THE DEMOGRAPHY AND POPULATION STATUS OF LIONS (*Panthera leo*) IN THE MANA POOLS NATIONAL PARK, ZIMBABWE

by

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Finally, I give thanks to my Lord and Saviour Jesus Christ who has brought special people into my life during this research, who has blessed me with a wonderfully interesting job and who has propped me up when I needed it. To Him be all the glory.

DECLARATION

I hereby declare that this thesis submitted by me to the University of the Free State for the degree **Philosophiae Doctor (Ph D)**, is my own independent work and has not previously been submitted by me to any other University. I furthermore cede copyright of the thesis in favour of the University of the Free State.

Norman John Monks

Bloemfontein

28 November 2008

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1. INTRODUCTION

1.1 Lion distribution and status in Africa

Lions (*Panthera leo*) are a charismatic wildlife species that are emblematic to many of wild Africa. Historically the range of lions extended beyond Africa to parts of Europe and over much of Asia. Skinner and Chimimba (2005) note that within historical times, the range of lions more than any other wildlife species has been dramatically reduced. Outside of Africa, in present times, lions only occur in the Gir Peninsular of India (Ravi Chellam & Johnsingh, 1993). Being a mega-predator, highly sociable and hunting in groups, lions are not easily ignored when there is a lion/human interface. The activities and requirements of large carnivores such as lions bring them into conflict with local people (Woodroffe, 2000), and lions are not tolerated near human habitation. The remaining populations in modern Africa are confined naturally to large protected areas such as National Parks. More artificially they are found within fenced game farms where they are exploited mainly for hunting purposes.

Historically, lions ranged throughout the African continent apart from the interior of large deserts and within rain forests (Figure 1.1). Recent attempts to obtain population estimates of lions in Africa (Nowell & Jackson, 1996; Bauer *et al*., 2002; Chardonnet, 2002) and to map out their current range and status (IUCN, 2006) all combine to indicate that the lion population in Africa is under threat. Human population pressure (Cardillo *et al.*, 2004) with resultant lion-human conflict and the fragmentation of suitable habitat are the most important factors causing the decline of the African lion. As natural protected areas become surrounded by human habitation or in some cases, by excessive sport hunting activities, the forces of edge effects are manifested in the wild lion populations and although the area in which they are in may be large, lions (especially males) forage widely so that their movements are frequently outside of the protected area (Woodroffe & Ginsberg, 1998).

1.2 Research and monitoring of lion populations continent-wide

Lion populations have been well studied and monitored in East and Southern Africa. Reports on demographic and behavioural studies carried out on free-ranging lions in southern Africa (Smuts, 1976; Smuts *et al.*, 1977; Mills *et al.*, 1978; Smuts *et al.*, 1978; Anderson, 1981b;

Smuts *et al*., 1980; Starfield & Bleloch, 1983; Stander, 1991; Mills & Shank, 1992; Mills, *et al*., 1995; Maddock *et al*., 1996; Yamazaki, 1996; Funston *et al*., 1998; Orford *et al.*, 1988; Funston *et al*., 2001; Funston *et al*., 2003) provides excellent base-line data. Whilst the work carried out in eastern Africa is invaluable and forms the basis in many ways for the southern African work, there are some important differences between the two regional populations. However, there is a paucity of scientific publications regarding the status of the African lion in other countries continent-wide. Lion researchers throughout east and southern Africa (IUCN, 2006) showed clearly how lion distribution in individual countries extended beyond political boundaries into neighbouring countries and how important it is to have these ranges open and protected. By creating Transfrontier Parks running as contiguous conservation areas extending across political boundaries, and by creating corridors linking fragmented protected areas, the range of lions (and other large mammals such as elephants) can be extended. Progress at this level is slow and the success will depend on relevant Governments committing themselves to common management practices in order to conserve wildlife in their traditional range.

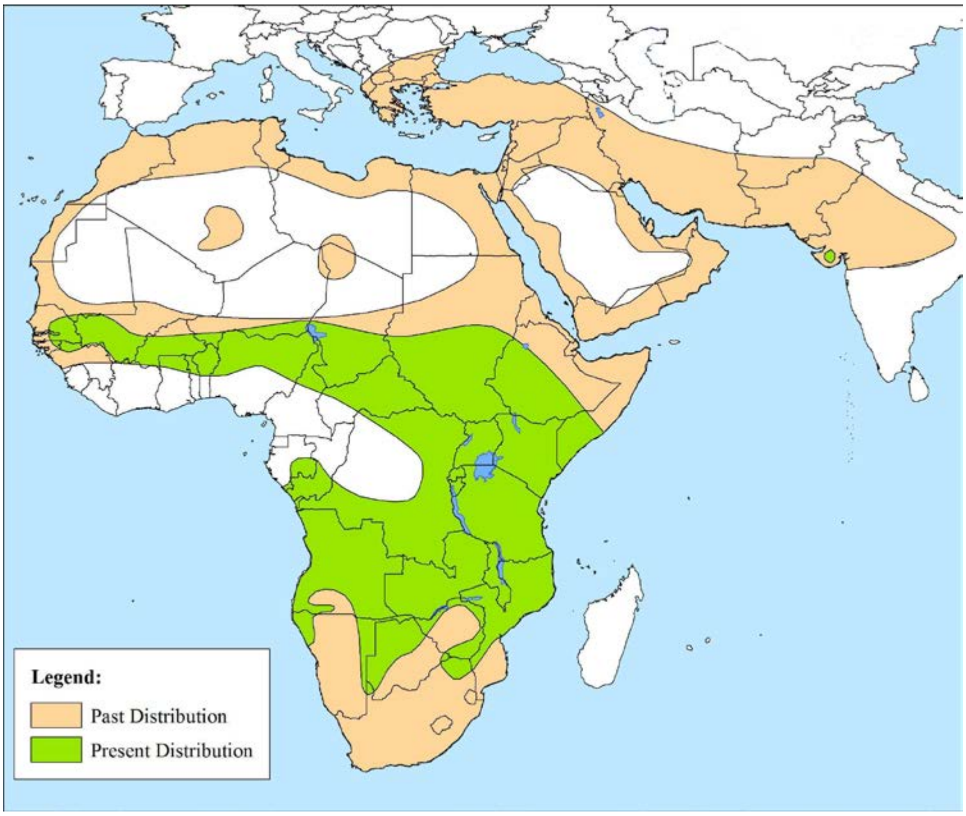

Figure 1.1 Past and present distribution of lions in Africa (Barnett *et al.*, 2006).

1.3 Lion distribution and conservation in Zimbabwe

Zimbabwe is a land-locked country in southern Africa (Figure 1.2), bordered by Botswana (to the west), Zambia (to the north), Mozambique (to the east) and South Africa (to the south). In Zimbabwe, 13.7% of the total area of the country is set aside as protected areas for wildlife. These areas are administered by the Zimbabwe Parks and Wild Life Management Authority (ZPWLMA), and include National Parks (53.1% of total protected area), Safari Areas (37.2%), Recreational Parks (6.9%), Sanctuaries (2.6%) and Botanical Reserves and Gardens (0.2%). Sport hunting is only allowed in Safari Areas. This is on strict enforceable sustainable quotas which are set by the Scientific Services Branch of ZPWLMA.

Figure 1.2 Geographical context of Zimbabwe.

In Zimbabwe lion distribution is fragmented and confined to the large Parks and Safari areas on the periphery of the country (see section 2.1). These areas consist of the Hwange/Matetsi complex in the west of Zimbabwe, the Gonarezhou National Park in the south-east of Zimbabwe, the Matusadana/Chizarira/Kariba complex, and the mid-Zambezi Valley in the far north of Zimbabwe. Movement of lions into adjoining countries does occur. The most important contiguous protected areas with lion populations are found in the mid-Zambezi

Valley in the extreme north of Zimbabwe and the Hwange/Matetsi complex in the west of the country. The Great Limpopo Transfrontier Conservation Area in the south east of Zimbabwe meets up with South Africa and Mozambique and this will also be an important lion range.

Communal Lands adjoin most of the large parks in Zimbabwe; the most important of these in terms of lion conservation are the Sebungwe complex south of the Kariba Dam, the Hwange/Matetsi complex in the west and the Dande/Guruve complex in the mid-Zambezi Valley. Communities adjoining protected areas should benefit from wildlife both by co-management of the wildlife with which they have to live and by receiving financial returns under the CAMPFIRE program (Communal Areas Management Program for Indigenous Resources). The CAMPFIRE programs reduce the hard edges that often exist between protected areas and communities. It allows locals to view wildlife as a valuable resource to be looked after and not as a threat to be removed. This sustainable utilization philosophy has proved to be the best conservation tool in Zimbabwe, given that there are human-wildlife conflicts and an ever increasing demand for more land. Whilst villagers will largely tolerate damage to crops by elephants, they are less likely to accept loss of livestock by lions. Unless they can see the value of a lion to the community when it is taken off for sport hunting or problem animal control, snaring and poisoning of lions (revenge killings) will inevitably take place.

1.4 Lion management, research and monitoring in Zimbabwe

In Zimbabwe the lion population is estimated to be between 1 000 to 1 700 animals (Chardonnet, 2002; Bauer & Van der Merwe, 2004). At present the current range of lions in Zimbabwe is about 60 000 to 90 000 km² compared to an estimated range of 250 000 km² in the early 60’s (Child & Savory, 1964).

Few in-depth studies have been carried out on wild lion populations in Zimbabwe. Only in the Hwange National Park (Loveridge & Macdonald, 2002) and in the Matusadona National Park (Purchase, 2002a) have long-term studies been carried out. Van Meulen (1976) carried out a short-term study on lion in the Matetsi Safari Area in the north west of Zimbabwe; Cumming (personal communication) carried out an unpublished study of lions in the Sengwe area of Zimbabwe in 1976; and Dunham (1994) carried out a short-term study in the Mana

Pools National Park. However, no in-depth studies of lions have been carried out in the area targeted for this study.

At a workshop held in Harare in 2005, a "Conservation Strategy and Action Plan for Lion in Zimbabwe" was formulated and the needs for lion conservation in the country discussed (Zimbabwe Parks and Wildlife Management Authority, 2006). In the report it was stated "Information on the population status, current distribution and trends (as opposed to range) still remains lacking for most wildlife areas although there are estimates of numbers for some areas". The Mana Pools National Park fell under the category of an area "deficient in population status and trends" of lions and the goal of this study was to partly address that situation.

1.5 Sustainable utilization of lions in Zimbabwe

The concept of sport hunting of lions has been discussed by Whitman and Packer (1997) for East Africa, and by Loveridge (2005) for Zimbabwe. In Zimbabwe, sport hunting of lion and of other selected wildlife species is permitted in Safari Areas (consumptive tourism) but not in National Parks. Revenue generated from the Safari Areas exceeds that generated in National Parks (non-consumptive tourism) and actually contributes to the financial upkeep of parks in many cases. The inclusion of lions on a hunt greatly increases financial returns and hunt sales (Grobbelaar & Musulani, 2003). In the Selous Game Reserve, Tanzania, lions are one of the three main wildlife species most sought after by sport hunters (Creel & Creel, 1997). The high value of lions makes this species important economically, and more positively, makes its conservation status more important. Quota setting of lions in the mid-Zambezi Valley, Zimbabwe, has been mainly based on adaptive management which has included moratoriums on hunting until the age and trophy quality of shot lions show an upward trend (Grobbelaar & Musulani, 2003).

Over 56% of all Safari Areas in Zimbabwe are located in the mid-Zambezi Valley (see detail in section 2.1). Downstream of the Kariba Dam the Zambezi River flows generally north and then eastwards between Zimbabwe and Zambia. On the Zimbabwean side, the ZPWLMA administers all of the land up to near Kanyemba in the east which borders with the western boundary of Mozambique. Within this area only the Mana Pools National Park has a non-hunting land-use category. Although hunting is not allowed in the Mana Pools National Park, the park does act as a source for wildlife utilized for hunts (including lions) in the surrounding Safari Areas.

Once every two years, aerial surveys to obtain population estimates of large mammals are carried out in the mid-Zambezi Valley, Zimbabwe. The ZPWLMA together with an independent non-Governmental Organization such as World Wide Fund for Nature and African Wildlife Foundation, carry out the country-wide surveys (which cover all large Parks, Communal Areas and Safari Areas in Zimbabwe with elephant populations). Based on the results of the surveys, sustainable trophy-hunting quotas are set for all species being hunted. Lions are difficult to census due to their retiring secretive behaviour and ability for camouflage (Bertram, 1979; Nowell & Jackson, 1996) and it is not possible to obtain a population estimate by carrying out aerial surveys or other more common census methods. Pennycuick and Rudnai (1970) and Schoenewald-Cox *et al.* (1991) maintain that only intensive study will give an accurate estimate of lion population size and population status.

In the Mana Pools National Park, game-viewing is a major tourist attraction. Most visitors come into the Park with the hope and expectation of seeing lions. Lion tracking with tourists, which was introduced for this study, assists in data collection and has proved to be extremely popular. It has also raised public awareness for the need to conserve this vulnerable species. Thresher (1982) gave a value lions had in terms of game-viewing in the Amboseli National Park, Kenya. This was calculated as US$ 128 750 for one male lion taking into account entry fees and 2.5% of time that tourists spent watching the lion. Nowell and Jackson (1996) indicate that if lions are not present for game viewing, expected revenue collection will be lower.

1.6 Background to the study

The mid-Zambezi Valley is an important protected area with a perceived good population of lions. Despite the fact that over 56% of all Safari Areas in Zimbabwe are found in the mid-Zambezi Valley and that lions are on quota for sport hunting, there has been no detailed population study carried out in the Zambezi Valley on this species. Dunham (1994) carried out a brief study of the effects that changing prey availability (due to drought) had on a lion population in the Mana Pools National Park. No telemetry or identification techniques were used but observations being made during annual Road Strip Counts were used primarily to obtain population density estimates for the larger herbivore species (Dunham, 1994).

Although no hunting is allowed in the Mana Pools National Park, the park is sandwiched between the Safari Areas and thus acts as an important sanctuary to some breeding wildlife which then spills over into the Safari Areas. In the Safari Areas only male lions are hunted on quota and it was not known whether this selective hunting had affected the lion population in the Mana Pools National Park adversely because no base-line data existed on the lion population there.

Concerns were expressed in the late 1980's by a number of photographic tour operators and visitors to the Mana Pools National Park that the lion population on the floodplain was decreasing. Some of these concerns were documented as firm conclusions by a specific tour operator (Pope, 2004), alleging that he saw more lions between 1980 and 1983 than after that period.

Two hypotheses for the apparent decline of lions were put forward by operators and visitors from anecdotal reports and observations:

- The first hypothesis was that there had been an increase in the spotted hyaena (*Crocuta crocuta*) population on the floodplain, an area of 95.5 km^2 (as measured by GIS for this study) and,
- The second hypothesis was that sport hunting in the Safari Areas surrounding the Mana Pools National Park was having a negative effect on the recruitment of young lion into the population. Hunters usually select for a particular demographic group within the lion population (male lions in their prime). This selection can result in prides being without a resident male, and also allows for infanticide by incoming males.

The study of Cooper (1991) gave weight to the two hypotheses. Both hypotheses together or separately, if correct, would suggest that the lion population structure in the Mana Pools National Park would exhibit the affects of the high spotted hyaena population and the effects of sport hunting. These external influences acting against the lion population would be exhibited by poor recruitment of cubs to adulthood and fewer adult males (Rodgers, 1974;

Packer *et al.,* 1988; Yamazaki, 1996; Whitman & Packer, 1997). Over-exploitation of lions by sport hunting does not only cause changes in the structure of a lion population within the areas being hunted; it can also affect the population in adjacent non-hunting areas due to "edge effects" (Woodroffe & Ginsberg, 1998). This may especially be so if, as is the case of the Mana Pools National Park, there are no man-made or natural physical boundaries between the two different land-use areas.

Loveridge (2005) showed that the lion population in the Hwange National Park (north-west Zimbabwe) was being adversely affected by high quotas from the surrounding Safari Areas. The Mana Pools National Park is also surrounded by Safari Areas, where hunting of lions takes place, albeit at low quotas. Therefore, it was hypothesized that the lion population would not be similarly affected in the Mana Pools National Park. Lions are susceptible to over-exploitation due to their socio-ecology (Greene *et al.,* 1998) and are regionally placed in Category 2(A) "vulnerable" by IUCN (2006).

Both hypotheses put forward by photographic tour operators and concerned public were possible and creditable and arose from concerns based on subjective observation. However, there was no empirical data collected to substantiate the theories and there was no base-line data available giving the population demography and status before 1980 and, moreover, before the present study was undertaken. The affects of the increased tourism activity (including tourists being allowed to walk on the floodplain unaccompanied by professional guides) was not considered. Non-consumptive tourism is not necessarily unobtrusive and "eco-friendly" (Monks, 2003; 2005).

The ZPWLMA initiated the present study to investigate the alleged decline in the lion population and the author was transferred to the Mana Pools National Park to carry out the study but on a part-time basis whilst running the park.

1.7 Objectives of this study

The objective of the study was to establish the demography and population status of lions in the Mana Pools National Park, Zimbabwe. This would take into account the population characteristics, group composition, home range size and dispersal of lions in the study area.

The main objective had to be studied in the proper context; therefore, other factors related to lion ecology were also included as a major part of the study, namely:

- The topography and vegetation of the study area
- The prey population
- Prey preferences
- Drafting of a lion management plan for the mid-Zambezi Valley.

2. STUDY AREA AND HISTORICAL PERSPECTIVE

2.1 The study area (General)

The Mana Pools National Park is situated in the mid-Zambezi Valley, in the extreme north of Zimbabwe (Figure 2.1). The Park is part of 16 672 km² mostly uninhabited protected area (apart from the border towns of Kariba and Chirundu) set aside for the conservation of wildlife both for non-consumptive tourism (photographic) and consumptive tourism (sustainable sport hunting). No hunting takes place in the Mana Pools National Park.

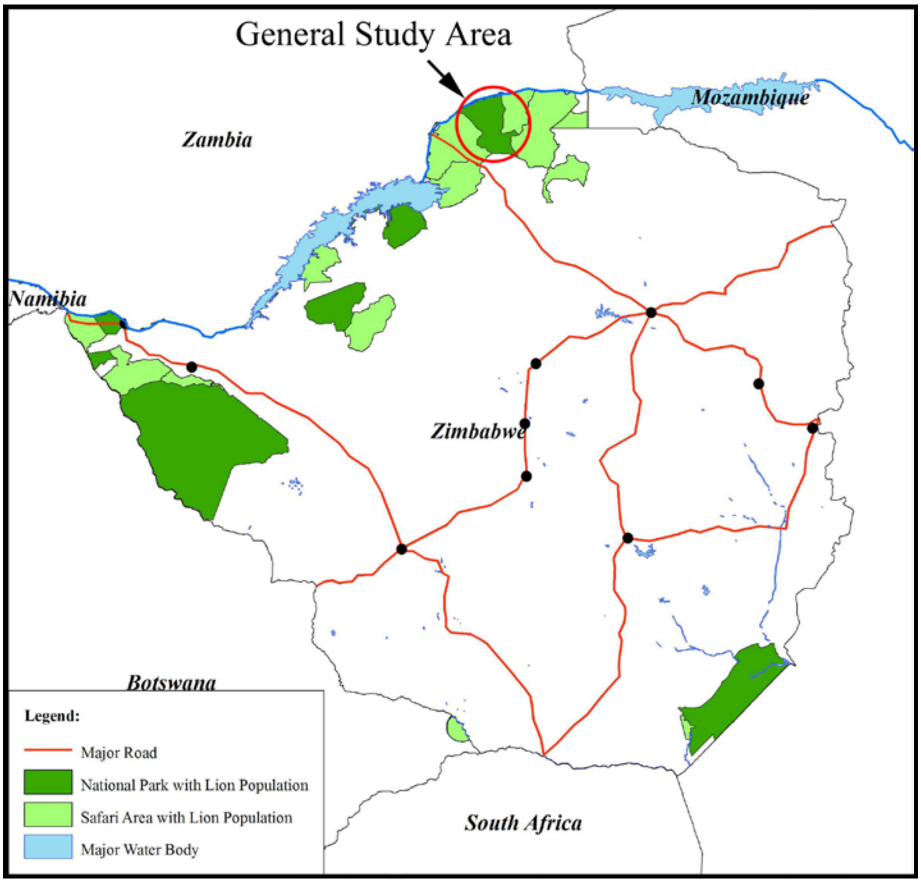

Figure 2.1 Parks and Safari Areas in Zimbabwe with naturally occurring lion populations also showing the general study area.

The term "Mid-Zambezi Valley" is used loosely to describe the section of un-flooded country along the Zambezi River between the Kariba Dam (Zimbabwe) and the Caborra Bassa Dam in Mozambique. Geographically the Mid-Zambezi Valley, Zimbabwe is situated in the extreme north of Zimbabwe, south of and including the Zambezi River (Figure 2.1). In this study the term “Mid-Zambezi Valley” refers to the un-flooded area of land between the Kariba Dam and the confluence of the Luangwa River near the Mozambique border, and south of the Zambezi River inclusive of the Zambezi Valley floor and parts of the Zambezi Escarpment. The Mana Pools National Park was the general area of study with the Zambezi floodplain in the park being the main focus for the study.

The Mid-Zambezi Valley is a vast, mostly uninhabited area set aside for the conservation of indigenous flora and fauna. It comprises six wildlife areas (Figure 2.2) all administered by the Zimbabwe Parks and Wildlife Management Authority (ZPWLMA) namely: Charara Safari Area (1 692 km²), Hurungwe (also known as Urungwe and Nyakasanga) Safari Area (2 894 km²), Mana Pools National Park (2 196 km²), Sapi Safari Area (1 180 km²), Chewore Safari Area (3 390 km²) and Dande Safari Area (523 km²). The Doma Safari Area, although shown in Figure 2.2, is not considered to be in the Zambezi Valley.

