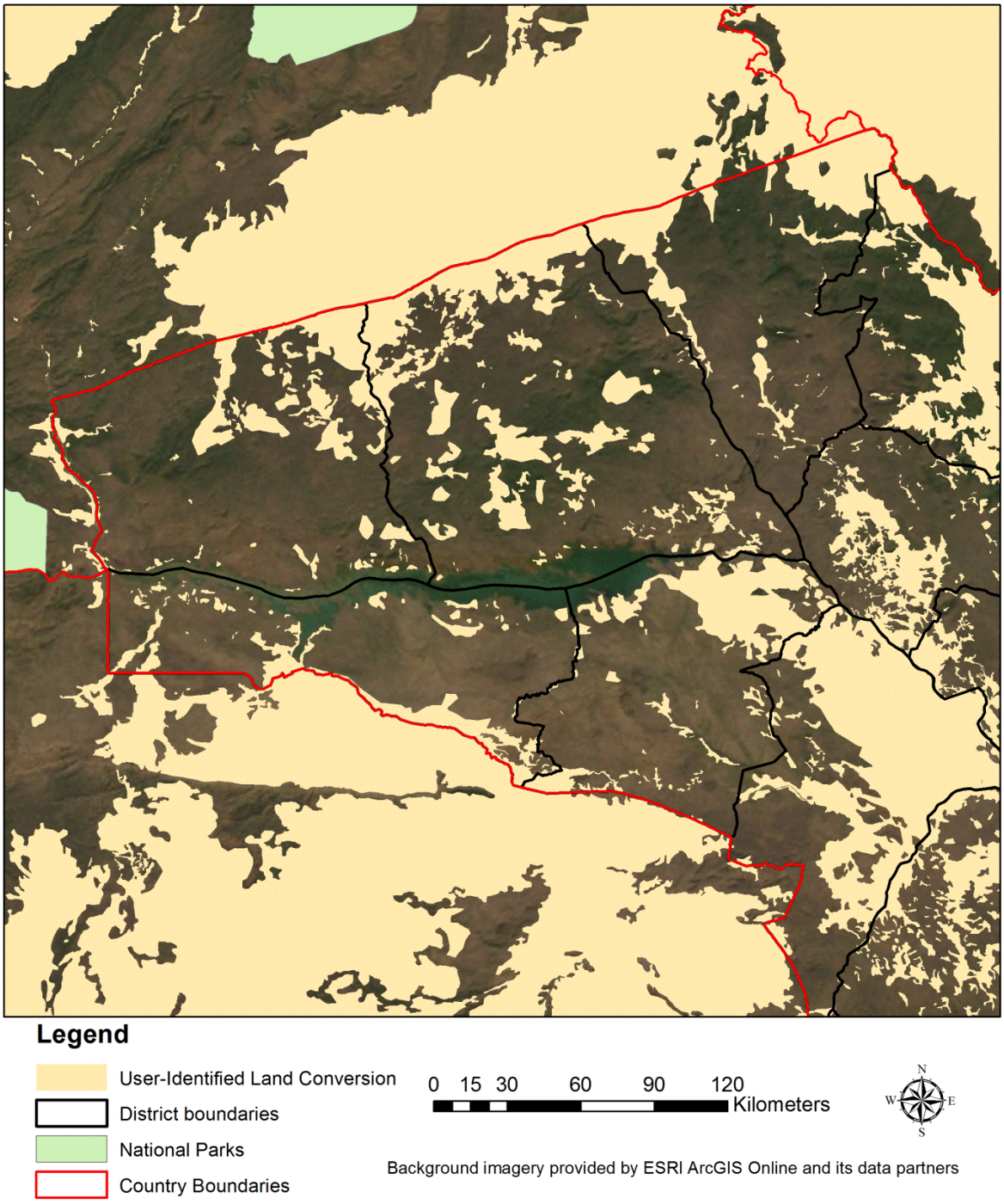
a. Malaria?	Y N	If yes, how many people? _____
b. Animal attack?	Y N	a. If yes, how many people? _____ b. From what animal? _____ c. Why do you think that? _____ _____
c. Childbirth?	Y N	If yes, how many people? _____

Notes:

Appendix B: Line diagrams of selected wildlife species shown to interviewees during our survey to establish the presence and absence of species across the survey area. An additional two species were shown to interviewees but are not included here. Drawings by Megan Cattau based upon *Smither's Mammals of South Africa: A Field Guide* [29] and *The Kingdon Field Guide to African Mammals* [30].



Appendix C: User-identified land conversion (UILC) throughout the region.



Appendix D: Lion densities for selected nearby areas based off recent lion reports.

Report	Location	Area (km^2)	Number of lions (low - high)	Lion density per 100 km^2 (low - high)
Chardonnet 2002	Lower Zambezi NP	9140	183 (128-283)	2.00 (1.40 - 3.10)
	Matusadona NP and surrounds	14000	310 (248-372)	2.20 (1.77 - 2.66)
	Mana Pools and surrounds	13000	495 (396 - 594)	3.80 (3.05 - 4.57)
	Niassa National Reserve	15000	500 (350-650)	3.30 (2.30 - 4.30)
	North Mozambiqe non-gazetted areas	50000	150 (105-195)	0.30 (0.21 - 0.39)
	Tete Province	25000	125 (87 - 163)	0.50 (0.35 - 0.65)
Bauer & Van Der Merwe 2004	Chewore Safari Area	2704	100 (60-140)	3.70 (2.22 - 5.18)
	Dande Safari Area	988	50 (30-70)	5.06 (3.01 - 7.09)
	Mana Pools NP	14000	97 (83- 112)	0.69 (0.59 - 0.80)
	Matusadona NP	16000	120 (72-168)	0.75 (0.45 - 1.05)
	Niassa National Reserve	15000	175 (105-245)	1.17 (0.70 - 1.63)
IUCN 2006	Greater Niassa (outside the Reserve) (26)	86470	100-250	(0.12 - 0.29)
	Matusadona (39)	1430	50-100	(3.50 - 7.00)
	MZ south of Labannakass (35)	12400	50-100	(0.40 - 0.80)
	Mid-Zambezi (34)	20030	250-500	(1.25 - 2.50)
	Niassa National Reserve (25)	41590	800-900	(1.92 - 2.16)
	Petauke corridor (33)	4560	<50 (used 10 and 40 for estimating density)	(0.22 - 0.88)
Chardonnet et al. 2009	Chawalo community program	3632	62	1.70
	Chifunde community program	3683	51	1.37
	Chipera community program	3200	22	0.69
	Chiputu community program	2969	20	0.69

	Extension community program	2477	25	1.01
	Muze community program	4640	15	0.32
	Nhenda community program	2933	50	1.70
	Chifunde district (outside of community programs)	6135	21	0.34
	Marávia district (outside of community programs)	5789	20	0.34
	Zumbo district (outside of community programs)	2638	9	0.34
	Overall NW Tete province	38096	295	0.77
	Niassa National Reserve	42914	800-900	2.10

Appendix E: The distribution of carnivore-livestock conflict throughout the study area based on interview responses.