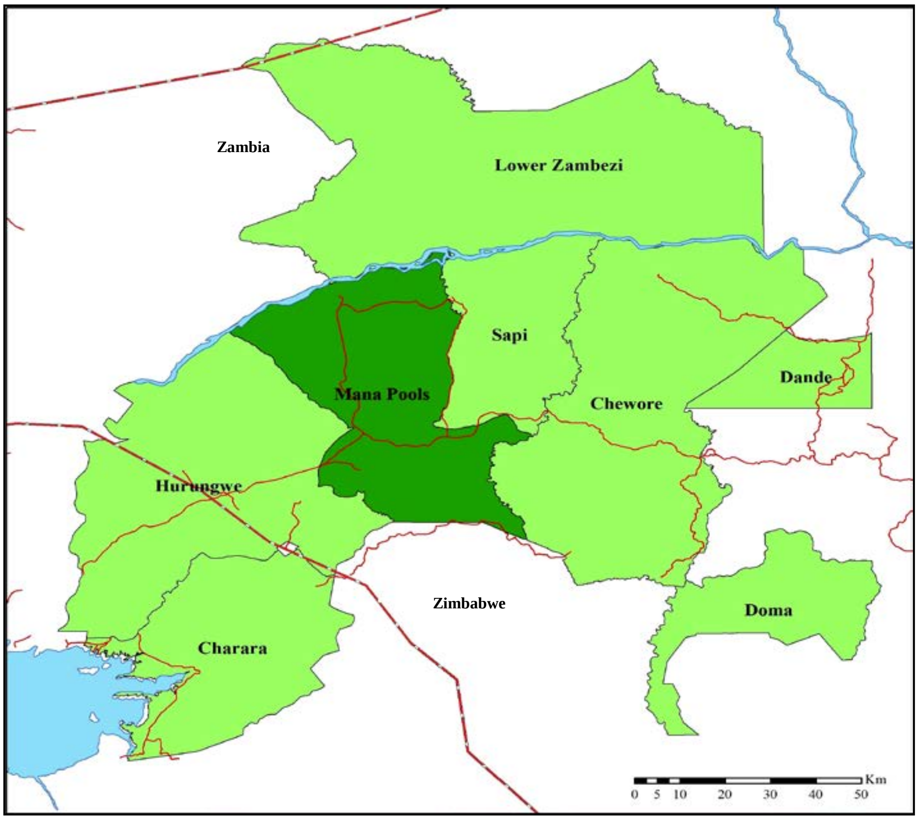

Figure 2.2 The Mana Pools National Park and surrounding Safari Areas in the mid-Zambezi Valley, Zimbabwe, showing also the Lower Zambezi National Park, Zambia.

In Safari Areas, although land-use is mainly consumptive tourism, a range of outdoor activities including fishing, boating, camping, and game viewing also takes place. In the Mana Pools National Park, land use is strictly non-consumptive tourism including canoeing, fishing, walking, game-viewing, photography, and camping.

There are no fences or physical boundaries between the different land-use areas west to east, so that wildlife can move freely along the Valley floor virtually from alongside the Kariba Dam and downstream to Mozambique (Figure 2.2). The Zambezi River in the north is not a permanent barrier to larger wildlife species (including, as this study has shown, lions), that use shallow areas and islands as crossing points. In the extreme south of the Valley is the Zimbabwe Zambezi Escarpment, comprising precipitous hills rising abruptly to over 300 m above the Valley floor. The escarpment forms a physical barrier to many wildlife species, but elephants have created paths along contours, and lions and other wildlife species do sometimes move up the escarpment. However, the Mukwichi Communal Lands (where agriculture is practiced) are on the plateau directly south of the escarpment. Wildlife tends to avoid these inhabited areas. In addition, at the southern extent of the escarpment, a tsetse fly (*Glossinia morsitans* and *G. pallidipes*) control game fence and corridor has been put in place to restrict animal movement south into the Mukwichi Communal lands and commercial farmland further south. This man-made barrier was an effective obstruction to most wildlife movement out of the Valley. In recent times the fence has not been fully maintained and some sections are no longer standing.

During this study, no reports were received of lions killing livestock in the Mukwichi Communal Land which is along the boundary of the Mana Pools National Park. No other inhabited areas apart from tourist camps are located near or in the study area, except for Chirundu Town in the west. Across the river in Zambia, human settlements do occur to the north-west of the study area but directly opposite is the Lower Zambezi National Park (Figure 2.2).

2.2 Historical perspective

Prior to 1955, the area was sparsely populated by the local Va Doma and Mkorekore people living a subsistence lifestyle. In 1912, twenty two kraals with 440 male tax payers were recorded (Du Toit, 1982). In 1957, just prior to the translocation of local people from the Zambezi Valley (in preparation of the completion of the Kariba Dam in 1958), 2 230 tax payers were recorded in Chief Dandawa's section of the Valley floor. Due to tsetse fly (*G. morsitans* and *G. pallidipes*) no livestock was present in the Valley. The local settlements shifted during the rains because many areas on the floodplain became waterlogged and uninhabitable. Crops were not a main feature of this subsistence lifestyle since wildlife decimated crops. Hunting and trade in ivory (later to become illegal under colonial government and subsequent government) were the main human activities.

The Urungwe Non-hunting Reserve was established under proclamation No. 2 of 1955. This area was situated in the mid-Zambezi Valley between the Rukomechi River in the west and the Mozambique boundary in the east. In 1958, the area was proclaimed a wildlife refuge and the local people were relocated to the Mukwichi Communal Land on the plateau above the Zambezi Escarpment. In 1960, most of the Valley Floor east of the Rukomechi River was included in the Urungwe Non-Hunting Reserve (Wildlife Conservation Act 1960–Schedule 2 Government Printer).

The Urungwe Non-hunting Reserve was split up in 1963, and the area between the Rukomechi and Sapi Rivers became the Mana Pools Game Reserve. The southern boundary of Mana Pools only extended about 25 km to the south of the Zambezi River, giving an area of just 865 km^2. The area west and south of Mana Pools was incorporated into the Rukomechi East Controlled Hunting area. In 1964 the Mana Pools Game Reserve was extended to include most of the Rukomechi east Controlled Hunting Area increasing the area to 1 927 km^2. Hunting still took place in the north-west of the reserve as part of the Urungwe Controlled Hunting Area. One of the hunting camps was situated at Vundu Camp in the present Mana Pools National Park.

In 1968, the western boundary of the Mana Pools Game Reserve was extended westward to include the Rukomechi River alluvium and south-westwards to include the Rukomechi Research Station (tsetse fly research). In 1975, the Mana Pools Game Reserve was gazetted as the Mana Pools National Park (Parks and Wild Life Act 1975, Schedule 1 Rhodesian Government Printer). With these additions to the area, the Mana Pools National Park covered 2 196 km^2. In 1983, the Mana Pools National Park, Sapi Safari Area, and Chewore Safari Area were awarded World Heritage status.

2.3 Geology and geomorphology

The Zambezi Valley is part of the down-faulted African Rift Valley system with the Valley floor lying between the Zambezi escarpments in Zambia in the north and Zimbabwe in the south. The Valley floor is relatively flat and gently undulating, and stretches about 60 km between the two escarpment ranges at its widest point. At the Zambezi River, the Valley floor lies at approximately 350 m above sea level, rising gently to about 640 m above sea level at the base of the escarpment. The escarpment then rises abruptly from the Valley floor to an altitude of about 1 000 m above sea level. The escarpment consists of rugged hilly country that stretches southwards to the central plateau of Zimbabwe.

Du Toit (1982) in his report on the environmental implications of a proposed hydro-electric scheme on the Zambezi River, Zimbabwe, notes that information on the geology of the Zambezi Valley is not definitive; being derived from a number of unpublished reports that cover decades. Anderson (1981; cited by Du Toit, 1982) gives a more consolidated report on the geology and geomorphology of the area. The escarpment is comprised of metamorphosed and deformed paragneisses and gneisses rocks. These rocks are formed from ancient rocks of the Basement Complex whilst the Valley floor is comprised of younger Triassic sedimentary rocks (Karoo sediments). Much of the present landscape was formed by erosion since early Tertiary time.

2.4 Soils

Thompson (1958) and Henderson and Griffiths (1959) describe the soils in the Valley based on a reconnaissance to assess the irrigation potential of the area. Over most of the Valley, soils have developed on the Triassic formations of the Karoo System. In general these soils consist of fine to medium-grained sands on the surface horizon overlying an impervious layer of compacted strongly alkaline soil known commonly as “mopane” soils. Soils derived from the Aeolian sandstone of the Upper Triassic are found mainly in the northern half of the Valley.

These sandstone-derived soils are fine to medium grained and have a low water retention capacity. Extensive dry forests and thickets botanically classified as *Xylia torreana* dry forests (Hoare *et al.*, 2002) are found on this soil type. Alluvial deposits are found along the major rivers, namely the Zambezi, Rukomechi, Chewore and Sapi Rivers. These soils vary in texture but are generally sandy with poor water retention. On older alluvia such as the riparian forests along the Zambezi, the soils are deep with a greater content of clay. Thompson (1958) describes the soils on and above the escarpment as being derived from gneisses and are shallow, medium grained lithosolic sands.

2.5 Permanent water supplies

The Zambezi River forms the northern boundary of the study area and is the main permanent source of water in the mid-Zambezi Valley (Figure 2.3).

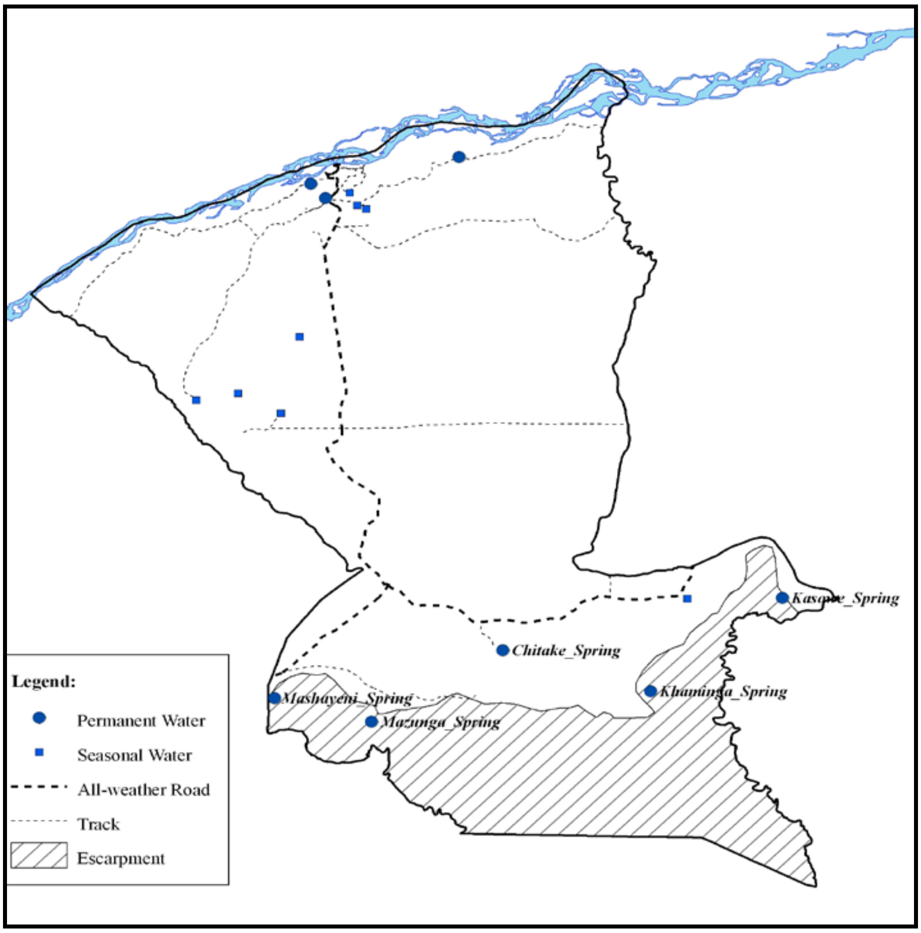

Figure 2.3 Location of permanent and semi-permanent water in the Mana Pools National Park.

Other major rivers such as the Rukomechi, Sapi, and Chewore rivers are seasonal, their dry season flow being dependent upon the previous seasons' rainfall. Elephant and other large herbivores dig for water in the sands of these rivers, but towards the end of the dry season the sub-surface water usually dries up.

There is one man-made dam (Chimutsi Dam) near the escarpment base in the southern Urungwe Safari Area (outside of the study area) and it provides water all year to the wildlife in this area.

2.6 Climate

The Mid-Zambezi Valley experiences one rainy season a year which falls between November and April.

The mean annual average rainfall taken over a 15 year period (1992 to 2007) was 679.4 mm (Figure 2.4). The mean maximum and minimum temperatures taken over the same period were: maximum 34.7ºC and minimum 18.7ºC (Figure 2.4).

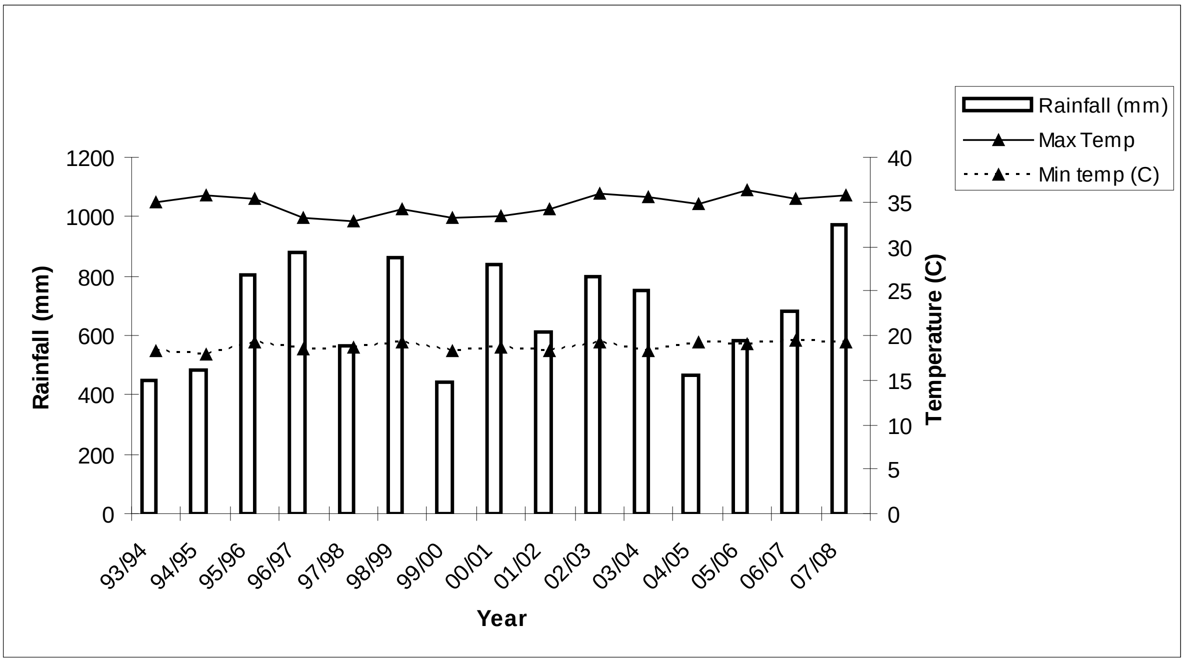

Figure 2.4 Mean annual rainfall and temperature for the Mana Pools National Park (1993/4 to 2007/8).

In Figure 2.4, the rainfall is shown for two years (e.g. 1993/1994) as being one season (i.e. November 1993 to April 1994). The temperatures are for the latter year (i.e. the 1993/1994 temperature is for January to December 1994).

2.7 Habitat types

Guy (1977) describes the vegetation of the Zambezi Valley between the Kariba and Mupata gorges, and recognizes 17 vegetation types. Muller and Pope (1982) updated this classification and whilst only recognizing 10 major vegetation types, sub-classify various major vegetation types according to physiognomy. Swanepoel (1989) used the classification of Muller and Pope (1982) for the Mana Pools National Park and expanded on areas not covered in that work.

For this study, 10 habitat types were recognised using the 2002 satellite imagery (Figure 2.5). These 10 habitat types can be very broadly divided into the floodplain, Valley floor, and Escarpment habitats:

- Zambezi River floodplain (mainly *Faidherbia albida* woodland with divisions)
- Zambezi Valley floor consisting of:
    - Dry forests (*Xylia torreana*)
    - *Acacia tortillas* woodland savannah
    - *Colophospermum mopane* woodlands (with divisions)
- Zambezi Escarpment (*Brachystegia/Julbernardia* woodland).

The Zambezi River floodplain (Figures 2.6.1 and 2.6.2) was mapped in more detail for this study since this was the primary area in which the research was carried out. This was done by using the Geographic Information System (GIS) and ground-truthing.

2.7.1 *Faidherbia albida* woodland along the Zambezi River (General Description)

This habitat type is the most important in terms of the distribution and density of wildlife in the study area. It extends along the Zambezi River from west of the Rukomechi River to east of the Sapi River, an area of 95.5 km² (measured by GIS mapping). This key tree species has a “seasonally-inverted foliage” (Dunham, 1990) that supplies shade and food during the dry season, with leaf and fruit production taking place after the rains. Dunham (1990) estimated the production of *Faidherbia albida* pods to be in the region of 1 000 kg $ha^{-1}yr^{-1}$ in the Mana Pools area. Crude protein of the entire fruit is 13.8% and that of pods only 6.0%. Most large herbivores utilize the *Faidherbia albida* pods heavily as the alluvium dries out and as food productivity decreases in the under-storey and in the hinterland. This phenomenon results in heavy concentrations of ungulates congregating on the floodplain from August to November.

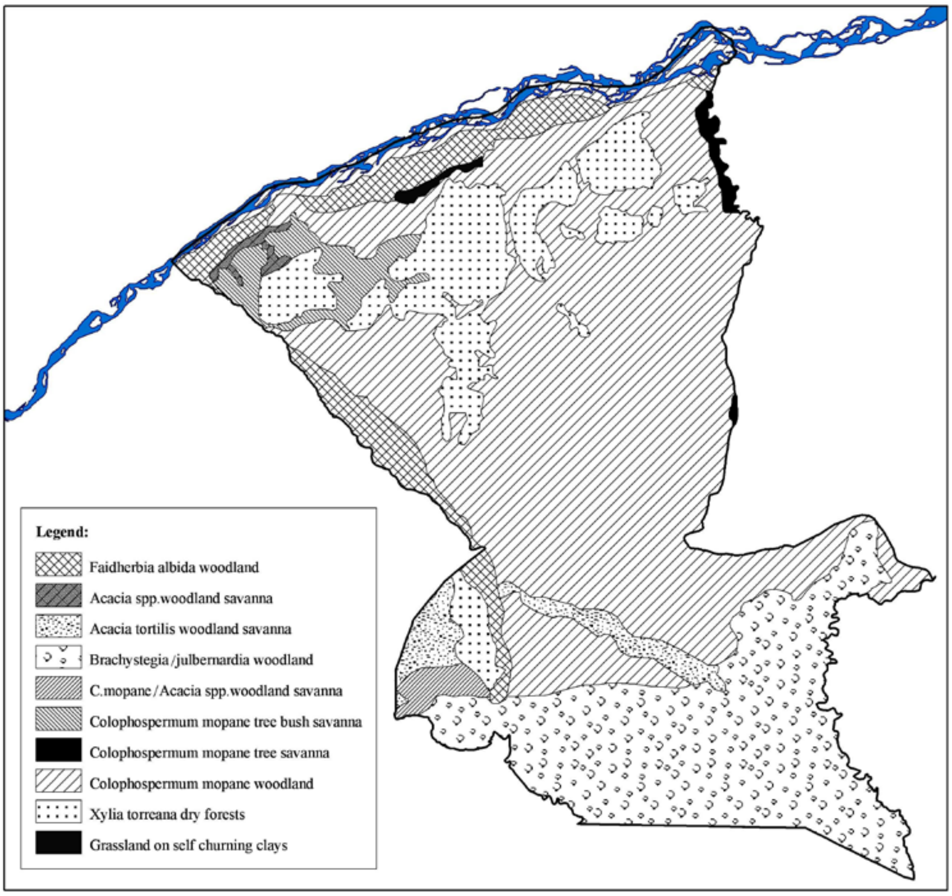

Figure 2.5 Habitat types in the Mana Pools National Park.

Jarman (1972) states that these concentrations of ungulates are some of the highest found in southern Africa. The density of ungulates in this vegetation type has important significance for the distribution and density of lions in the study area. From aerial surveys it is calculated that 63.5% of the lions' prey species are found in this vegetation type (Monks, 2003). The *Faidherbia albida* woodlands are divided according to physiognomy.

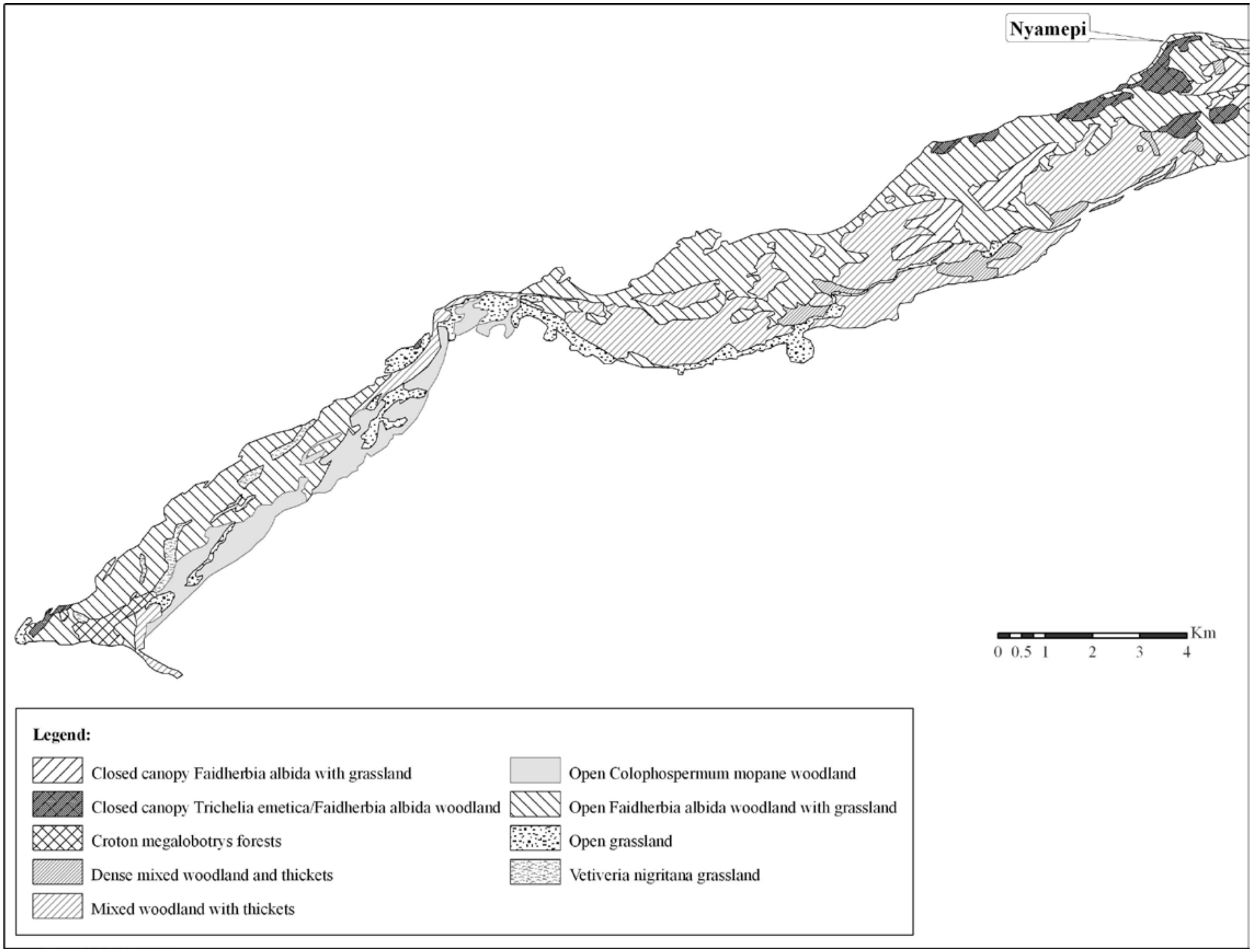

Figure 2.6.1 Habitat types on the Zambezi Floodplain (West) Mana Pools National Park.

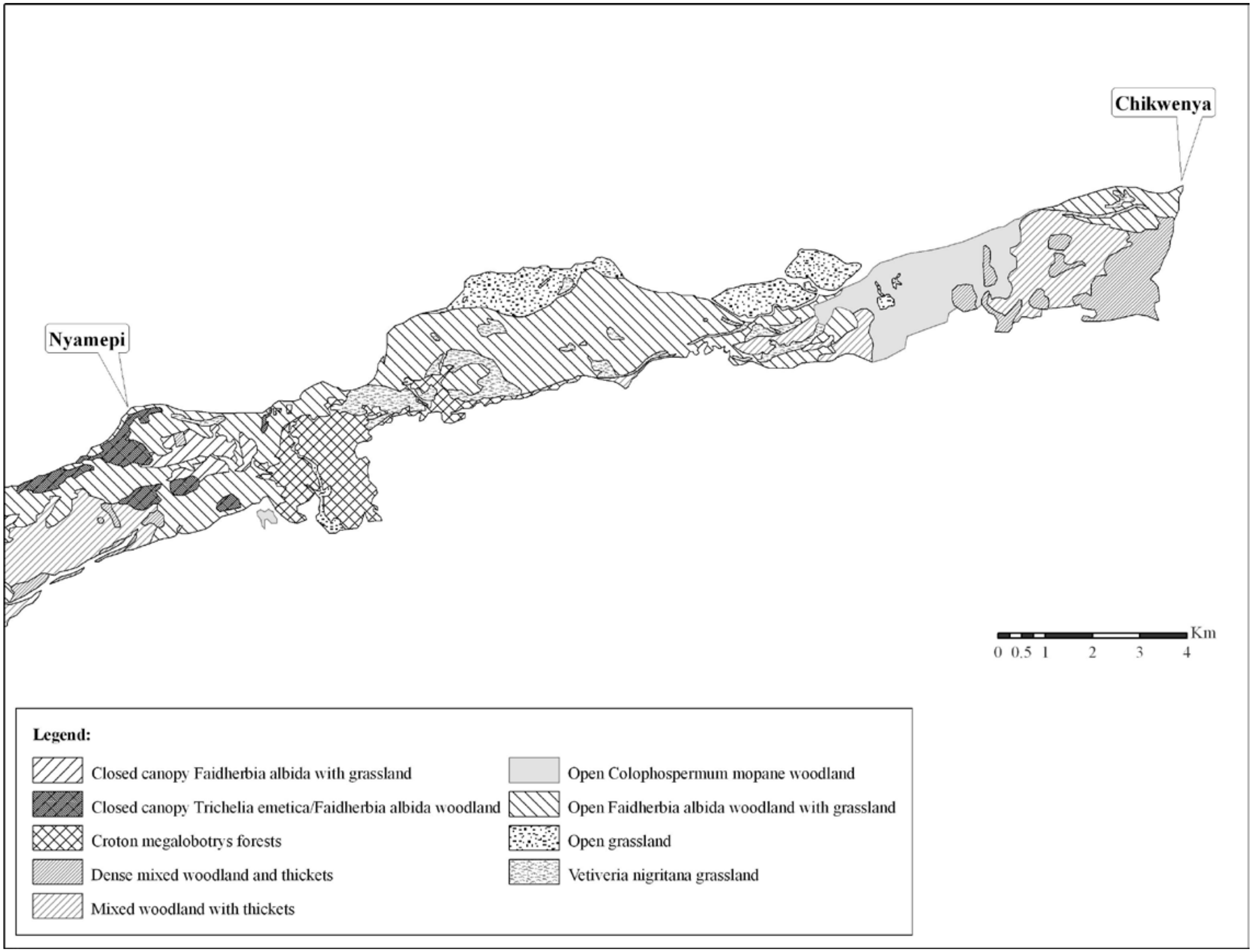

Figure 2.6.2 Habitat types on the Zambezi Floodplain (East) Mana Pools National Park.

2.7.2 Mixed woodland with thickets

On the high banks of old river channels, mixed stands of *Faidherbia albida*, *Combretum imberbe*, *Kigelia africana* and *Lonchocarpus capassa* woodland occur in about equal proportions. The under-storey consisting mainly of *Combretum mossambicense* is moderately thick, providing cover for lions. This habitat type occupies 20.07 km² (20.7%) of the floodplain.

2.7.3 Closed canopy *Trichelia emetica* and *Faidherbia albida* woodland

This closed woodland consists of mature *Trichelia emetica* with a well distributed under-storey of *Combretum mossambicense* and *Diospyros senensis* thickets. This habitat type does not have high food productivity potential and most wildlife use these areas for shade and shelter. This habitat type occupies 2.12 km² (2.19%) of the floodplain.

2.7.4 Open *Faidherbia albida* woodland with grassland

This type consists of open mature *Faidherbia albida* woodland, with no under-storey and with *Vetiveria nigritana* grassland found along old river channels. This grass is characteristic of the transition zone between secondary perimeter grassland and edaphic valley grassland (Vesey-Fitzgerald, 1960, 1963; cited in Atwell, 1970). Lions are able to use these grassland islands from which to ambush prey. This habitat type occupies 39.08 km² (40.3%) of the floodplain habitat.

2.7.5 Mixed woodland with thickets

Consists of more evenly spaced mixed woodland with *Combretum imberbe*, *Faidherbia albida* and *Lonchocarpus capassa* woodland interspersed with moderately dense thickets of *Combretum mossambicense* and *Diospyris senensis*. Mixed woodland with thickets occupies 20.07 km² (20.07%) of the floodplain.

2.7.6 Closed canopy *Faidherbia albida* with grassland

Closely spaced *Faidherbia albida* woodland in extensive *Vetiveria nigritana* grassland characterises this habitat type. This is typically found on low-lying areas that were previously inundated when the Zambezi River flooded pre-impoundment. The area contribution that this habitat types makes to the floodplain is 3.12 km² (3.1%).

2.7.7 Open grassland

Open short grassland on the eco-tone between *Colophospermum mopane* woodland and the floodplain vegetation is characteristic of this habitat type. Zebra in particular favour these areas. Open grassland on the floodplain has an area of 3.8 km² in extent and contributes 3.9% of the total floodplain habitat.

2.7.8 Open *Colophospermum mopane* woodland

Comprises mature "cathederal" *Colophospermum mopane* woodland that borders a pre-impoundment flooded area. The woodland has an open under-story and wildlife is not found in large numbers here. This type occupies 39.08 km² and contributes 40.3% of the floodplain habitat.

2.7.9 *Vetiveria nigritana* grassland

Pure stands of this grassland with sparsely placed *Faidherbia albida* trees characterise this habitat type. Numerous hippo tracks open up the grassland in which are small pans and waterways. Buffalo favour this type of habitat and the grassland provides cover for lions. In extent this occupies 3.92% of the floodplain and contributes 3.9% of the floodplain habitat.

2.7.10 *Croton megalobotrys* forests

Forests of varying thickness of this tree type are found along streams and stream banks where sand deposits have been made during flooding. These forests are dense and provide good cover but have very little food potential. These forests occupy 5.69% of the floodplain habitat (5.9% of the floodplain habitat types).

2.8 Valley Floor

2.8.1 Mature *Colophospermum mopane* woodland

This is the most extensive vegetation type in the Zambezi Valley, found on shallow poorly drained sodic soils on the Valley floor and on the poorly drained clay soils associated with the Zambezi alluvium. In the latter areas, the woodland is heavily degraded with the canopy loss being reduced to as little as 10% (Muller & Pope, 1982). The vegetation is characterised by pure stands of mature trees with a sparse under-storey. Young *Colophospermum mopane* may be found below the canopy and common shrub species such as *Boscia mossambicensis, Boscia matabelensis, Ximenia americana* and *Balanites aegyptiaca* are associated with this vegetation type. The majority of the Zambezi Valley floor is covered with mature mopane woodland.

2.8.2 Mature *Colophospermum mopane* tree bush savannah

This habitat type is found adjacent to the dry deciduous *Xylia torreana* woodlands and riparian communities and has a dense under-storey consisting of *Boscia mossambicensis, Combretum obovatum* and *Combretum elaeagnoides.* Various tree species are associated with this mopane type, the most common being *Acacia robusta*, *Shrebera trichoclado* and *Xeroderris stuhlmannii*. This type also occurs on the edges of the Zambezi alluvial system and inland between the floodplain and the densely wooded mature *Colophospermum mopane* on the Valley floor.

2.8.3 *Colophospermum mopane* tree savannah

Small stands of this type occur in the north-east and consist of open mature woodland with good grass cover.

2.8.4 *Colophospermum mopane-Acacia* spp. woodland savannah

This type is found in the extreme south-west of the park in possibly disturbed areas. Mature stands of *Acacia tortillas* and *Colophospermum mopane* open woodland with a well grassed under-storey is characterised by this type.

2.8.5 *Xylia torreana* dry forests

This vegetation type has been described by Hoare *et al.* (2002). These dry forests comprise tree species that are uncommon elsewhere such as *Xylia torreana*, and shrubs such as *Dalbergia martini* and *Citropsis daweana*. This habitat type is an important wet season range to most browser species which will move off the floodplain and the springs in the north when the rains set in. During the dry season elephants (mainly family groups) are found in these forest patches within easy range of the Zambezi River. During the height of the dry season nyala are found in the forests as well as duiker and oribi, (see **Appendix 1** for scientific names of wildlife in the Zambezi Valley). Large browsers such as eland and kudu tend to move onto the floodplain when the *Faidherbia albida* woodland begins dropping fruit (August-November). At calling stations in these dry forests lion numbers appeared to be low.

2.9 Escarpment vegetation

2.9.1 *Brachystegia/Julbernardia* woodland

The rugged Zambezi Valley escarpment vegetation is characterised by mature *Brachystegia spiciformis, Brachystegia boehmii* and *Julbernardia globiflora* woodland (collectively termed miombo woodland). This vegetation type covers much of the Zimbabwean central plateau. Lions were only rarely seen in the escarpment area of the study area. Along the Zambezi Valley Escarpment within the ZPWLMA estate, a management program is in place to carry out early burns to protect these fire-sensitive plant species from late uncontrolled, hot burns.

2.10 Human influence

2.10.1 The Mana Pools National Park

The Mana Pools National Park floodplain has a high tourist activity with currently an average of 860 visitors in the park per month (station records). Tourist activities include game drives, walks, canoeing, camping, and fishing. All game-viewing tourist roads are situated on the flood-plain with the majority of activities taking place in 46.4km² of the 95.5 km² floodplain. A limit of 50 vehicles per day has been set so that, in theory, there is at least a space of one kilometre between vehicles. No off road driving is permitted. The noise and activity of vehicles in a relatively small area does disturb wildlife although they tended to accept slow moving vehicles but panic when vehicles are moving fast. The major anthropogenic disturbance is from tourists on foot. Tourists without a guide tend to approach wildlife without understanding how their activities affect the animals. By analyzing data collected from observing collared lions, Monks (2005) found that lions deliberately moved into thickets as soon as they observed tourists on foot. Other wildlife species also evaded people on foot, often moving off when tourists were still some distance away.

The fact that tourists can walk on the floodplain is a unique experiment in an area with potentially dangerous wildlife, but it has proved to be very popular and has become part of the essence of the Mana Pools National Park.

2.10.2 Surrounding Safari Areas

Activities in the Safari Areas are similar to that taking place in the Mana Pools National Park with the addition of hunting. Hunting is a major disturbance to wildlife but the hunting season only lasts six months (between May and October) so wildlife are without human disturbance for six months of the year. Human numbers on Safari are low (usually a maximum of six clients per hunt, with three vehicles operating at one time).

The two Safari areas adjoining the Mana Pools National Park (Nyakasanga in the west and Sapi in the east) have an annual lion quota of only one adult male each and so the effects on the social organisation (Whitman & Packer, 1997), and hence population status of the lions would be negligible. Chewore South Safari Area has a quota of 5 lions per annum and the effect of this selective off-take is yet to be determined.

In the Safari Areas lions are shot at bait set in trees at strategic points and only males are taken. The hunter remains hidden exerting little disturbance to wildlife. The actual shooting is of course a major disturbance factor. No night hunting is allowed in areas administered by National Parks and there is no bow hunting. All Safari hunters fulfil their lion quota and this may indicate that the quota is set at a sustainable level. Trophy quality measurements indicate that mature males are being taken off, but quality of mane varies considerably (N.J. Monks, personal observations).

2.10.3 Poaching activities

Like most parks in Africa and elsewhere in the world, poaching does occur. There are three types of poaching in the Mana Pools National Park. Firstly, fish poaching along the Zambezi River which has little disruptive potential for wildlife inland unless the fishermen are acting as carriers for ivory poachers. Secondly, commercial poaching which concentrates mainly on elephant for the ivory. Poachers will not use the floodplain due to the human activity taking place there and the threat of detection. Most poaching takes place in the south of the park, Thirdly, subsistence poaching occurs on the hard boundary with Mukwichi Communal land where snares are set.

No incidents have been reported by rangers of lions being illegally shot or snared. Anti-poaching patrols cover the whole park but concentrates on areas of known illegal activities. These areas also correspond in the dry season to where there is water inland, and many pans and springs have names given to them by rangers that indicate what was found there, for example “six rhino pan” or “two elephant spring”. Poaching is under control but not eradicated, and parks staff work tirelessly to ensure the integrity of the Mana Pools National Park.

3. MATERIALS AND METHODS

3.1 Survey to establish areas of highest lion density

At the beginning of the study in 2001, a survey was carried out using calling stations (Figure 3.1) to establish the spatial distribution of lions and to confirm (from anecdotal reports) the area of highest lion density.

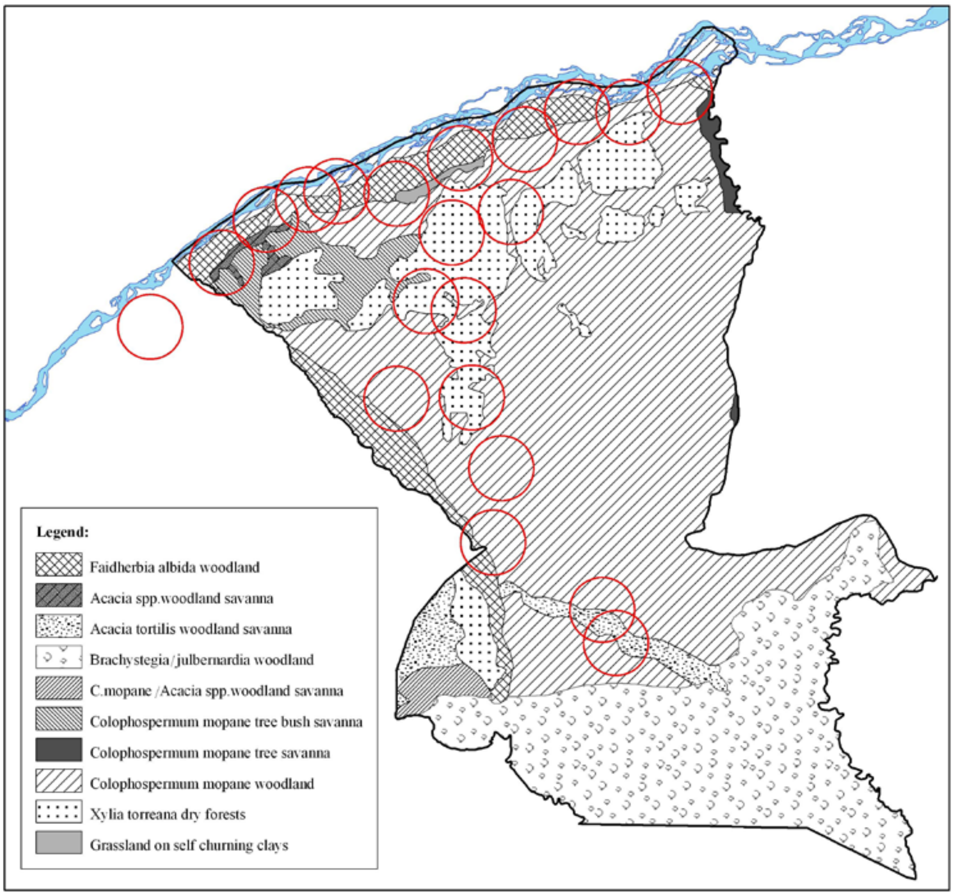

Figure 3.1 Distribution of calling stations to ascertain lion presence and distribution.

Due to the many constraints that this study faced it was necessary to concentrate the limited resources and effort in areas having a high representative population of lions. These areas also correlated to areas holding a local high prey density, such as at Chitake Spring, or in places of overall high density such as on the Mana Pools Zambezi River floodplain. Other areas of low or unknown lion presence were not systematically surveyed subsequent to the original survey, although opportunistic sightings were recorded and used.

No empirical historical data exists for lion numbers and distribution in the Mana Pools National Park. Therefore, tourist, tour operator, and staff sightings from 1992 to 2001 were analysed to obtain an indication of spatial distribution and an attempt was made to obtain a minimum population number. The records were too vague and poorly presented for a minimum lion population to be obtained, but the spatial data was useable. Later, after the study began in all earnest, tourist sighting records were utilized as visitors were encouraged to participate in data collection and there was an improvement in sighting records.

3.2 Estimate of a minimum lion population size in the Mana Pools National Park

A minimum lion population size was calculated using data from various sources. This included radio telemetry and staff sighting records. Sighting records giving location and number of lions (with age and sex break-downs) were obtained using radio telemetry from marked prides, from trained parks staff, Safari guides,[1] and from visitors to the floodplain and Chitake Spring[2]. Lions coming up to a calling station were counted but the data was not used on its own to obtain a minimum lion population estimate for the park due to limitations in the survey method.

The calling station survey to ascertain lion presence and distribution covered 20.15% of the whole park (Figure 3.1). On the Zambezi floodplain, where this study was concentrated, 74.4% of the area, including the upper terraces consisting of open *Colophospermum mopane* woodland, was surveyed. On the Valley floor, 17.43% of the area was covered. Only one road is in place in the mid-area of the Mana Pools National Park and this runs from west to east. A small portion of this road was surveyed but the rest of the road had not been maintained and was impassable. The Zambezi Escarpment and the far south-east of the park were not surveyed.

Distress calls broadcast at calling stations covered on average an area of 23.76 km^2 per site encompassing a number of habitat types (Figure 3.1). Seven of the 10 habitat types (listed in section 2.7) were covered during the initial survey.

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[1] See under acknowledgements.
[2] Thanks especially to Leah Beevor and Clyde Elgar.

3.3 Spatial distribution of lions in the Mana Pools National Park

Spatial distribution of lions throughout the park was obtained from the same sources (radio telemetry, tourist sightings, and staff sightings). Historical sightings (1992 to 2001) by tourists were used but they showed limited coverage because most sightings were from roads. During this study, sightings of study prides using radio telemetry gave local (home-range) spatial data. By clumping all the sources of data, it was possible to obtain an approximate distribution of prides in the park. These points were plotted on a map using GIS (for GIS methods see 3.5). Parks staff sightings were invaluable as they covered most areas of the park during anti-poaching patrols on foot.

A total of 1 376 tourist and staff sightings points plus data collected by telemetry during the study made the original distribution map almost unreadable. In order to produce a more meaningful illustration of lion distribution throughout the park, clumped data points were removed and one foci point left to indicate a distribution point.

Tourist sightings records of lions decreased in the rainy season (November to April) as visitor numbers to the park declined. However data collection on marked prides using telemetry continued for the study and parks staff patrols were maintained so that data collection was constant, although not of all areas in the park.

Maddock and Mills (1993) used tourist sightings in the Kruger National Park to obtain a minimum population estimate of wild dog (*Lycaon pictus*). Purchase (2002) argues that for selected wildlife species, tourist sighting records (where they are encouraged to participate in information gathering) are suitable for working out minimum populations.

3.4 Calling stations, darting, collaring, tracking and data collection

3.4.1 Calling stations

Using the limited road network, calling sites were chosen so that as much of the study area and different habitat types could be covered as possible (see detail in Figure 3.1). All work was carried out at night from sunset to midnight and one hour was spent at each calling station if no lions had come up before that time. The method of call-ups followed that of Smuts and Whyte (1977), Ogutu and Dublin (1998) and Mills *et al.* (2001).

After the initial call-ups further call-up stations were set up and may have covered some areas several times. This could be (a) when a previous call-up had not been successful, (b) when a collared animal needed the collar removed or replaced, (c) equipment malfunctions after a short period of calling, (d) when fresh spoor of lions, or visual sightings were seen during the day in an area previously surveyed and there was a likely possibility of marking a lion because of their known presence in the area.

A calling station site was chosen which had adequate cover for the lions to feel safe as they approached and open enough for the author to visually locate approaching animals. Bait, in the form of a freshly culled animal (usually an impala), was secured to a suitable tree at a height which spotted hyaena could not reach, and that would necessitate the lions having to stretch upwards in order to get to the bait. It was important to ensure that the bait was not too high up on the tree or else the lions lost interest and moved off. Intestines from the culled animal were used to scent the ground in order to attract and direct lions investigating the calls right up to the bait in the tree (Smuts *et al.,* 1977).

Loudspeakers were set up in the tree above the bait. Distress calls (of a pig and a calf) were broadcast using a 12 volt amplifier (Sharp PW1000) connected to a portable CD player. Two 18 inch public address-type cone speakers rated at 50 watts and 80 ohms were used, and the recordings played at full volume. The calls were played for 5 minutes followed by silence for a period of 5 minutes. The procedure was repeated until lions came to the bait or one hour had passed. The surrounding area was surveyed using a pair of night vision binoculars. No spotlights were used to search for lions. All predators coming up to the bait were identified and recorded and the time sequence that lions and spotted hyaena came to the bait was recorded.

If lions did not come up to the bait within an hour, the bait and speakers were collected and another site found. Having animal bait was more effective in getting the lions focussed at the calling stations than by only using call-ups vocalisations (Ogutu & Dublin, 1998; Mills *et al.,* 2001).

A broadcasting distance of between 2.0 and 3.5 km (Bowler, 1991) was achieved depending on topography, vegetation type, and cover. When calculating the area covered at calling stations, the average range was obtained from the maximum and minimum range. When analysing data from the calling stations, duplicated call-up sites were included. A total of 64 call-ups were carried out but of these only 20 sites covered unduplicated call-ups (Figure 3.1). Using an average broadcasting distance of 2.75 km radius, each calling station covered 23.76 km^2. This meant that several habitat types were covered during one call-up session.

3.4.2 Darting and collaring

The area around the bait was regularly scanned with night vision binoculars and when lions were up at the bait the drug mixture[3] was prepared [715 mg Ketamine HCl (Kyron Laboratories S.A.) and 180 mg Xylazine HCl (Kyron Laboratories S.A.)]. A disposable dart (3 cc) was filled with the drug mixture and the dart shot from a relative short distance with a dart gun (Pneu-Dart Inc., Williamsport, Pa) powered by a .22 powder charge. On impact, a second charge in the dart pushed the plunger down injecting the drug.

Once the lions were up at the bait, they were counted, aged and sexed (where possible). Usually one lion was chosen for immobilization and radio collaring and when it was in the right position it was darted in the rump or shoulder. In only two cases were two lions darted together at a site. In order to see sufficiently to carry out the darting, a spotlight with a red filter was directed on the individual long enough to aim and fire the dart. The author did the darting and collaring whilst the other team members carried out morphological measurements and blood and tissue collection. Morphological measurements followed the format set by De Waal *et al*. (2004) at the African Large Predator Research Unit (ALPRU).

On being hit by the dart, the targeted lion usually grunted, showed some antagonism to other lions feeding and then continued feeding as though nothing had happened. The drug took between 10 to 15 minutes before the full effect of anaesthesia was seen. During this time the team remained in two vehicles and the activity of the darted lion was watched closely using night vision binoculars.

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[3] Advice received from Dr. Chris Foggin. Department of Veterinary Services, Wildlife Section, Harare, Zimbabwe.

When the darted lion showed full signs of being anaesthetised the author drove up to the animal, leaned out of the vehicle and tapped it with a pole to make sure that it was fully under the effect of the drugs. If the lion showed any signs of being partially awake, a top-up of drug was administered using a pole syringe. The vehicle was then withdrawn and the animal checked again after 10 minutes.

When it was safe to do so, the two vehicles drove up to the immobilised lion and parked around it in a “V” formation so that the darted lion was between the two vehicles and only one side needed to be watched for attack by other lions. In most cases, the rest of the pride was very focussed at the bait and did not show any nervousness about the vehicles or the activity taking place.

A VHF radio collar in the 146 Mega Hertz range (Sirtrack, New Zealand) was activated, checked for functioning and then fitted around the lions’ neck. In the early stages of the research project, some collars fitted to males were put on too loosely and thrown (fallen off because the mane hair, being compressed, made the collar look too tight). Two lionesses managed to throw their collars as well. Thrown collars were collected and fitted on new lions where feasible although in some cases hyaena (or lions) had chewed at the collar making it unusable.

Once the procedure was completed the immobilized lion was given 25 mg Yohimbine HCl (Kyron Laboratories S.A.), to reverse the Xylazine. By the time the procedure was nearing completion the Ketamine had largely been metabolised and recovery after the administration of Yohimbine was steady, although not immediate. Members of the team remained in the vicinity of the immobilized lion until it was fully recovered to ensure that no accidents occurred and to protect it in case of attack or by an active interest from other lions, spotted hyaena or (as happened on a few occasions), by elephant. The rest of the pride, after feeding at the bait, usually waited around the recovering collared lion and when it was up and moving they moved off with it.

3.4.3 Tracking and data collection

The marked lions were tracked using a Telonics [Telemetry Electronics Consultants (USA)] TR 4 programmable 9 volt portable receiver. Individual frequencies of the collared lion could be set using the facility provided for in the receiver. Headphones were worn to listen for the signal (a one second pulse). A motion-sensor in the collar transmitter altered the rate of the signal pulse depending on activity: a one second pulse when the collar was stationary speeding up to two every second when there was movement, then increasing further when the collar had been stationary for more that 24 hours (on a dead lion or if the collar had fallen off).

Tracking was carried out from an open vehicle traversing roads in the study area. The tracker stood on the back of the vehicle rotating the aerial through 360º whilst listening for a signal. There was no aeroplane or micro-light support to assist in tracking. Once a strong signal was picked up tracking continued on foot. Transmitting distance was on average 2 to 3 km. In order not to disturb the lions so that they could be observed, the approach was made from downwind using normal hunting techniques (crouching down, moving slowly, scanning the area and using bushes to hide behind). Once the lions were seen, a GPS reading was taken, and the habitat type noted, group structure recorded and other data such as killed prey species, behaviour, and the presence or absence of other lions in the area also recorded.

In the field, lions were aged according to the methods described by Smuts *et al*. (1978). This involved judging the size of the cubs against the size of the mother and also looking at morphological indicators such as the undeveloped mane in immature males. The age classes assigned were: small cubs (0-1 year of age), large cubs (1-2 years of age), sub-adults (2-4 years of age) and adults (4+ years of age). Sub-adult females were difficult to distinguish against an adult female, but its general body condition, lack of (or fewer) scars and smaller teats helped in identifying it as a sub-adult. Later when the lions in the pride were better known, the general behaviour of the sub-adult females confirmed the age-class.

A total of four discrete prides of lions were identified on the Zambezi River floodplain in the Mana Pools National Park, extending from the west on the edge of the Hurungwe Safari Area to the east in the Sapi Safari Area (see Figure 2.2). These prides were named according to their core areas (from west to east), namely the Rukomechi pride; Nyamepi pride; Nyamatusi pride and Chikwenya pride. A fifth pride was identified in the Jesse bush area on the Valley floor and accordingly named Jesse pride. No collars were fitted to individuals in the Jesse pride but data was collected and all sightings were recorded. The sixth group of lions, with a core area at Chitake Spring on the Valley floor at the base of the Zambezi Escarpment, was named the Chitake pride.

Not all marked lion groups could be followed at equal frequencies. This frequency depended on the distance the group's core area was from base camp. The Nyamepi pride on the Zambezi Floodplain was most intensely studied.

3.5 Home ranges

Each time a marked individual or known pride was seen, a map reference was obtained of the site in which they were first seen, using a GPS. For mapping these home ranges, a geographic information system (GIS) was built of the study area, incorporating layers of lion data, National Parks infrastructure, vegetation, rivers and water points, elevation, political and administrative boundaries and satellite imagery. All spatial data analysis and presentation was done using a combination of the ArcGIS, Ilwis and Surfer software packages[4]. Home ranges were originally estimated and delineated using the KernelHR program and this data was then added as a layer to the generated map. Because only one pride (Nyamepi) had sufficient data points to produce a meaningful home range map using KernelHR, the 100% Minimum Convex Polygon (MCP) method was used for the other prides to calculate home range. For comparative purposes the Nyamepi pride home range was also calculated using the MCP method. All mapping was done using ArcMAP.

Map coordinates of un-collared lions were also collected during the study in order to get a measure of lion occupation in the rest of the park (outside of the Zambezi floodplain and Chitake Spring) and plotted on a map of the Mana Pools National Park using GIS. This gave a rough overall indication of lion occupancy in the Park.

3.5.1 Analysis of home ranges

Sighting data of marked lions was analysed using the 100% Minimum Convex Polygon (MCP) method and measuring area by GIS. The home range for the Nyamepi pride had

[4] Mr. Douglas Lawrence, Remote Sensing Specialist.

sufficient data points for the program KernalHR (Seaman & Powell, 1997) to be used although for comparative purposes this was also calculated using the MCP method.

3.6 Demography and population characteristics

During this study each time lions were seen, the pride composition (age and sex composition) and numbers was recorded. Data was then analysed to obtain inter-birth intervals, age at first birth, success of cubs, dispersal, population size and density, take-overs by other males and male tenure.

Pride composition changed throughout this study as members moved up in age classes, new cubs entered the pride, new males came into the pride and sub-adults moved away. An overall pride structure was calculated for the Zambezi floodplain prides and for the Chitake prides by dividing pride data into years and selecting year partitions (from first confirmed sighting to one year later) and taking that pride structure as being representative of that pride for that year. The pride composition for each marked pride was then pooled to obtain an overall pride composition for all marked prides. Inter-birth intervals were calculated by following the reproductive history of the prides over the study period. The Nyamepi pride had the most comprehensive data and their reproductive history is shown separately.

3.7 Habitat preference

When lions were seen, the habitat type in which they were located was noted. The frequency in which lions were found in a particular habitat was calculated. In addition a subjective measure was made of the ease or difficulty with which the lions could be seen without the use of telemetry (difficult, moderately easy and easy) as a measure what degree of opportunity tourists had of seeing lions.

3.7.1 Analysis of habitat preferences

The frequency in which lions were found in a particular habitat type was calculated by combining all sightings in a particular habitat type and then obtaining a percentage against all habitat types combined.

3.8 Prey selection and prey density

When lions were found on a kill the prey species was recorded. If the prey was large such as a hippopotamus or juvenile elephant it was checked (using binoculars) to ascertain how fresh it was and if there were signs of teeth and claw marks. Obviously old carcasses could have died naturally or been appropriated from other predators so this data was not included in the analysis unless other signs indicated that the lions had made the kill. In each case the area around the site was checked to ascertain what had led to the animal dying.

In the case of lions killing the animal, signs confirmed this (e.g. the prey animal spoor showing flight with lion tracks following; lion spoor intermingling with that of the prey species, and evidence of a scuffle taking place). The chances of finding lions on small carcasses such as duiker or young of smaller animals are low. Other workers (Mitchell *et al.*, 1965; Makacha, 1969; Rodgers, 1974; Funston *et al.*, 2001) acknowledge this difficulty when calculating prey preference. A total of 139 kill records were obtained during the study period.

An estimate of prey density on the Zambezi River floodplain was obtained by carrying out a road strip count using available roads. Extensive surveys could not be made of the entire park, however population estimates for prey species throughout the three main strata of the park (Floodplain, Valley floor and Zambezi Escarpment) were obtained from aerial surveys carried out by the African Wildlife Foundation in conjunction with the Zimbabwe Parks and Wild Life Management Authority (Dunham, 2003).

3.8.1 Analysis of prey selection

Prey selection ratings were calculated by dividing kill frequency by the relative abundance of that species (Pienaar, 1969; Ruggiero, 1991). Prey selection percentage was calculated as a percentage using the number of a species killed over the total contribution of kills by all species. An estimate of prey density on the Zambezi River floodplain was obtained by carrying out a road strip count using available roads. Data was analysed using the Distance program (Laake *et al*., 1994). Biomass of wildlife was obtained by taking the body weight of the prey species and multiplying it by the estimated population of that prey species.

3.9 Morphometric measurements

Morphological measurements were taken of immobilised lions using the measurements developed by the African Large Predator Research Unit (De Waal *et al*., 2004). The data has not been analysed for this study and more data will be collected during monitoring of the lions. The measurements were comprehensive as shown in the ALPRU data form (**Appendix 2**).

3.10 Serology

Blood was drawn from the femoral vein of immobilised lions[5] (blood from smaller veins tended to clot in the needle as it was being drawn). The sample was allowed to stand in a cool place for four hours and the separated serum was drawn off and frozen. The frozen samples were later taken in an ice-packed cooler box to the Veterinary Wildlife Research Laboratory (Harare) for analysis. Only 11 blood samples were taken from the 19 animals darted and marked. The serum was tested for Feline Immunodeficiency Virus[6].

3.11 Other members of the large mammal predator guild at calling stations

During call-up sessions all activity taking place around the bait and all carnivores coming up to the bait were recorded. The response to the broadcasted distress calls by carnivores was noted and frequency calculated.

3.11.1 Analysis of predator guild

Comparisons between the time it took the two main competing predators, lions and spotted hyaena, to come up to bait (from the start of calls to appearance at the bait); the % response of lions and spotted hyaena to the calling station and the percentage time lions and spotted hyaena came to calling stations with their young was worked out from the 64 call-ups made during the course of this study. Other large predators coming up to the bait were also recorded but only percentage response to calling stations were obtained from this data.

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[5] Dr. Murphree-Monks.
[6] Through Dr. Chris Foggin. Department of Veterinary Services, Wildlife Veterinary Unit, Harare, Zimbabwe.

3.12 Dispersal in young males

Young males were judged to have emigrated if they were no longer seen with the natal pride over a period of sightings. The subjective criterion used by Hanby and Bygott (1987) was used to determine the fate of a young male if he was not seen again in the natal pride, namely: if a single male disappeared it was judged to be dead but the disappearance of two or more males was assumed to be due to emigration.

3.13 Mortalities

Lion mortalities were recorded throughout the study period. Where possible the cause of death was ascertained and the age of the animal at death was estimated.

3.14 Vegetation mapping and area calculations of the primary study area

The vegetation map produced by Swanepoel (1989) was used as a base for this study. For the present study a vegetation map was produced using the GIS. All data was logged using the Universal Transverse Mercator (UTM) system, with the Clarke 1880 Ellipsoid and the Arc1950 datum. This is the system used in the Zimbabwe Surveyor General 1:50,000 maps of the area and was maintained to enable the use of these maps in the study. Original vegetation mapping was done in 2004 by the Forestry Commission mapping office (Harare) for this study using Landsat satellite imagery.

Subsequent more detailed mapping of the floodplain vegetation (the primary study area) was carried out using a principal components analysis (PCA) image built from a 2001 Aster satellite image by a Remote Sensing Specialist for this study[7]. This satellite platform has a higher spatial resolution than Landsat and also captures more bands across the electromagnetic spectrum. Areas of spectrally similar vegetation were demarcated and mapped (Figures 2.6.1 and 2.6.2) using the satellite imagery and then these were defined and confirmed on the ground by the author.

[7] Mr. Douglas Lawrence.

The Zambezi River floodplain in the Mana Pools National Park stretches from the Rukomechi River in the west to the Sapi River in the east. The total area of floodplain is 95.5 km^2 (measured by GIS) and this is further divided into three distinct sections (Rukomechi-Vundu = 14.5 km^2, Vundu-Chiruwe River = 46.4 km^2 and Chiruwe River-Sapi River = 34.6 km^2). Open *Colophospermum mopane* woodlands are found on the southern edge of the floodplain and this area was also measured since lions do use it in their home ranges. This was calculated (again using GIS) to be 149.5 km^2 making the whole primary study area adjoining the Zambezi River, 245 km^2. The *Colophospermum mopane* woodland fringing the floodplain abuts on to the dry *Xylia torreana* forests but mapping did not continue into this vegetation type.

4. RESULTS AND DISCUSSION

4.1 The study prides

A total of 23 lions were darted and of these 22 were fitted with radio-collars and one male marked with an ear-tag. A total of 18 collars were put on lions along the Zambezi floodplain and four on the Valley floor lions at Chitake. Full particulars of all the radio-collars used are shown in Table 4.1. Some lions had to be darted and collared twice during the study period due to transmitter batteries reaching the end of their life span and to maintain continuity of data collection. On two occasions the thrown collars were retrieved and used on other lions. No GPS collars or aerial tracking was used in this study.

Table 4.1 Lions collared in the different prides and the transmitter frequencies

Pride	Date collared	Sex	Age Class	Collar No. (MHz)	Re-darted	New collar	Notes
Nyamatusi	6.3.01	Female	Adult	146.120			Died Nov 2003
Rukomechi	28.5.01	Female	Adult	146.024[1]			-
Nyamatusi	15.10.01	Male	Adult	146.060			Died May 2005
Nyamepi	26.10.01	Female	Adult	146.380	1.5.05	146.420	
Nyamatusi	4.12.01	Male	Adult	146.200[1]			-
Nyamepi	1.4.02	Male	Adult	146.040	19.11.04	146.140	Died Jan 2006
Nyamepi	24.4.02	Male	Adult	146.100			Died April 2003
Nyamepi	24.4.02	Male	Adult	146.160			Died April 2005
Chitake	28.6.02	Male	Adult	Ear tag 82			-
Chitake	28.6.02	Female	Adult	146.300			Died July 2008
Nyamepi	3.8.02	Female	Adult	146.180			In Zambia
Rukomechi	9.8.02	Female	Adult	146.080			-
Rukomechi	14.8.02	Male	SA	146.024[1a]			-
Chitake	17.11.02	Male	Adult	146.200[1a]			-
Nyamatusi	11.9.03	Female	Adult	146.280			Threw collar May 2004
Chikwenya	26.11.04	Female	Adult	146.220			-
Nomad?	24.12.04	Male	Adult	146.320			Shot in Chewore on commercial hunt (80 km from dart point)
Nyamepi	25.12.04	Male	SA	146.260			In Zambia
Nyamepi	4.8.05	Male	Adult	146.750			-
Chitake	8.9.05	Female	Adult	146.730			-
Chikwenya	20.10.05	Male	Adult	146.770			-
Nyamatusi	14.7.06	Female	Adult	146.340			-
Chitake	7.7.07	Male	SA	146.360			Seen in Chewore south

[1]Collar fell off and used on recipient lion.

[1]a Recipient lions.

The lions collared in the different prides are discussed below.

4.1.1 The Nyamepi pride (Zambezi Floodplain)

This pride occupies the *Faidherbia albida* woodland and mopane woodland fringes (see sections 2.7.1 to 2.7.9) giving variations in the structure of this habitat type. The woodland varies in under-storey density from very open (Figure 4.1) to almost closed thickets.

Figure 4.1 *Faidherbia albida* woodland - some of the habitat occupied by the Nyamepi lions.

When the study began the Nyamepi pride consisted of two adult females, one adult male and two sub-adult offspring (male and female). One adult female from this pride was darted and collared on 26 October 2001 and data collection began. The other adult female was darted and collared on 3 August 2002 to ensure continuity of data collection. In April 2002 a male was darted and collared in the west of the park in another pride territory (Rukomechi). This male was alone and it was assumed that he was a nomadic male, however three weeks later on 24 April 2002, a coalition of two adult males were darted and collared in the Nyamepi territory, and whilst working on them the lone male #4 appeared. The Nyamepi females also appeared at the bait and subsequent data collection on this pride showed that all collared animals were members of one pride.

4.1.2 **The Nyamatusi pride** (Zambezi floodplain)

This pride inhabits an area dominated by large areas of *Vetiveria nigritana* grassland. Tracking this pride was difficult due to the very dense grassland (Figure 4.2).

Adult lioness #12 was darted and collared in March 2001 and data collection began on this pride which occupies the Nyamatusi area on the Zambezi floodplain. Other members of the pride were identified and located during tracking of female #12 and in October and December 2001 two adult males #6 and #20 were collared. In September 2003 an adult lioness #28 was collared followed by a further adult lioness #34 in July 2006.

Figure 4.2 *Vetiveria nigritana* grassland with mature *Faidherbia albida* woodland - some of the habitat type occupied by Nyamatusi lions.

4.1.3 **The Chikwenya pride** (Zambezi Floodplain)

This pride's habitat is varied consisting of the same habitat types mentioned above but sometimes extending into the *Xylia torreana* forests and *Colophospermum mopane* woodland bordering the floodplain (Figure 4.3). One female was collared in November 2004 and a male in October 2005. This pride moves between the Sapi hunting area and Nyamatusi in the Mana Pools National Park.

4.1.4 **The Rukomechi pride** (Zambezi floodplain)

The Rukomechi pride occupies a variety of habitats ranging from open *Faidherbia albida* woodland to open *Cynodon dactylon* grassland interspersed with large swathes of *Vetiveria nigritana* grassland.

One lioness was darted and collared on the western edge of the Nyamepi territory in May 2001. She had multiple wounds caused by fighting and was in the company of a young lioness. She later was found in the Rukomechi area in the west of the park on the floodplain. A sub-adult male in this pride was collared in August 2004.

Figure 4.3 Typical *Xylia torreana* dry forest and *Colophospermum mopane* bordering the floodplain.

4.1.5 **The Chitake pride** (Zambezi Valley floor)

Adult male #82 was darted and marked with an ear-tag in June 2002. On the same exercise an adult lioness #30 was also darted and a collar fitted. Three subsequent lions were collared at Chitake: a mature male #20 in November 2002; an adult lioness #73 in September 2005 and a sub-adult male #36 in July 2007. This pride occupies a small area around Chitake Spring consisting of mixed woodland with open degraded areas (from previous settlements) and thick *Croton megalobotrys* woodland found along the Chitake River downstream of the spring.

The radio collars had a battery life averaging three years and before the collar stopped transmitting, the collar was replaced or a new individual in the pride was collared if possible. Transmitting distance varied, but signals were usually picked up at distances from 2 to 3 km depending on the topography. The signals of one collar (#6) transmitted over a distance of just over 4 km but this was the exception.

Tourists were encouraged to participate in the research by accompanying tracking sessions and no complaints of lions being collared were received. Packer (2003) defends the use of radio collars in various projects in Tanzania, showing how valuable data on wildlife could only have been collected by use of telemetry. This has also been the case for this first detailed study of lions carried out in the mid-Zambezi Valley, Zimbabwe.

4.2 Demography

4.2.1 Lion distribution

Although investigating lion distribution in the park was largely addressed by the call-up method, it had its constraints. In order to obtain a better overall distribution pattern of lions in the Mana Pools National Park, all sighting records (radio telemetry, tourists, and Park staff) were combined. The approximate distribution of the 11 prides is shown in Figure 4.4.

There are no artificial water supplies in the park and natural dry season supplies are not evenly distributed. The two main sources are from the Zambezi River in the north and from the perennial Chitake and Kasowe springs in the south at the base of the Zambezi Escarpment on the Valley floor. Wildlife follows this distribution and large mammal carnivores such as lions fit the same pattern as they follow their food source (Figure 4.5). Of the 11 estimated prides in the park, only six prides were studied; four were on the floodplain and two on the valley floor. In the mid-east of the park no prides were seen during foot patrols (Figures 4.4 and 4.5). The Zambezi River in the extreme north with riparian vegetation attracts heavy concentrations of wildlife during the dry period and also supplies a perennial water source.

Lions on the Zambezi floodplain do not have markedly different dry and wet season ranges since their prey base is constant although there is some movement of wildlife southwards as the Valley floor seasonal pans fill with water.

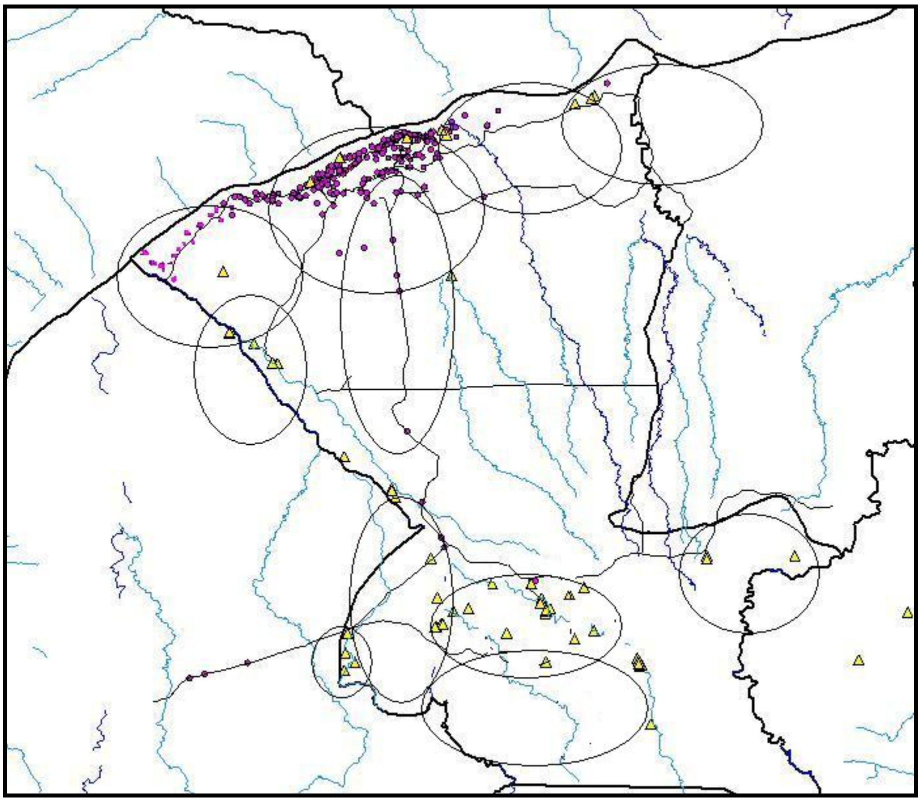


Figure 4.4 Distribution of the 11 lion prides in the Mana Pools National Park.

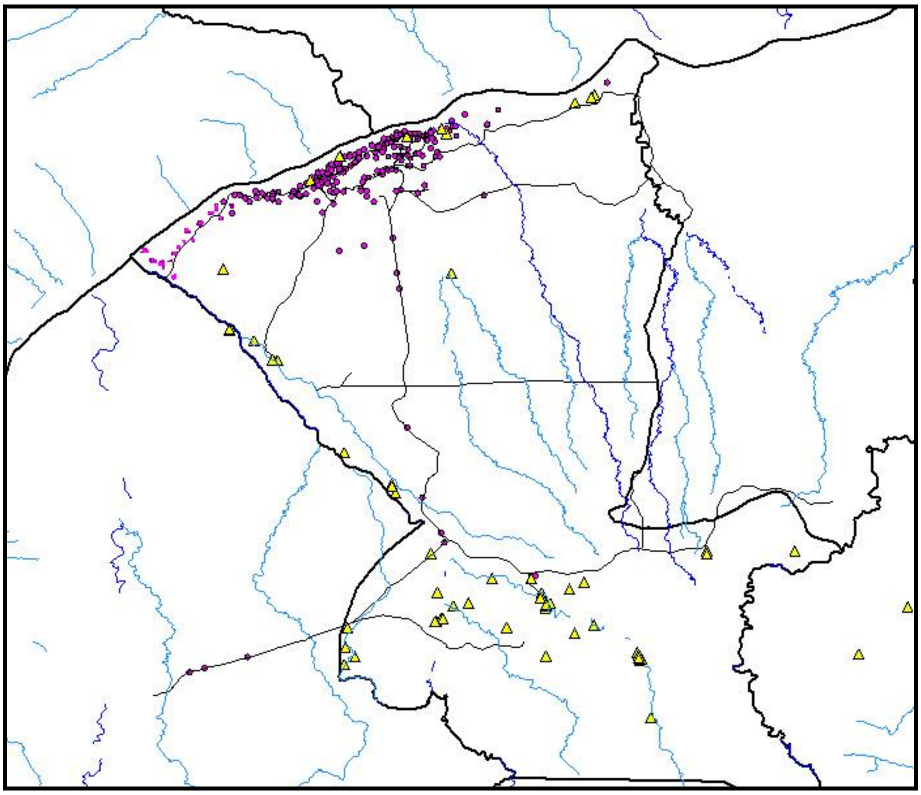


Figure 4.5 Dry season distribution of lions in the Mana Pools National Park [Purple dots from telemetry and tourist sightings; yellow triangles from foot patrols].

The southern lion population is locally distributed around perennial springs along the base of the Zambezi Escarpment during the dry season. These springs are the only water source for distances exceeding 30 km and support large localised wildlife concentrations. In the wet season, as natural pans fill with rain water, wildlife move away from the springs northwards and also east and westwards into areas that previously had no water. The Chitake lions show a wider wet season range as they follow wildlife away from the spring.

The Valley floor lions (apart from the permanent spring prides) are without water during the dry season and there is movement of these lions onto the floodplain or towards the springs. Clarke and Berry (1992) found that in hot conditions lions are not able to obtain their water requirements from their prey alone. The Jesse lions on the Valley floor make forays to the permanent ox-bow lake (Long Pool) near the Zambezi River or to the river itself. When the Jesse lions came onto the floodplain during the dry season the Nyamepi lions tended to move to the far east of their range on the border with the Nyamatusi lions. They were usually able to avoid confrontation although it is assumed that skirmishes did occur. At Rukomechi[1], safari guides reported periodic disputes and disruption in the resident lion pride there as new lions (probably from the Kanga pan area) came into the area during the dry season or from Nyakasanga Safari area. Unfortunately no lions were marked from these areas to confirm these impressions beyond doubt, however some of the Jesse bush lions were recognised by the author and a tour operator[2] and their spoor was frequently tracked back into the Jesse bush areas from the floodplain.

4.2.2 Population size and density

Pride sizes due to the sociality of lions are measured by the number of adults and sub-adults in the population (Smuts 1976; Stander, 1991). A minimum population size of 67 lions (adults and sub-adults) was calculated for the park (Table 4.2) as at the end of 2007. Low-density large predators such as lions are difficult to census (Schaller, 1972; Smuts, 1976; Funston & Herrmann, 2001) and this figure may be an underestimate. At the estimated density an equivalent of 3.05 lions/100 km² for the whole park is calculated. Density ranged from 0.65 lions/100 km² in the Zambezi Escarpment to 12.7 lions/100 km² on the Zambezi

[1] Wilderness Safari guides at Rukomechi.
[2] Mr. Ferreria, Goliath Safaris.

floodplain and associated mopane terraces. A density of 2.21 lions/100 km² was calculated for the Valley floor lions.

Of the estimated minimum number of 67 adult and sub-adult lions in the park, 31 were on the Zambezi floodplain (95.5 km²) and adjoining *Colophospermum mopane* woodland terrace (149.6 km²), together comprising 245 km². Thus, 46.3% of the adult lion population occupies an area of just 11.2% of the whole park. On the Valley floor (an area occupying 67.9% of the park) an estimate of 33 lions was calculated, whilst in the Zambezi Escarpment (20.9% of the park) only three lions were noted and these could have come from the Chitake pride.

Table 4.2 Minimum population and density estimates of lions in the Mana Pools National Park

Area	Number of lions	Lions/100 km²
Zambezi Floodplain and terraces (245 km²)	Adults and sub-adults	
Rukomechi Camp (Wilderness Safaris)	5[1]	
Nyamepi area	11[1]	
Nyamatusi area	9[1]	
Chikwenya area	6[1]	
Total	**31**	**12.7/100km²**
Valley floor (1 492 km²)		
Kanga Pan	11[2]	
Jesse bush	6[4]	
Chitake Spring, Valley floor	6[1&3]	
Rukomechi tsetse fly Research Station	3[4]	
Mashayeni Spring	2[2]	
Kasowe Spring	5[2]	
Total	**33**	**2.21/100km²**
Within the Zambezi Escarpment (459 km²)		
Mazungu Spring	3[4]	
Total	**3**	**0.65/100km²**
For whole Mana Pools National Park (2 196 km²)	**67**	**3.05/100km**

[1] From telemetry.

[2] From waterhole counts Wildlife and Environment.

[3] Additional information from Leah Beevor and Clyde Elgar.

[4] Patrol reports and personal sightings.

It was not possible to determine the population size with any degree of accuracy for the whole park. However the population estimate on the floodplain is judged to be accurate for two reasons: firstly, on the Zambezi floodplain, a number of calling station sites were set up during the course of this study, and no large groups of unmarked lions were seen, and secondly, whilst tracking the collared groups, no new lion groups were seen. Single and paired lions were encountered but these were judged to be nomads passing through the area. The same degree of accuracy cannot be applied to the rest of the park since the Valley floor was not well covered, and the far east of the park was not covered at all.

The break down of possible prides (Table 4.2) on the Valley floor may not be accurate since it is possible that the Chitake group, Rukomechi Research Station group, the Mashayeni group and the Mazungu Spring group in the Escarpment are all members of the Chitake pride. Apart from this the actual population estimate will not change. The Kasowe Spring pride is definitely a discrete pride but the Kanga pan and Jesse bush groups could be members of one pride. Unfortunately resources did not allow for members of these lions to be collared and followed and only opportunistic irregular sightings were made of the groups. The unmarked Jesse group and marked Chitake group were observed more frequently than the other Valley floor groups.

During road strip count surveys to obtain density estimates of large mammals on the Zambezi floodplain in the present study area, Dunham (1992) counted a mean of 4.39 lions (all ages) per 100 km travelled in the Nyamepi area (between 1981 and 1984) and a mean of 4.1 lions per 100 km driven between 1985 and 1989. The road strip counts were primarily carried out to obtain densities of wildlife but lion were also counted when seen. This was carried out in the Nyamepi area where the tourist road network is concentrated. The area surveyed (using the formula: distance travelled multiplied by the average perpendicular distance animals were seen from the road) was estimated to be 50 km^2 (Dunham, 1992). It is not possible to compare the present population figure with these density figures since road strip counts cannot be used to accurately estimate lion density. However it is interesting that the Nyamepi pride still occupies the same territory. Dunham (1992) reported seeing prides (all ages) of 10 or more lions in the area in 1982, 1983 and 1984. The present pride in the same area consists of 11 animals (all ages).

Pride females will occupy a territory for succeeding generations, the territory being handed down from mother to daughter (Grinnell & McComb, 1995). The size of the pride will depend on the food supply and social behaviour (Bertram, 1973). Lion distribution and population density correlates closely with prey distribution and density (Schaller, 1972; Bertram, 1973; Mills *et al*., 1978). In addition, if the prey base in a territory is constant then there is unlikely to be changes in the territory boundaries of a pride (Bertram, 1975). The Zambezi floodplain holds 63.5% of prey species taken by lions and also has the highest density of lions in the park. The prey density is normally constant and food and water supplies do not change except during drought when food sources for wildlife may decrease although with wildlife die-offs the food source for lions may be increased for a time. The constancy in pride size and territory suggests that there are no external forces being exerted to adversely affect the pride and that the pride size fits the ecological carrying capacity of the area.

A lion population density of 3.05/100 km^2 for the whole park is low when compared to the density of lions in some other conservation areas in Africa (Table 4.3). The dry Zambezi Valley floor had a lion density of 2.21 lions/100 km^2 and is comparable to lion densities in drier ecosystems such as the Kalahari Gemsbok National and the Etosha National Parks. Since there are no artificial water supplies in the Mana Pools National Park, the Valley floor can be considered arid apart from two good permanent water sources in the south and the Zambezi River in the north. The density of lions on the floodplain and associated terraces (12.7 lions/100 km^2) is more in keeping with the Kruger National Park (Smuts, 1976) at 9 lions/100 km^2 and the Kafue National Park (Mitchell *et al.*, 1965) which had a density of 12 lions/100 km^2.

Smuts (1976) found that with the provision of artificial, stabilized water supplies in the Central district of the Kruger National Park new lion prides became established in the area as wildlife built up. Stander (1991) also found that the density of lions in the Etosha National Park was higher in areas of increased water points per area size and hypothesises that this is because of the higher prey density in that area. Lion density on the Mana Pools floodplain is high and this natural source of water stretching 45 km along the northern park boundary has the same effect on wildlife densities as the provision of artificial water supplies seen in drier parks in Africa.

Table 4.3 Lion density in the Mana Pools National Park and other protected areas in Africa

Ecosystem	Lion density/100 km²	Source
Kruger National Park	9	Smuts, 1976
Kafue National Park	12	Mitchell *et al.*, 1965
Kalahari Gemsbok National Park	1.5	Mills *et al.,* 1978
Etosha National Park	1.6-2.0	Stander, 1991
Serengeti	7.9-9.4	Schaller, 1972
Whole of Mana Pools National Park	3.05	This study
Mana Pools National Park - floodplain	12.7	This study
Mana Pools National Park - Valley floor	2.21	This study

4.2.3 Population characteristics

4.2.3.1 Preamble

The terms “pride” and “group” are used interchangeably here, since, they broadly refer to a collection of lions living cooperatively together. “Pride” more usually refers to the family unit whilst “group” refers to members of the pride that have split and formed smaller units but in essence the two terms are interchangeable unless described otherwise. Prides are “fission-fusion” social units with pride members breaking up into smaller groups and ranging within a defined area and later re-joining. Lions typically live in stable matrilineal groups that vary in size but have at its core adult females and their related offspring. The pride is attended by one or more adult males who will remain with the pride for varying periods of time but will in most cases look after their progeny from birth to about two years of age. The pride will cooperate in hunting, looking after and raising cubs as well as defending a territory. The females in the group are territorial and will not tolerate other lionesses into their territory. During his tenure with a pride, the males will also vigorously defend the territory. Females are highly philopatric and offspring females prefer to remain near their natal pride and form a new group if there is space. The offspring males disperse when they become sexually mature, leaving the natal group with same sex cohorts. Age of dispersal will depend on social pressure, but Funston *et al.* (2003) and this study showed that in savannah woodlands maturing males will stay for a longer period with the natal group then in grassed areas such as the Serengeti plains.

In determining the status of a lion population, population size and density is not the most important parameter and is in fact just one aspect of a number of socio-ecological variables (Funston & Herrmann, 2001) that need to be looked at. The objective of this study was to describe the population characteristics of lions in the park in order to present base-line data for future studies and management and to ascertain whether the lion population in the Mana Pools National Park showed signs of being under threat. Any major changes in the pride structure due to anthropogenic influence, imbalances in the large predator guild, prey density changes or by disease can result in the pride stability being broken.

4.2.4 Sex ratios and age classes

Data for population characteristics of lions in the Mana Pools National Park was obtained from six separate prides (Table 4.4). The four marked floodplain prides and the one marked Valley-floor pride provided most of the data. However, by analysing the opportunistically collected data on the unmarked Jesse pride, it was also possible to obtain some population characteristics of this pride.

Table 4.4 Sex and age structure of six prides in the Mana Pools National Park as established during the period March 2001 to July 2007

Pride	Adults		Sub-Adults		Large cubs	Small cubs	Pride size	Adults + Sub-adults
Floodplain	♂	♀	♂	♀				
Rukomechi	1	3	1	1	0	1	7	6
Nyamepi	2	4	2	3	0	3	14	11
Nyamatusi	2	4	1	2	1	2	12	9
Chikwenya	1	2	2	1	1	1	8	6
Total	6	13	6	7	2	7	41	32
Mean	1.5	3.3	1.5	1.8	0.5	1.8	10.3	8.0
Range	1-2	3-4	1-2	1-3	0-1	1-3	7-14	6-11
Valley Floor								
Jesse	1	2	1	2	0	4	10	6
Chitake	1	4	1	2	3	5	16	8
Total	2	6	2	4	3	9	26	14
Mean	1.0	3.0	1.0	2.0	1.5	4.5	13.0	7.0
Range	1-2	2-4	1-2	2-4	0-3	4-9	10-16	6-8
All groups								
Total	8	19	8	11	5	16	67	46
Mean	1.3	3.2	1.3	1.8	0.8	2.7	11.2	7.7
Range	1-2	2-4	1-2	1-2	0-3	1-5	7-16	6-11

Lion population characteristics for the study area (Tables 4.5 and 4.6) are displayed in a similar manner to that shown by Smuts (1976) for the Kruger National Park. Sex ratios and age classes of the MPNP lion population are compared to those presented for the Kruger National Park (Smuts, 1976), the Kalahari Gemsbok National Park (Mills *et al.*, 1978), the Etosha National Park (Orford & Perrin, 1988), the Lake Manyara National Park (Makacha & Schaller, 1969) and Hluhluwe-Umfolozi (Maddock *et al*., 1996).

All sighting data from telemetry and from trained parks staff (n = 810) and from tour operators (n = 173) collected over the period 2001 to the end of 2007 was analysed and the sex ratio for the six known prides in the Mana Pools National Parks was calculated. Tourist records were not used for demographic calculations. The pride structure varied over the study period as cubs were born, age classes moved upwards, sub-adult lions left the natal pride, new males entered the pride and old lions died. To obtain population characteristics of lions in the Kruger National Park, Smuts (1976) marked 310 lions in the Central District of the park which represented 45% of the population. For the Mana Pools National Park this represented 45.5% of prides and 67.2% of the estimated minimum population number, although only five prides out of an estimated 11 were marked.

Table 4.5 Population characteristics in the Mana Pools National Park and other protected areas in Africa

Area/Pride	**Sex Ratio**			**Age classes as a % of known prides***					
	AD	SA	AD+SA	AD	SA	LC	SC	AD+SA	Cubs
	♂:♀	♂:♀	♂:♀						
Rukomechi	1:3.0	1:1.0	1:2.0	57.1	28.6	0	14.2	85.7	14.3
Nyamepi	1:2.0	1:1.5	1:1.8	42.9	35.7	0	21.4	78.6	21.4
Nyamatusi	1:2.0	1:2.0	1:2.0	50.0	25.0	8.3	16.7	75.0	25.0
Chikwenya	1:2.0	1:0.5	1:1.0	37.5	37.5	12.5	12.5	75.0	25.0
Jesse	1:2.0	1:2.0	1:2.0	30.0	30.0	0	40.0	60.0	40.0
Chitake	1:4.0	1:2.0	1:3.0	31.3	18.8	18.8	31.3	50.0	50.0
All prides this study	**1:2.5**	**1:1.7**	**1:1.97**	**41.4**	**29.3**	**6.6**	**22.7**	**70.7**	**29.3**
Kruger N.P.[1]	1:2.1	1:0.6	1:1.5	53.3	17.1	8.8	20.9	70.3	29.7
Kalahari Gemsbok N.P.[2]	1:2.1	1.1.4	1:1.8	41.9	25.7	6.8	35.7	67.7	32.4
Hluhluwe-Umfolozi[3]	1:2.9	1:1.5	1:0.7	48.4	30.6				18.5
Etosha N.P.[4]	1:2.9	1:5.0	1:3.1	59.4	12.3	3.2	25.1	71.6	28.3
Lake Manyara N.P.[5]	1:2.3	1:2.2	1:2.2	36.1	44.4	13.9	5.6	80.5	19.5

[1]Smuts, 1976; [2]Mills *et al.*, 1978; [3]Maddock *et al.*, 1996; [4]Orford & Perrin, 1988; [5]Makacha & Schaller, 1969.
*(AD=adult, SA=sub-adult, LC=large cub, SC=small cub)

4.2.5 Pride sizes

The average pride size of the study lions (adults and sub-adults) on the Zambezi floodplain was 8.0 (range 6-11) and 7.0 (range 6-8) in the Valley floor prides. Total pride sizes (all individuals) was 10.3 (range 7-14) in the floodplain lions and 13 (range 10-16) in the Valley floor lions. The average adult pride female size was 3.2 (range 2-4). Prides on the floodplain tended to remain together as discrete groups throughout the dry and wet season; indicative of the high prey dencity during the year. Depending on available surface water on the Valley floor (related to the previous season's rainfall), the Chitake pride with its core area around Chitake Spring showed a different pattern. This pride, at one time consisting of 23 individuals, showed the typical "fission-fusion" behaviour of coming together for a time and then splitting and rejoining later. Pride sizes are shown for other protected areas (Table 4.6).

Table 4.6 Mean group sizes of lion prides in seven protected areas in Africa

Ecosystem	**Mean group size**	**Source**
Etosha National Park, Namibia	5.0	Stander, 1991
Kruger National Park, South Africa	11.8	Smuts, 1976
Kalahari Gemsbok National Park, South Africa	11.5	Mills *et al.*, 1978
Hluhluwe-Umfolozi Park, South Africa	9.2	Maddock *et al.*, 1996
Selous Game Reserve, Tanzania	3.4	Rodgers, 1974
Kafue National Park Zambia	4.62	Mitchell *et al.*, 1965
Mana Pools National Park, Zimbabwe	7.4	This study

Although the sample size (6 prides) was low, the population characteristics calculated for lions in this study, fell within the proportions of other protected lion populations in Africa (Tables 4.3, 4.5 and 4.6).

The mean female group size was 3.2 and each pride had an adult male(s) in attendance (range 1-2). The sex ratios and percentage that age classes contributed to the population fell within the parameters of other lion populations. The percentage adult contribution to the population was slightly lower than the Kalahari Gemsbok National Park (41.4% for the Mana Pools National Park and 41.9% in the Kalahari Gemsbok National Park) but it was higher than documented for the Lake Manyara National Park (36.1%). The cubs comprised 29.3% of the population, which was higher than for the Hluhluwe-Umfolozi, Etosha and Lake Manyara

National Parks, but lower than the Kalahari Gemsbok National Park. According to Mills *et al.* (1978) this percentage contribution of cubs is a good indicator that the lion population in the Mana Pools National Park is healthy and viable.

4.2.6 Cub survival

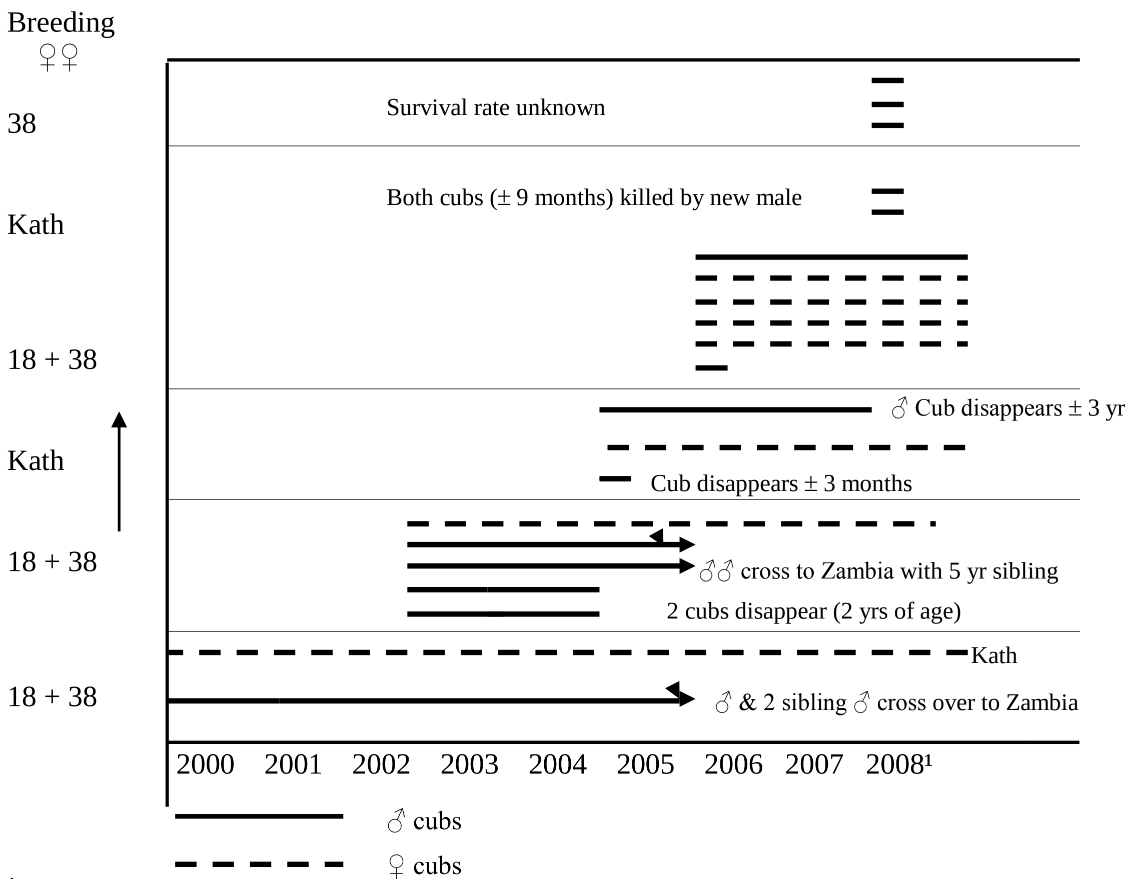
Five of the six studied prides provided sufficient data in orer to calculate cub-survival. Overall cub survival in the Mana Pools National Park lion population was 66.3%. In the Nyamepi pride cubs had a survival rate of 66.7%. This is the pride that was thought (Pope, 2004) to be decreasing due to large numbers of spotted hyaena. In 1999, before the study began, two identifiable females were noted to have three cubs. It is not known whether there were others that were born but two of the three survived to adult-hood (66.7%). In 2002, six cubs were born and three survived (50%). In 2004, a female cub from the 1999 litter had three cubs and two survived (66.7%). In 2006, six cubs were born to the pride and five survived (83.3%). The Chitake pride had a cub survival rate of 60%, the Nyamatusi pride 72.3%, the Jesse pride 67%, and the Chikwenya pride 64.3%. It should be noted that the measure of reproductive success in lions is the survival of cubs up to the age of one year (Packer *et al.*, 1988).

Depending on the prey availability, female lions bring their cubs from a den into the pride at the age of several weeks (Schaller, 1972; Eloff, 1980). During the time in the den it is usually not possible to count the actual number of cubs born and it is therefore difficult to accurately assess pride survival. However, once the cubs have joined the pride their survival rate can be monitored. Schaller (1972) found that cub mortality was highest in the first year of life and that 25% of cub mortality could be attributed to starvation. A constant food source is essential and cub survival follows the prey pattern throughout habitat types. In Tanzania nearly two thirds of cubs on the Serengeti plains died before one year of age but in the Ngorongoro Crater (a more wooded area) mortality was only one third (Packer *et al.*, 1988).

On the floodplain and at Chitake Spring, the prey source was constant. There are many factors that affect the survival rate of cubs, such as the synchrony of oestrus and birth (Packer & Pusey, 1983). In prides where lionesses have synchronised oestrus and cubs are born more or less at the same time, there is a higher rate of cub survival since the mothers communally feed the cubs and care for them as well as take care of each other and share in hunting and protection. The amount of available food, the density of other predators in the large predator guild and the presence or absence of a territorial male are other factors that will singly or together affect cub survival. A high density of spotted hyaena as seen in Savuti (Cooper, 1991) and the lack of territorial males severely affect cub survival.

4.2.7 Age of first litter and inter-birth interval

Females had their first litter between 43 to 53 months (n = 3). Reliable data was only available for three lionesses in the Nyamepi group (Figure 4.6). Lionesses #18 and #38/42 were estimated to be between 18 and 24 months when the study began and their first litter was seen 25 months later (making their age at first litter between 43 and 49 months). Their one progeny (Kath) could be aged accurately and she produced her first litter at 53 months. In the Kruger National Park, 46% of young lionesses produced their first litter between 46 and 56 months of age while the rest were between 57 and 65 months (Funston *et al.*, 2003).



[1]2008 data included to give a final representation of the reproductive output of this pride which has now split.

Figure 4.6 Reproductive output and cub mortality of the Nyamepi pride, the Mana Pools National Park (2001-2008).

Inter-birth intervals could be calculated for the Nyamepi (37.5 months), Nyamatusi (42 months), Chikwenya (38.5 months) and Chitake prides (36 months). On average prides produced cohorts of cubs every 38.5 months (range 36 to 42 months, n = 4) where there had been no previous incidents of infanticide. The inter-birth interval for the Mana Pools National Park was larger than that of lions studied in East Africa (Packer *et al.,* 1988) but similar to the studies carried out in woodland savannah in southern Africa (Funston *et al*., 2003). There could be two reasons for this larger inter-birth interval: firstly, the juvenile survival rate is higher and lionesses devote more time raising their offspring, and secondly, sub-adult males spent an extended time with the natal group (Funston *et al.,* 2003). In the same study, in the Kruger National Park which has a savannah woodland habitat, the mean inter-birth interval was 40 months. Pusey and Packer (1987) found the inter-birth interval to be 24 months in the Ngorongoro Crater, Tanzania.

The pride sample size for estimating inter-birth intervals was small (n = 4) and the results are not definitive. However the study area could also be broadly categorised as tree savannah and the dispersal period of sub-adult males also matched that of Funston *et al.* (2003). If the inter-birth range had been shorter showing periods similar to the results of Packer and Pusey (1987) then the results for the Mana Pools National Park could be viewed with more caution since cub survival and age of dispersal of sub-adult males affect the inter-birth interval.

The population parameters presented above fall within the range of other lion populations in protected areas throughout eastern and southern Africa. If the lion population in the Mana Pools National Park was being adversely affected by a high density of spotted hyaena and an excessive adult male take-off in the surrounding Safari areas, then it would follow that the population structure would show the effects of these external forces. A high spotted hyaena population would result in low cub survival and a low percentage cub contribution to the population. The depredations of spotted hyaena (kleptoparasitism and killing of cubs), and with adult females struggling to obtain enough of the kill before spotted hyaena showed up (to the expense of cubs) would all seriously affect pride success (Cooper, 1991). In addition prides would be without a pride male and take-overs would be frequent.

Funston and Herrmann (2001) calculated cub survival to be 59% in the Kalahari Transfrontier National Park and Rudnai (1973) estimated it to be 51% in the Nairobi National

Park. In the Kruger National Park Funston *et al*. (2003) found the survival rate of cubs to one year of age was 84%. From the data collected during this study cub survival rate for the Mana Pools National Park was calculated to be 66.3%. In the Mana Pools National Park all prides had pride males with single males protecting 66.7% of the prides. Funston and Herrmann (2001) showed that there was no significant difference in survival rates in prides protected by single or coalition males, where single males protected 43% of prides. Whilst the percentage of prides protected by one adult male is higher in the Mana Pools National Park, the pride sizes are smaller and one would not expect prides this size to have a large coalition of attending males.

Purchase (1999) surveyed spotted hyaena in the Mana Pools National Park and most of the park was covered including the floodplain. The results showed the spotted hyaena population in the Mana Pools National Park to be in the low-medium density range (0.168 hyaena/km^2) when compared to other protected areas in Africa. The Ngorongoro crater had a spotted hyaena density of 1.43/km^2 (Kruuk, 1972), the Kruger National Park 0.07-2.0/km^2 (Mills, 1985) and the Selous National Park 0.320/km^2 (Creel & Creel, 1996).

It would appear that the theory of (a) an abnormally high spotted hyaena population and (b) that the lion population on the floodplain was under threat have been dispelled by the empirical work that has covered both aspects of these concerns. As far as over-hunting is concerned, ZPWLMA records show that one male lion is taken on quota for each of the two Safari areas immediately adjacent to the Mana Pools National Park. In Chewore south, five male lions are on quota and here the situation may be different. Two of the collared males from the Mana Pools National Park at one time moved into Chewore south. Male #32 was shot and male #36 is still in the Safari Area. It is possible that nomads and dispersing sub-adult males find that all territories in the Mana Pools National Park are taken and vigorously defended and that trying to gain a pride and territory is less difficult in Chewore south where five adult males are removed each year, thus possibly reducing competition for pride tenure. This is purely conjecture and more work is needed on this aspect of lion ecology.

4.2.8 Dispersal

Throughout this study pride females and female offspring tended to remain in their natal territory area. However, two instances were recorded of female dispersal in prides: firstly, within the Nyamepi pride, when old female #18 swam to Zambia with four members of her pride (further discussed below) leaving her sister female #38/42 with the remainder of the pride, and secondly, during a call-up and darting exercise sub-adult female #02 was darted and collared on the edge of the Nyamepi pride territory. The female had recently been in a conflict with other lions as she had sustained multiple bites to her legs, and back. When next found she and her sibling were in the west of the park with the Rukomechi pride where she has remained to date.

All other dispersals occurred in young males. The average age that young males left their natal group was between 36 to 57 months (n = 9, x = 39.8 months). When lions were immobilized to fit collars, criteria such as teeth wear and colour, nose pigmentation, mane growth and scarring was noted and the animal given an approximate age so that collared sub-adult males could be assigned an age at dispersal. Only one male could be aged accurately, namely male #26 left the natal group at 57 months (Table 4.7 and Figure 4.6).

Table 4.7 Dispersal of lions in the study prides at the Mana Pools National Park (2001-2008)[1]

Pride	Individual	Age	Tenure with pride	Circumstances of dispersal	Notes
Nyamepi	#26 ♂ 2 siblings ♂ 1 ♂	57 m 36 m ,36 m ± 30m	57 m 36 m 30 m	Born into pride eventually left when new male came in.	Crossed to Zambia
Nyamepi	#18 ♀ and 3 SA ♂ 1 AD ♀	Old ±36 m ±4 yr	12 yr	Founder member of pride, left with 3 SA males and 1 AD female, when new male came in.	Crossed to Zambia
Rukomechi	#24b/40 ♂ “Livingston” ♂	±42 m ±42 m	±3-4yr	New male into pride.	Left with male sibling, took over Nyamatusi pride.
Chikwenya	#77 and sibling ♂	±42 m		New male into pride	Eventually moved west & took Rukomechi pride
Chitake	#36 ♂	±38 m	±3-4 yr	Unknown	Moved from Mana Pools into Chewore Safari Area
Nyamepi Nomad	#32	Mature AD♂	Nomad?	Mated with Nyamepi lioness	Shot in Chewore Safari Area 2006, 80 km from dart site.

[1](m = month; yr = year; SA = Sub-adult; AD = Adult)

Funston *et al.* (2003) found that sub-adult males in the Kruger National Park dispersed on average at 38 months of age. They note that sub-adult males are able to take refuge in dense bush within the natal area and thus avoid aggressive attacks by pride males and adult lionesses thus delaying the age of dispersal. Some of the dispersing sub-adult males in the Mana Pools National Park prides were noted taking over a pride in the area they had moved to after being in the area from between 2 to 4 months. Male #26 and two male younger siblings took over a pride in the Lower Zambezi National Park in Zambia[3] about three months subsequent to leaving their natal area, and #24b/40 and a male named "Livingstone" took over the Nyamatusi pride. For male #26 and two younger siblings to have succeeded in taking over a pride is strange (usually same-age cohorts take over prides) but one explanation is that there was no adult male with the female pride.

Once sub-adult males leave their natal pride with similar aged cohorts, their survival will depend on the size of that cohort (Hanby & Bygott, 1987). The larger the age set, the greater the chances of chasing off pride male coalitions and taking over a pride. The larger coalition will have a longer reproductive life and a higher individual reproductive success (Bygott *et al.,* 1979; Packer & Pusey, 1982; 1983).

Hanby and Bygott (1979) found that in Serengeti coalitions in groups of three or more had a better chance of taking over tenure of female prides and retaining that tenure for longer than singletons and pairs. They also found that coalitions of three or more had greater opportunities of mating with more females and producing more surviving offspring than singletons and males. In the Mana Pools National Park the average female pride size was only 3.2 (range 2-4) which is relatively small in terms of the Serengeti but normal for southern African prides. It is doubtful whether there would be any advantages of coalitions of three or more taking over small prides in the Mana Pools National Park situation although the Nyamepi pride at one stage had a coalition of three males which was soon reduced to two. Male coalitions from various prides appeared to move freely into other territories, however, these incursions were not prolonged. The Nyamatusi males were seen with the Chikwenya pride; the Nyamepi male coalition was seen with Rukomechi pride and the Jesse males entered infrequently into the Nyamepi territory.

[3] Manager Lower-Zambezi Conservation Society Zambia.

Bygott *et al.* (1979) found that when large groups of males (in proportion to the number of females) were in a pride for more than two years they had opportunities to gain access to one or more neighbouring prides as well. This was also seen on the Zambezi floodplain although the prides were not large: Pride males stayed with the pride for at least two years until the cubs were two years of age (mean tenure 33.25 months; section 4.2.10). During this period pride females, if they had synchronised oestrus and births, would not be ready for mating. With an inter-birth interval of 38.5 months and assuming that gestation is 110 days, the lionesses would only come into the next oestrus cycle at about 34.8 months after producing the last litter of cubs.

Females of the individual prides were never seen to mix with other lion prides although there was some overlap in territories. All incursions were of short duration and territory boundaries tended to be respected. The core area of the pride's territory was never violated by other prides during incursions - all trespassing was on the outer boundaries of the territory. Harvey and Kat (2000) reported the same behaviour in the Moremi lions of Botswana.

Lion space-use within their home ranges was determined by prey availability which varies with habitat type (Spong, 2002). On the Zambezi floodplain, habitat varies but territories covered multiple types throughout the floodplain and prey availability was constant. Dispersing lions find it difficult to find a new area on the floodplain in the Mana Pools National Park due to the localised distribution of water and prey. The Zambezi floodplain is at maximum 3 km wide, and thereafter the lions face very low prey densities and lack of water necessitating forays (and possible pride conflicts) onto the floodplain.

Adult female #18 (±12 years old) dispersed from her natal area in Nyamepi into Zambia probably as a result of an increase in the pride size and the appearance of a new male (the pride at this time did not have cubs as far as was known). Pride size prior to emigration was 11, including four male sub-adults and three female sub-adults. The sub-adult females and one male remained with female #38/42 in their natal pride area and female #18 emigrated with an adult female and the three sub-adult males. The sex ratio split in sub-adults could mean that female #38/42 has joined with the new male and female #18 with sub-adult males could not. The question then arises: why did she emigrate with the sub-adult males who normally would form a coalition and leave the pride on their own? Population pressures may have precipitated this move and also competition of food resources, but if the sub-adult males had left as a coalition on their own, it would have relieved pressure to a large degree. Since this lioness #18 is nearing the end of her reproductive life she may have chosen to remain with her offspring rather than face a new male.

Territorial behaviour is an important spacing mechanism (Schaller, 1972). Not only does it restrict the number of predators in an area from over-utilizing the food source but it also allows for a more even spread of utilization of food sources. On the Zambezi floodplain prides occupy all available space and this space is determined by the prey density. As the prides grow, (especially if there is a preponderance of females that will remain with the pride or remain close by) demands on the food resource will cause a serious imbalance in the predator-prey relationship and create social pressures within the pride. What was seen on the floodplain during this study points to these facts and the only place to which excess lions can disperse is across the river into Zambia or into other territories or out of the park. Lions have been seen swimming to Zambia on a number of occasions and one tour operator[4] filmed an individual in a group being attacked by crocodile whilst the rest of the group made it safely over the river. It would seem therefore that only extreme pressure would drive lions (especially adult females) to leave their natal pride to seek areas elsewhere. Hanby and Bygott (1987) found that when females made excursions they later returned within 48 months to the natal pride.

During a study on wild dog in the Lower Zambezi National Park (directly across the Zambezi River from the Mana Pools National Park) Leigh[5] (personal communication) estimated a density of 8 lions/100 km² in that area which may suggest that there is space for other lions, although, whether there is sufficient prey is not known.

4.2.9 Home ranges

Home ranges were calculated using two methods: firstly, the KernalHR programme for home range estimation (Seaman & Powell, 1997) for the pride that had sufficient data points and secondly, the 100% Minimum Convex Polygon (MCP) method for lion groups that had fewer

[4] Mr. Garth Thompson.
[5] Kellie Leigh: African wild dog conservation.

fixes. The home ranges estimated for the different prides in this study are shown in Figures 4.7 to 4.9.

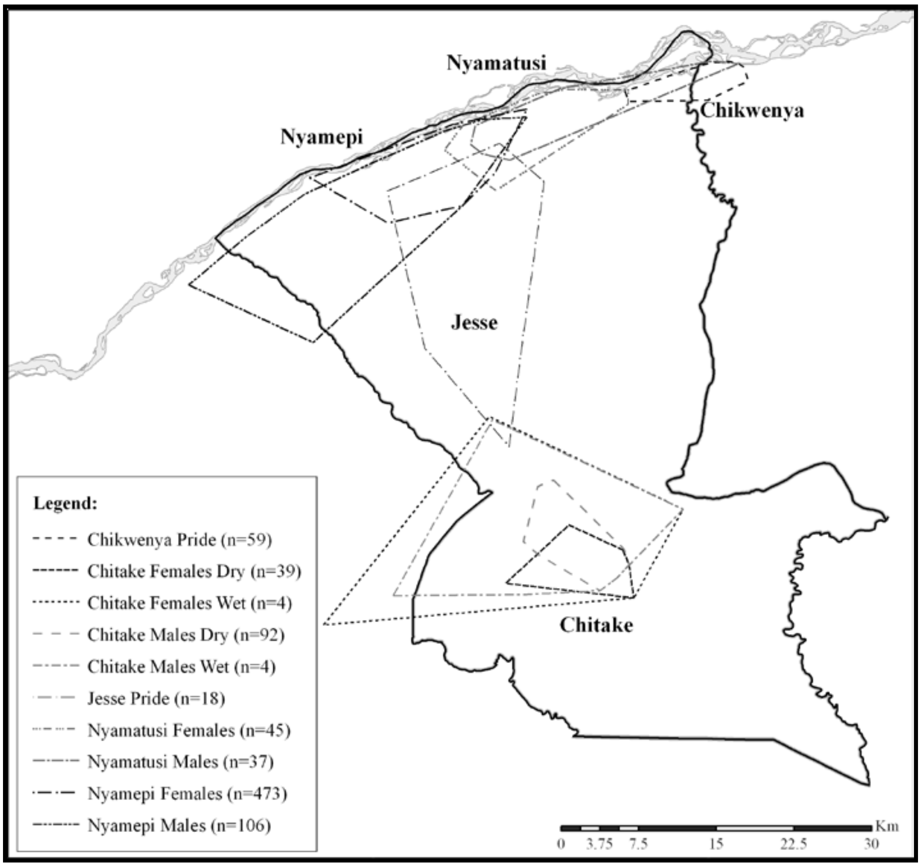


Figure 4.7 The home ranges of the lion prides studied in the Mana Pools National Park.

The wet and dry season home ranges were calculated for Chitake lions since their area of activity shifted between seasons, whilst the floodplain lions remained in the same area.

The home ranges of the floodplain lions (both wet and dry season) ranged between 28.1 km² and 278.2 km² (Figure 4.8). The Valley floor lions (Chitake and Jesse) had dry and wet season home ranges of between 50.2 km² and 379.3 km² (Table 4.7). Home ranges differed between sexes in the Nyamepi pride with males ranging within an area of 278.2 km² and the females keeping within an area of 111.2 km² (Figures 4.7 and 4.9).

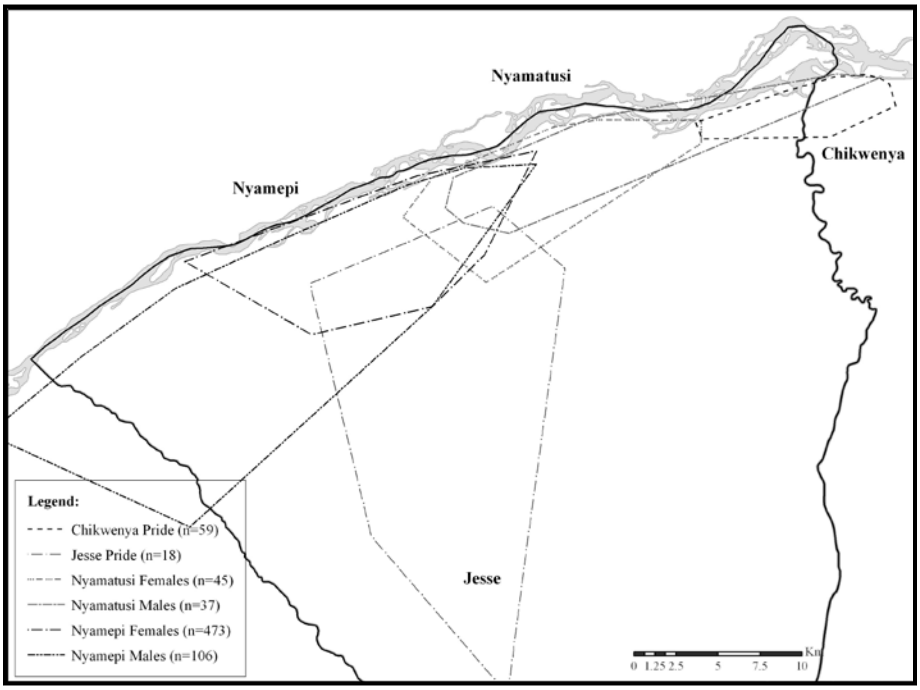


Figure 4.8 The home ranges of the Zambezi floodplain lion prides.

Data points for the Nyamatusi male and females were low (n = 37 for males and n = 45 for females). Their calculated home ranges were 86.4 km² and 82.1 km² respectively. This is considered to be an underestimate for the males. The home range could not be calculated for the Rukomechi pride. Although assisting in collecting demographic data, the Tour Operator guides had no GPS equipment and used colloquial names of general areas for sighting data which gave vague data points. Data points for the Chikwenya pride were also collected by Tour Operator guides but this was only in the concession area of Chikwenya camp and as a result the home range is very small (28.1 km²) and cannot be considered accurate. The combined wet and dry season home range of the Valley floor Jesse pride (sexes not differentiated) was 264.6 km².

The Nyamepi male home range was almost two and a half times that of the females. Although only discontinuous data points were collected (i.e. no GPS collars were used) for the Nyamepi females, the intensity of data points (n = 473) made it possible to use KernalHR to calculate the 50% and 90% contours giving the use intensity. The 50% contour gave an area of only 22.3 km² whilst the 90% contour gave an area of 41.1 km². The total area of use was calculated as 63.4 km² which was 42.9% less than the MCP calculation. This was expected as the KernelHR, using the 90% limit discards the outliers, whereas the MCP incorporates outlying points.

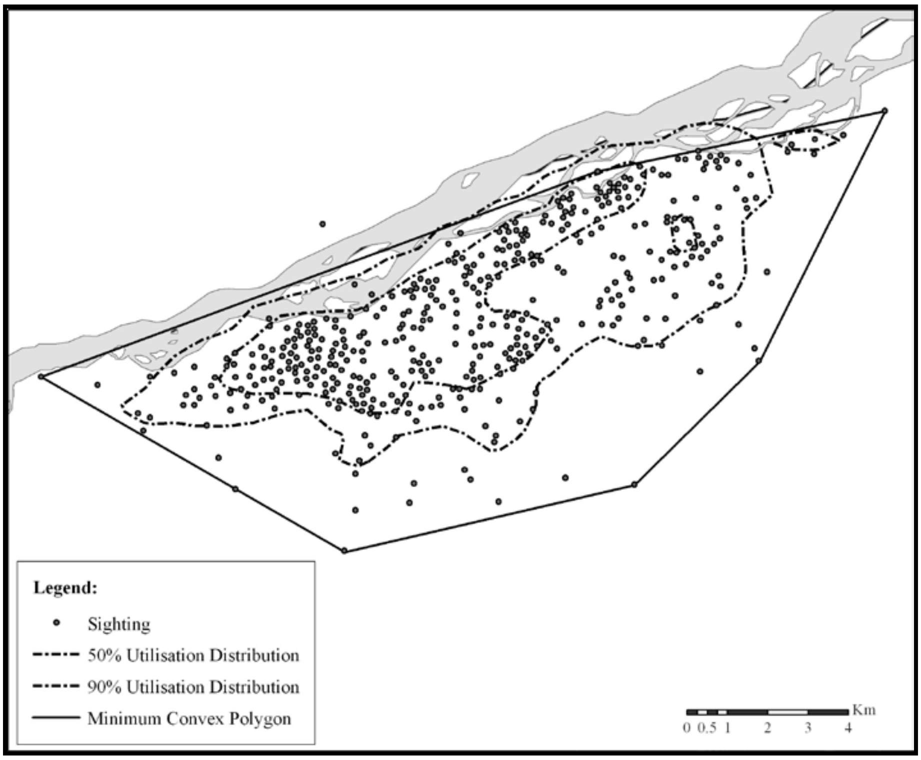


Figure 4.9 The home range of the Nyamepi lions showing 50% and 90% utilisation distribution.

When using ordinary VHF radio collars continuous location fixes could not be made and data points are missed. Whilst the 50% and 90% areas of utilization distribution agree with the field knowledge gained on this pride, the 100% MCP-derived area was used in order to compare the home range of this pride with others. Outliers such as the data points collected when the Nyamepi males made excursions into Nyakasanga Safari Area were included in the calculation of the home range even though they were infrequent visits. Macdonald *et al.* (1980, as cited by Funston *et al.*, 2003) and Harris *et al.* (1990, as cited by Funston *et al.*, 2003) are of the opinion that when data points are few and an internal estimate of intensity range-use cannot be determined, the 100% MCP is an acceptable method. During a study in the Selous Game Reserve, Spong (2002) used small data fixes (range 6-162) to obtain home range estimates.

The number of sighting fixes (using a GPS) from the five prides varied (range 18-473). The Jesse pride had only 18 discontinuous fixes in all. Whilst the Chitake pride had more fixes, these were localised around the Chitake Spring in the dry season. The statistical accuracy of the home ranges, apart from the Nyamepi pride females, should be viewed with caution. However, although there is limited sighting data of other prides, field knowledge of the prides makes the home range estimates more than a "best guess". Ideally more data points should be used and the use of GPS collars would be invaluable for calculating home range data.

The home range size of the floodplain and valley floor lions corresponded with prey distribution and numbers. The large variation between the dry and wet season range of the Valley floor lions (28.1-379.3 km²) was particularly noted as wildlife dispersed from the Chitake Spring. There are inaccuracies involved in the home range data. The more fixes obtained the greater the accuracy and just one missed signal while a lion is out of range could result in the MCP being much smaller if the data fixes are small. Unfortunately resources were not available to use GPS collars or aerial tracking in this study. Whilst the home ranges are estimates, they do nevertheless give an indication of the large variation in ranges during the dry and wet season. The Nyamepi males had a large range compared to the females since they made excursions out of the park. It is known with a high degree of certainty that the Nyamepi females did not range out of the park. Their home range was very well defined by the Chiruwe River in the east and Vundu camp in the west. The home range size of the Nyamatusi pride is an underestimate, especially for the males.

When compared to home ranges of lions in other protected areas in Africa (Table 4.8) the Mana Pools National Park lions have a home range similar to that of the Serengeti lions, but much smaller that seen in the more arid Kalahari Transfrontier Park and the Etosha National Park. The concentrated prey base both at the Chitake Spring (in the dry season) and on the Zambezi floodplain (all year round) reduce the area of most activity since lions do not have to follow migrating prey or forage between water points as the prey moves.

4.2.10 Pride male tenure

Sufficient data was available on the Nyamepi and Nyamatusi prides to calculate male tenure. On average male coalitions stayed with the pride for 33.25 months (range 26-42 months). In the Nyamepi pride a coalition of three males remained with the pride for 34 months before two new males came in. These two males were with the pride for 26 months before other new males came in. In the Nyamatusi pride a coalition of two males were with the pride for 42 months and the new males stayed for 31 months.

Table 4.8 Lion home ranges in the Mana Pools National Park and other protected areas

Study area	Home range (km^2)	Reference
Kruger National Park	60	Smuts, 1976
Serengeti National Park	39-400	Schaller, 1972
Queen Elizabeth National Park	20-500	Von Orsdol, 1984
Kalahari Transfrontier Park	266-4532	Funston *et al.*, 2001
Etosha National Park	150-2075	Stander, 1991
Mana Pools National Park	28.1-379.3	This study

Long tenures in a pride by males reduce cub mortality as there is less likelihood of pride take-overs during the period when the cubs are the most vulnerable (Bygott *et al.*, 1979). The percentage time male coalitions were seen with pride females ranged from 44.6% in the Nyamatusi pride to 86.3% in the Nyamepi pride (Figure 4.10).

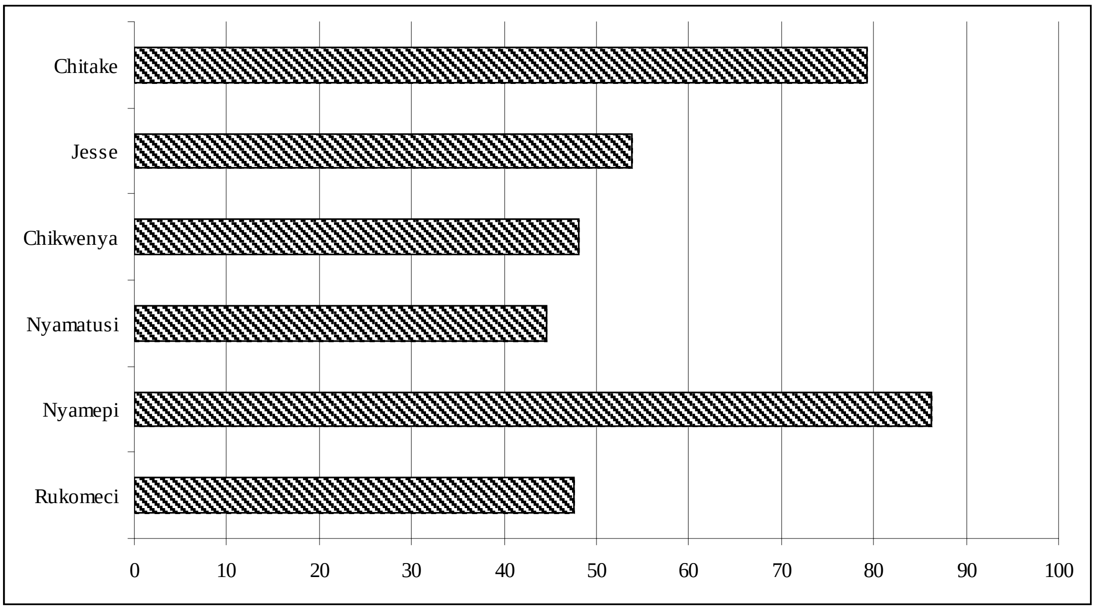


Figure 4.10 The percentage time male coalitions were seen with pride females.

There was a ratio of 1.3 adult males to 3.2 adult females (see Table 4.4). In the Etosha National Park prides averaged 1.8 adult males and 4.8 adult females (Stander, 1991). It is unlikely given the small area that can ideally sustain lions and prey (the Zambezi food-plain) that the lion prides will build up any larger than they are at present and this will also curtail the size of male coalitions.

4.3 Prey density and prey preference

4.3.1 Prey density estimates

Prey density on the floodplain was estimated by carrying out road strip counts (Table 4.9) in October 2002 when visibility was good. Prey density for the rest of the Park was calculated using the aerial count figures carried out by African Wildlife Foundation in conjunction with ZPWLM (Dunham, 2003).

Table 4.9 Density estimates of prey species in the Mana Pools National Park

Estimated population on the MPNP floodplain using road strip counts and foot transects				
	Biomass (n)	Density (n/km²)	Estimated totals ±SE	Biomass (kg)
Buffalo[1]	97.7	7	668	65 264
Eland	79.2	0.77	73±0.15	7 582
Impala	15.9	44.19	4 215±1.43	67 019
Kudu	39.8	0.55	52±0.20	2 070
Warthog	17.4	1.10	105±0.14	1 827
Waterbuck	45.0	1.79	171±0.67	7 695
Zebra	53.2	5.19	495±0.18	26 334

Aerial survey in 2003 showing % contribution of prey species in the study area		
Zambezi River floodplain	Valley floor	Zambezi Escarpment
63.5%	36.2%	0.3%

[1]Buffalo were not seen on road strip counts and so the density estimates obtained from foot transects are used.

The Mana Pools National Park was divided into three main strata for the aerial surveys (Zambezi floodplain, Valley floor and Zambezi Escarpment). Using the density estimates from the aerial survey of known prey species, it was possible to calculate the percentage contribution prey species made to the three distinct strata in the park (bottom of Table 4.9).

The road strip counts followed the tourist roads along the floodplain and a total of 10 transects were carried out (one in the morning and one in the afternoon each day). Road strip counts could not be carried out at Chitake Spring. Wildlife was generally accustomed to vehicles and sighting distance was not extreme. Animals such as buffalo are easily missed on transects as they move in large herds rather than being distributed evenly. During the counts no buffalo herds were seen and the population estimate for buffalo was derived from foot transects.[6] Impala density was highest on the floodplain, followed by buffalo, zebra, waterbuck, warthog, eland, and kudu. Ranking for kg biomass (Table 4.9) was impala, buffalo, zebra, waterbuck, eland, kudu and warthog. The confidence intervals for all species except impala (which were more frequently seen) were wide and the density estimates and subsequent calculations carried out on the estimates should be viewed with the normal caution one extends to sample counts.

4.3.2 Prey preference

A total of 139 kill records were collected during the study. Of these 90 were collected from the floodplain and 49 from Chitake Spring at the base of the Zambezi Escarpment on the Valley floor. From the prey frequency ratings, the prey selection ratios and kill frequencies were calculated.

4.3.2.1 Prey selection ratings

This was calculated for lions on the floodplain (after Pienaar, 1969; Ruggiero, 1991). Prey selection ratings showed warthog as the most preferred species followed by kudu and eland (Table 4.10). Although impala were the most abundant species on the floodplain and the highest contributor of biomass (Tables 4.9 and 4.10) this species received the least rating in terms of selection. The selection rating for kudu was high showing second in the rating level. Selection rating for eland was also high followed at a lower level by buffalo. Observations on the floodplain during this study showed that the Nyamepi lions selected for eland during the height of the dry season when herds with young moved from the dry forests on the Valley floor onto the floodplain. Kudu were found in small groups and in terms of overall numbers were highly selected for by lions. Smaller groups of pride females frequently took warthog

[6] Wildlife and Environment, Zimbabwe.

and were able to hide in *Vetiveria nigritana* grassland at the river edges to ambush the warthog as they came down to drink.

Table 4.10 Prey selection ratings on the floodplain and percentage prey selection on the Valley floor in the Mana Pools National Park

Species	Population estimate	Relative abundance	Kills by lions	Kill frequency	Selective rating[1]
Buffalo	668	0.116	24	0.279	2.4
Warthog	105	0.018	19	0.221	12.3
Waterbuck	171	0.296	11	0.128	0.4
Impala	4 215	0.729	11	0.128	0.2
Eland	73	0.013	8	0.093	7.2
Kudu	52	0.009	8	0.093	10.3
Zebra	495	0.086	5	0.058	0.7

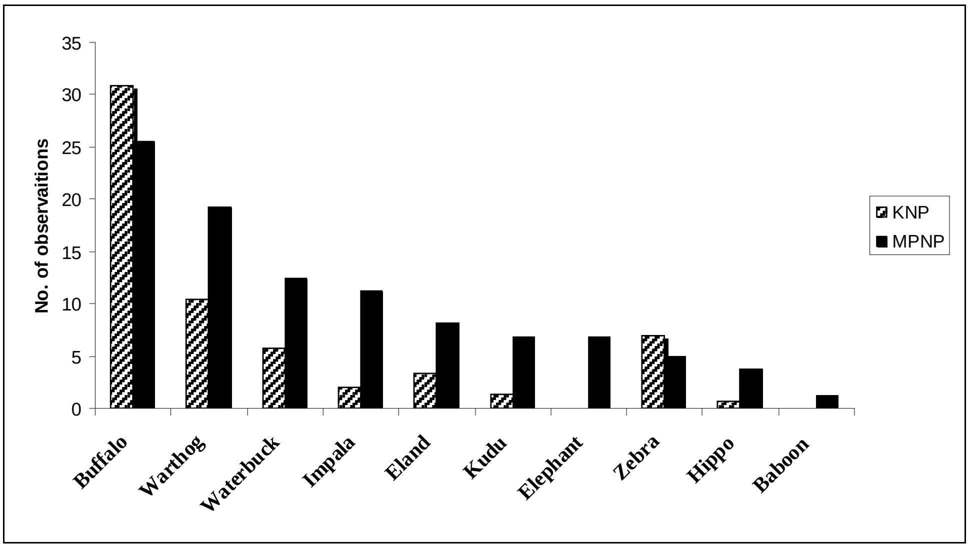
[1] calculated as the kill frequency/relative abundance

Impala on the floodplain occupy areas that are almost devoid of ground cover. At night they congregate in spatially discrete groups in open areas and are very vigilant. Funston *et al*. (2001) found that lions were not successful at killing impala when they stalked them. It was also found that impala occupied medium-dense bush (Funston *et al*., 1998). This is the case for some parts of the Mana Pools National Park floodplain but other parts are very open during the dry season with little cover beneath the mature *Faidherbia albida* woodland. In areas of dense thickets and during the rainy season lions may be more successful in stalking and killing impala. Wild dog were seen to predate heavily on impala and although records are not to hand, most kill reports received at the Nyamepi headquarters on wild dog hunts was of impala. Whereas lions stalk their prey (which was difficult in Mana Pools due to the openness of most areas in which the impala were found) wild dog run the prey down and were more successful as a result.

Waterbuck received a slightly higher selective rating than impala but it was still low. Herds of waterbuck congregate on low islands which have short perennial grasses and in the open *Faidherbia albida* woodland. Lions selected for zebra at a relatively low level. Herds of up to 20 zebra in separate families congregate on the floodplain and in the grassy areas between the floodplain and mopane woodland. Cover in the low-grassed areas is sparse and this may be the reason why they are not predated on at a higher level.

4.3.2.2 Kill frequencies

Kill frequencies were calculated by taking the number of individuals killed of each specific species divided by the total number of lion kills. Kill frequencies for the Kafue National Park, Zambia (Mitchell *et al.,* 1965) are compared with those of the Mana Pools National Park (Figure 4.11). There are some similarities in the vegetation along the floodplain and prey species in both Parks which have high densities of wildlife on the floodplain system.



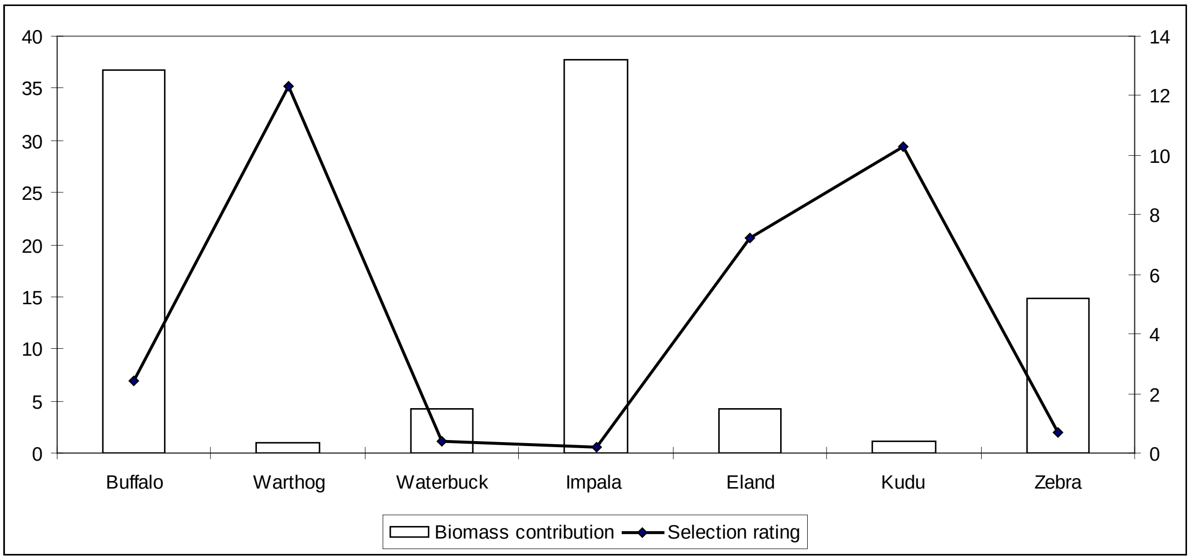
Kafue National Park (KNP) - Mitchell *et al.* (1965)

Figure 4.11 Lion kill frequencies in the Mana Pools National Park (MPNP) and the Kafue National Park (KNP).

In terms of overall percentage of prey species killed, buffalo kills were high (25% of all noted kills; Figure 4.11). Spong (2002) found that in the Selous National Park, buffalo accounted for 15% of prey species taken and Mitchell *et al*. (1965) recorded buffalo as the prey species over 30% of the time. Buffalo are the most favoured prey species of lions, when they occur in large numbers (Kissui & Packer, 2004; Funston *et al.*, 1998). Large discrete herds of over 250 buffalo range throughout the park, the herds being separated by the water deficient Valley floor in the dry season.

There are similarities in the prey selection between the Kafue National Park and the Mana Pools National Park in the first two species (buffalo and warthog). Waterbuck rated fourth in Kafue and third in Mana Pools; eland was fifth in each park and kudu was rated seventh in Kafue and sixth in Mana Pools. Thereafter differences occurred, for instance zebra rated third in Kafue and only eighth in Mana Pools. Although hippopotamus and young elephants were predated upon by lions, the figures were not used in the calculations for prey selection ratings on the floodplain (Table 4.10). Hippopotamus in the Zambezi River occur at a density of 33/km of river (unpublished data) and young and sick are killed on land.

When comparing prey selection against the biomass contribution of a species in the Park, (Figure 4.12), warthog selection was high and not sustainable. This interpretation should be viewed with caution since the Confidence Limit was high (52.7) when calculating density, making the warthog density data almost worthless. It is this authors' perception that there has actually been an increase in the warthog population. Although the relatively small size of a warthog cannot sustain large groups of lion they provide the intake requirements of the smaller lion groups. The high selection rating for eland and kudu is probably also a function of the survey method giving a low population number. Density estimates for buffalo, impala, and zebra were more realistic (Table 4.8) and the selection rating against the biomass of those species is more reasonable.



Elephant, hippopotamus and baboon not included in biomass calculation.

Figure 4.12 Selection rating and % biomass contribution of prey species.

There are no hippopotamus in the south of the park on the Valley floor. Hippopotamus did not rate high in kill frequencies in either the Kafue National or Mana National Pools Park (Figure 4.11). They are not easy animals for lions to bring down and most kills are probably made of young or sick weakened animals. Elephant were more frequently killed than zebra which is surprising. However, juvenile elephants are often not cared for by mothers with young and are then vulnerable to lion predation. No records of elephant kills were made in the Kafue National Park (Mitchell *et al.,* 1965).

4.4 Mortalities

Only nine lion mortalities were recorded. Four of these were adult males, two adult females, one a shot adult male, and two cubs. Two of these males had front leg injuries. Male #16 was found in an advanced stage of emaciation and subsequently died. On examination his "elbow joint" was found to be fused at an angle that made it impossible for him to move. The sample was sent in to the Department of Veterinary Services Wildlife Veterinary Unit where it was found that there was "severe peri-ostitis of the whole humerus and radius/ulna especially of the olecranon"[7]. The cause of this injury is uncertain but when examined on the fresh animal there were numerous wounds that appeared to be bite marks around the "elbow" so it is assumed that male #16 was in a fight with another male(s) and the "elbow" was broken during the engagement. Male #16 was about eight years old.

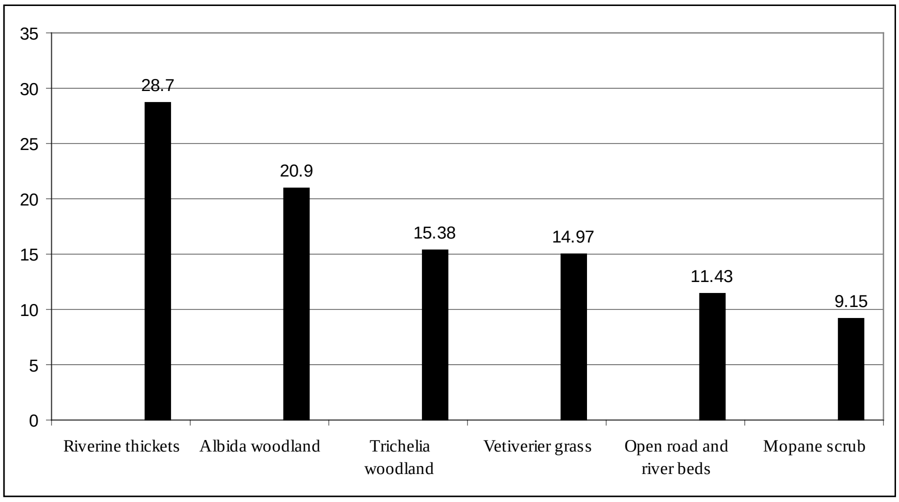
Adult male #4/14 also developed a limp but he recovered and later was found dead near a pan just after the rainy season (the skull was recovered and the collar was found in the pan, still transmitting). Cause of death was probably old age. Adult female #12 was found in a badly septic way after being in a fight. She had multiple bite wounds on her back and neck. When she was examined after the author darted her, the wounds were badly infected, and she died soon after. She was about 12-14 years old. Adult female #30 from the Chitake pride died of what appears to be old age. She was about the same age as female #12. Two cubs were found dead after being badly mauled after a pride take-over.

Adult male #32 was shot in Chewore Safari Area, about 80 km from the dart site in Nyamepi, Mana Pools National Park where he was collared. This male was about seven years old. The collar from adult males #10 and # 6 were found and it is presumed that they both died as the collars were on the animals for a long enough period to be confident that they were not loose.

[7] Dr. Chris Foggin.

4.5 Habitat preference

Each time lions were found, the habitat type they were in was recorded. The habitat type was also given a subjective rating related to how easy it would be to see the lions without the use of telemetry (Figure 4.13). Dense vegetation meant a low chance of seeing lions whilst open vegetation gave a better chance of seeing them (see 3.1.4). This crude measure was used to give some indication of tourist avoidance by lions (tourists are allowed to walk on the floodplain without a guide), that could be related to the fact that tourists were (supposedly) seeing less lions on the floodplain.



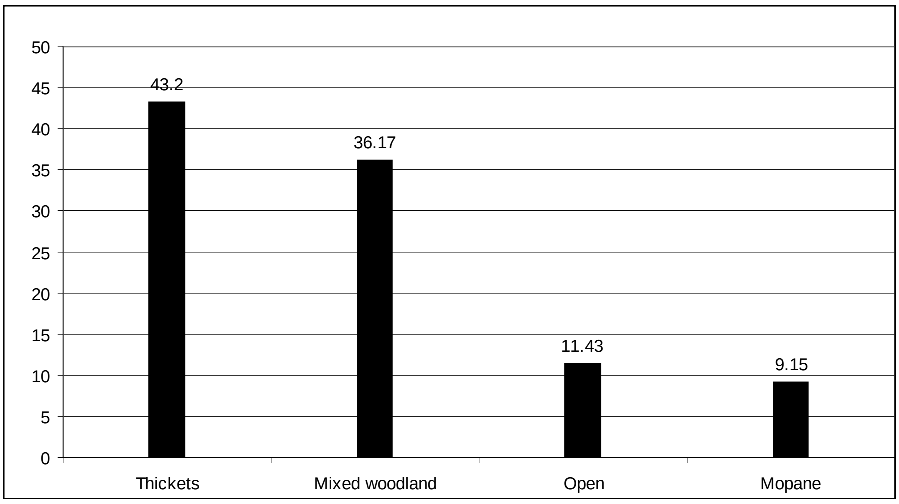


Figure 4.13 Habitat selection of the study lions (top graph) and selection for density of vegetation (bottom graph).

Riverine thickets and *Vetiveria nigritana* grassland was selected for 43.2% of the time. The *Faidherbia albida* and *Trichelia emetica* woodland was clumped as mixed woodland and was selected for 36.7% of the time. Lions were only seen in the open 11.43% of the time and in mopane scrub 9.15% of the time.

The method used to evaluate the selection of lions for vegetation in which they could effectively hide from visitors was crude and its limitations are recognised. Other factors such as worry by tsetse fly (*Glossina morsitans)* which have increased on the floodplain in the past five years (personal observation) could have driven the lions into denser bush to escape the tsetse flies. However, when observations were being made on lions they appeared to avoid tourists by selecting for dense vegetation where they could hide. For instance when the lions were resting one (or more) when periodically scanning the area would focus intensely in one direction and following the direction in which it was looking, often a tourist on foot was seen some distance away. In these instances the lions inevitably got up and headed into thick vegetation (usually *Combretum mossambicense* and *Vetiveria nigritana*). Whilst tracking lions on foot we often found the transmitter signal pulse increasing, alerting us to the fact the tracked lion was moving, and when next located it would be in dense cover completely hidden and we only knew that it was there by the loud directional signal.

Lions on the floodplain spent most of the time in vegetation that gave shade, shelter and cover. The Nyamepi pride went into very thick mixed woodland with dense undergrowth to den in and over the years always selected for the same general area. Since tourists walk most of the floodplain, these denning sites are extremely well chosen and only by telemetry has the general area been located. Prey abundance in these areas is low and pride females leave the denning sites and cubs in order to hunt.

4.6 Responses to calling stations

When carrying out call-ups on the Zambezi floodplain, the area was divided into three distinct sections (Rukomechi-Vundu = 14.5 km^2, Vundu-Chiruwe River = 46.4 km^2 and Chiruwe River-Sapi River = 34.6 km^2). A record was kept of all activity at and around the bait using night vision glasses and seven species of predators came up to the distress calls transmitted (Table 4.12).

Table 4.11 Responses by predators to calling stations on the Zambezi floodplain in the Mana Pools National Park

	Species coming to the bait						
	Lions	**Spotted hyaena**	**Wild dog**	**Side-striped jackal**	**Leopard**	**Cheetah**	**Crocodile**
Average time lapse between calls and response	45 min	30.4 min					
% response to calls	51.3%	70.3%					
Number of times young came to bait	33.3%	2.2%					
Response by other predators			3.1%	18.8%	9.4%	1.6%	3.1%
% time no response by any predator	9.4%						

Spotted hyaena responded to calls most frequently (70.3%), followed by lions. Other predators responding in order of frequency were side-striped jackal (*Canis adustus*), leopard, wild dog, crocodile, and cheetah. There are no black-backed jackals (*Canis mesomelas*) in the Mana Pools National Park. When lions were nearby, most other predators kept to the outer perimeter of the baited area. This often alerted the team that lions were in the vicinity.

The time lapse between calling and the appearance of a predator was only calculated for lions and spotted hyaenas. Spotted hyaena took on average 30.4 minutes to come up to the bait and lions 45 minutes. Spotted hyaena only brought their young up to the calling stations 2.2% of the time whilst lions with cubs came 33.3% of the time. There was no response by any predator 9.4% of the time.

During call-ups interactions between spotted hyaena and lions were noted. On no occasion did spotted hyaena mob pride females and juveniles at a bait site although there were times when lionesses on their own were seen but did not come to bait if spotted hyaena were at the bait first. One occasion was recorded of a spotted hyaena coming up to the bait first and immediately a large male lion that was not until then seen rushed up and chased him away. On another occasion three pride females and six one-year old cubs were at bait when spotted hyaena came nearby and a male lion that had been on the periphery ran after the spotted hyaena and killed it. At the one call-up site which was set up where there was a dead buffalo (natural mortality) a crocodile came up to the bait at which a spotted hyaena was feeding and tried to pull it away. A tug of war ensued until another crocodile came and the spotted hyaena then withdrew.

A total of 139.6 km^2 was covered during non-duplicated call-ups (Figure 3.1). Of this area a total of 105.7 km^2 was covered on the floodplain and surrounds (75.7%). Since the objective of the calling stations was to establish lion presence and to attract them to bait for darting and collaring, the survey design that Ogutu and Dublin (1998) and Mills *et al.* (2001) used was not followed. In retrospect this would have been useful and hopefully future work will cover this aspect and relative densities between lion and hyaena can be obtained building on from the work carried out by Purchase (1999).

4.7 Disease

Blood was drawn during collaring sessions and serum collected, frozen and sent to the Department of Veterinary Services, Wildlife Veterinary Unit[8] Harare. For this study the interest was on the incidence of Feline Immunodeficiency Virus (FIV). Of the 11 samples collected and tested for FIV, 80% were positive. None of the prides that were followed between 2001 and 2007 showed any indication of sickness other than identifiable external causes. Samples were taken from female #12 who was found with severe septicaemia (after being badly mauled in a fight) and as a precaution she was tested for tuberculosis but the results came back negative (in the Kruger National Park there is a high incidence of bovine tuberculosis). Fortunately the Mana Pools National Park is spatially distant from the Kruger National Park lion population.

Feline Immunodeficiency Virus is a lentivirus that infects both wild and domestic feline species. Southern and eastern Africa have the highest incidence of FIV infection with nearly 100% of individuals being infected (ALWG, 2004). It has been established that FIV has been present in wild lion populations for centuries - possibly many thousand of years (ALWG, 2004). The Serengeti lions which have been the most intensely studied had a high (nearly

[8] Dr. Chris Foggin.

90%) prevalence of FIV in the population, and there is no evidence that the virus has compromised the health of either the Serengeti or the Kruger National Park lions (ALWG, 2004). According to the ALWG (2004) only the lions in the Etosha National Park, Namibia and Hluhluwe-Umfolozi Reserve, South Africa have so far tested negative for the virus. Whilst individual fitness in studied animals in the Mana Pools National Park did not appear to be compromised by the prevalence of FIV, further serological studies would be useful in future (see under chapter 6).

5. CONCLUSIONS

Although there were an estimated 11 prides in the Mana Pools National Park only six prides were studied. Four of these six prides were on the Zambezi River floodplain which had the highest density of lions (46.3% of the estimated population in just 11.2% of the area of the park). Prey density was highest on the floodplain (an estimated 63.5% of all prey species are found on the floodplain). The study therefore was considered to be of a representative sample of the park population. All tourist activity is either on the floodplain or on the Zambezi River mostly within an area of 46.4 km^2 termed the "Nyamepi" area. The lion population was reputed to be decreasing in this area and generally on the floodplain.

Two main aspects had to be looked at in this study:

(1) What was the population status of the Mana Pools National Park lion population since it was thought that (a) there was an imbalance in the large mammal predator guild namely between lion and spotted hyaena with hyaena numbers thought to be excessive and (b) that there was over-utilization of trophy lion males in the adjacent Safari areas.

(2) How did the historical lion population compare with the present population?

The first question above was adequately answered whilst the second question could not be adequately answered apart from looking at the population density of lions in the Nyamepi section of the floodplain obtained through road strip counts between the years 1981-1989 (Dunham, 1992) and comparing them to the present study.

Literature indicated that knowing the population density of lions by itself would not reveal whether the population was under threat or not. What was required was a more in-depth study of the lion demography in the Mana Pools National Park since this would show any major imbalances in the population structure which could be related to outside forces working against the population.

Demographic and behavioural work carried out on free-ranging lions in southern Africa (Smuts, 1976; Smuts *et al.*, 1977; Mills *et al.*, 1978; Smuts *et al.*, 1978; Anderson, 1981; Smuts *et al*., 1980; Starfield & Bleloch, 1983; Stander, 1991; Mills & Shenk, 1992; Maddock *et al*., 1996; Yamazaki, 1996; Funston *et al*., 1998; Orford *et al*., 1988; Funston *et al*., 2001; Funston *et al*., 2003) provides excellent base-line data for other workers in the southern African region to compare the lion populations with which they are working. Whilst the work carried out in eastern Africa is invaluable and forms the basis in many ways for the southern African work, there are some important differences between the two regional populations. This has been highlighted again in this study.

This study has shown that variables in the population characteristics of lions in the Mana Pools National Park are within the proportions and parameters of other free-ranging lion populations in protected areas in Africa. There are no areas within the demographic parameters that would indicate the effects of some external force against the population such as an imbalance of competing predators or the effects of over-utilization of adult male lions in the adjacent Safari areas.

The lion population density in the Mana Pools National Park varied from 0.65 lions/100 km^2 in the Zambezi Escarpment to 12.7 lions/100 km^2 on the floodplain. Overall, the density of lions in the park was 3.05/100 km^2. It was found that the density of lions on the dry Valley floor (2.21 lions/100 km^2) was comparable to other wild lion populations in semi-arid areas. The high density of lions on the floodplain was more in keeping with the lion density in the Serengeti plains, the Kruger National Park and the Kafue National Park. These findings were normal and were what would be expected in the different habitat types. Sex ratios and age class variables were well within the parameters of other free-ranging lion populations in Africa. The number of adults in the population was lower than the Kruger National Park but was comparable to the Kalahari Gemsbok National Park and higher than the Manyara National Park. The percentage of cubs in the population was high but fell within the same ranges as the Kruger, the Kalahari Gemsbok and the Etosha National Parks. The percentage of large cubs in the population was lower than the Kruger National Park but sub-adult percentage was higher indicating that large cubs made it to the sub-adult age class which would not be the case if they were being selected upon by some external factor.

Cub survival was high and even with the low sample size (n = 5 prides), this is likely to be a true reflection of the population since the highest density of lions was on the floodplain and this was the area on which the work was focussed. The Nyamepi pride was well documented and the high survival rate was established from intensive data collection over the years 2001 to 2007.

The mean group size was low (7.4) when compared with the Kruger National Park (11.8) but was higher than the Etosha (5.0), Selous (3.4) and Kafue (4.6) National Parks. The group size is a function of the prey availability and size of the area and this study showed that lions in the Mana Pools National Park are confined to two main water source areas; one in the extreme south of the park (two perennial springs) and one in the extreme north of the park (the Zambezi River). It also showed that the Zambezi floodplain which is limited in size (a total of 95.4 km^2) is occupied by four prides and that there is no space for further territories in the area. The study also showed that lions were crossing the Zambezi River into the Lower Zambezi National Park and it is hypothesised that this is because there is population pressure on the available resources on the floodplain.

Mean female pride size was 3.2, which was similar to that of the Etosha and Hluhluwe-Umfolozi National Parks. Sex and age ratios were well within the parameters of other wild lion populations in Africa. If selective hunting of trophy males was affecting the population many of the variables looked at would be different to those of other non-hunted populations but this was not the case.

Reproductive parameters were similar to those found in other lion populations in southern Africa with the inter-birth interval being similar to that in the Kruger National Park but larger than that of eastern African lion populations. Dispersal age of sub-adult males was similar to that found in the Kruger National Park, but later than the eastern African populations. Home ranges were generally small but reflected the habitat type and density of prey species that occurred where the prides were situated. Only wet season ranges were large in the Valley floor Chitake pride and this was as a result of dispersing prey.

Each pride had at least one attending adult male and the percentage time that they were seen with the natal pride was high (44.6-86.3%). On average pride males remained with the female pride for 33.25 months which was similar to the Etosha National Park (38 months).

The prevalence of disease was not found in the lion population during the study although 80% of sera samples submitted for analysis were positive to Feline Immunodeficiency Virus

(FIV). As has been established elsewhere, this lentivirus has been in lion populations probably for thousands of years and does not affect the health of the wild lion populations (ALWG, 2004).

There is not an “imbalance” between the spotted hyaena and lion populations in the park. The survey carried out by Purchase (1999) on spotted hyaena in the Mana Pools National Park gave some surprising results. It was found that the spotted hyaena density in the park, when compared to other protected areas in Africa, was in the low-medium category (0.17/km^2). Spotted hyaena densities in other parks give some indication of this: Ngorongoro 1.43/km^2 (Kruuk, 1972); Serengeti 0.82/km^2 (Hofer & East, 1993); Selous 0.32/km^2 (Creel & Creel, 1996); Kruger 0.07-2.0/km^2 (Mills, 1985); Masai Mara 0.55/km^2 (Ogutu & Dublin, 1998). This does not mean to say that spotted hyaena don’t interact with the lion prides in the Mana Pools National Park. There have been substantiated reports of spotted hyaena mobbing females on a kill and driving them off. In every instance this has happened when the pride male was not with the pride. This might not have been normal as evidenced by the high survival rate of cubs, recruitment into higher age classes and the general health of the lion population.

The overall conclusion is that the lion population in the Mana Pools National Park shows normal variables and proportions in the population structure when compared against other free-ranging lion populations in Africa. This would tend to point to the lion population being normal and healthy at this time.

6. MANAGEMENT RECOMMENDATIONS

Lions appear on the IUCN "Red List of Threatened Species" and are assessed as "Vulnerable" (IUCN, 2008). Management of this species is necessary since their range is shrinking and the activities and requirements of lions bring them into conflict with people.

The Management recommendations given here come under three broad categories: (1) Management of lions in the Mana Pools National Park (2) Management in Safari areas surrounding the Mana Pools National Park, and (3) Management of lions in Zimbabwe.

6.1 Management of lions in the Mana Pools National Park

6.1.1 Continued monitoring

Base-line demographic data of the Mana Pools National Park lion population has been provided by this study. It is recommended that monitoring of the population continue and be expanded upon. The two wildlife authorities (ZPWLMA in Zimbabwe and the Zambia Wildlife Authority - ZAWA) should agree to formulate a collaborative research program for monitoring the lion population on both sides of the river. This may be facilitated by the proposed Mana-Lower Zambezi Transfrontier Conservation Area plan that is underway to draw in both partners for joint management of the protected area.

If possible one member from each of the discrete prides on the floodplain should have a radio collar so that further demographic data can be collected for monitoring purposes. If radio collars cannot be obtained due to lack of finances, lions can be hot-branded with unobtrusive brands in order to make them identifiable to the researcher. Sub-adult male lions should be marked in order to obtain more information on dispersal out of the natal areas. It was found during this study that the participation of the public in the research was invaluable since they provided transport and paid a gazetted fee to assist in tracking lions. A further survey to obtain density estimates of spotted hyaena should be carried out using the techniques followed by Mills *et al.* (2001), Purchase (1999) and Ogutu and Dublin (1998). The management (culling) of spotted hyaena is unnecessary and undesirable. Mills (1991) shows how human intervention in attempting to manage members of the large mammal predator guild can cause serious imbalances in the predator/prey balance and in the predator/predator balance. Schaller (1972) has stated: “Predators are the best wildlife managers”. This research has shown that the lion population is not under threat from spotted hyaena. The survey that Purchase (1999) carried out showed that the spotted hyaena population was in the low-medium density range when compared to other protected areas in Africa and this study could not find any contradicting evidence.

6.1.2 Provision of pumped water supplies on the Zambezi valley floor

Lions in the Mana Pools National Park are confined to the areas of natural water supplies where their prey is found. The Valley floor is without water from about August until the first rains in late November. Wildlife and lion distribution would be assisted by providing a more even distribution of water supplies on the Valley floor. However, because the provision of artificial water supplies has many problems associated with it, such as local degradation of areas around the source and also a build up of wildlife which in itself can cause problems, this management intervention should be approached with caution and not without an environmental impact assessment. Vegetation should be monitored annually around the water source to check on habitat destruction. This can effectively be done annually by the use of photo panoramas from a fixed point, and comparing vegetation change from successive photos. If three low-volume solar-powered submersible pumps are placed in three strategic places on the Valley floor, they can be regulated so that wildlife will not congregate for long periods around one area. Low-volume pumping will provide enough water for a limited amount of wildlife in much the same way that the springs do and will prevent rapid and concentrated impacts around the water source.

6.1.3 Wildlife surveys to obtain population numbers

Road strip counts on the floodplain should be undertaken annually to assess the population trends of wildlife in that area. Aerial surveys of the whole park would be useful but this will under current circumstances only take place if outside donors are involved. By carrying out joint surveys the population figures derived from the counts will have more credibility especially when it comes to obtaining population estimates of elephant (a high profile species that can be exploited). Management exercises (culling) should be approached with caution and only after detailed scientific investigation.

6.1.4 Vegetation work on the Zambezi floodplain

The vegetation on the Zambezi floodplain is undergoing change. Mature *Faidherbia albida* woodland is beginning to die back and thickets are forming. No recruitment of young *Faidherbia albida* is occurring although seedlings are established by the end of the rainy season, but do not survive past the third month (unpublished data). The whole hydro-ecology of the floodplain needs to be investigated. The Zambezi River Authority should be encouraged to simulate flooding downstream of the Kariba Dam to achieve some semblance of the original flooding regime. This will allow water to flow into channels inland and so provide moisture inland. Moisture for short periods simulating a flood will assist the re-generation of this key tree species and palatable grasses.

6.2 Management of lions in surrounding Safari areas

Monitoring programs should be set up in Safari areas adjacent to the Mana Pools National Park. This should include collaring and tracking to obtain demographic data and to set base-line data against which the population can be compared. In addition quota setting can be refined based on the results of the survey. This study has shown that male lions frequently transgress into the Safari areas with one individual wandering 80 km from the dart site into Chewore south and being shot as a trophy animal. Other males have been located outside of their core areas in the park well inside of the Safari areas.

Ageing of shot animals should be mandatory and penalties imposed on hunters taking off non-trophy animals. This should include a photograph and tooth for detailed ageing and the Safari Operator should be obliged to pay the costs for analysis since this method will ensure his industry and, more importantly, that the lion population is sustainable in the long run. Experience has shown that Safari Operators would be pleased to assist in this monitoring and control.

6.3 Management of lions in Zimbabwe

A Conservation Strategy and Action Plan for lion in Zimbabwe (2006) was formulated after lion workers and other ecologists met to discuss pressing issues related to lion management in

Zimbabwe. The author was one of the organising and participating team and much of what is mentioned in the bullets below is also mentioned in the strategy and action plan.

Management and research was a key issue that needed defining and articulation. It was agreed:

- That a standardised lion census method should be developed.
- The ecology and biology of lions including habitat and prey needed further study.
- Monitoring should be put in place to detect trends and changes as a result of habitat change, hunting, and conflicts with people.
- A method of rapid determination of a trophy animal through morphological features should be developed and disseminated to hunters.
- A protocol should be developed to put in place database requirements for monitoring population status including off-takes from hunting and problem animal control. This data should be used for management of best hunting practises.
- The legal and institutional framework under which incentives for utilizing wildlife as a land-use option should be reviewed.
- There was need to clarify policy with reference to the hunting of female lions. Up until now there is a ban on the hunting of female lions but the reason for this needs to be clear and legislation put in place in the Parks and Wildlife Act that makes it illegal to hunt female lions except under special circumstances.
- The socio-economic impacts of lions to village people needs to be assessed and stakeholder participation in management of lions in their areas needs to be put in place.

Protected areas in Zimbabwe hold the majority of the lion population however there are populations in various Communal Lands adjoining Parks such as the Guruve and Sebungwe complexes. Frank and Packer (2003) urged that science-based predator management plans linking protected and unprotected areas be initiated with the support of Governments. This fits in with the Conservation Strategy and Action Plan for Zimbabwe since one of the strategies is to optimize wildlife conservation-related net benefits to local communities and it would be beneficial in lion conservation if the ZPWLMA initiated research into the lion populations in these areas and assisted in mitigation and uplifting of communities by good predator management.

In Zimbabwe there are a number of lion captive breeding programs but there does not appear to be much control and monitoring of these programs. In addition, many of the programs do not have clear management goals. The ZPWLMA should be active in formulating a captive breeding policy with guidelines that should have legislative backing. Since there is a high incidence of Feline Immunodeficiency Virus in the lion population in Zimbabwe, movement of lions should be strictly controlled by the Department of Veterinary Services and the ZPWLMA. The Gonarezhou National Park in the south-east of Zimbabwe has recently become part of the Great Limpopo Transfrontier Conservation Area. It borders with the Kruger lion populations which carry bovine tuberculosis (bTB). Special effort should be taken to put in place a lion monitoring program in the Gonarezhou National Park since no work has been carried out on lions in the Park and there is no base-line population data in place. If the Gonarezhou lion populations became infected with bTB it would be difficult to estimate what effect it has had on the population and what degree of threat there is.

It is known that there is movement of lions between Zimbabwe and its neighboring countries and this was documented in IUCN SSC Cat Specialist Group: “Conservation Strategy for the Lion *Panthera leo* in Eastern and Southern Africa” (IUCN, 2006). Wildlife corridors should be maintained where they are already in place and created where they are not. This would obviously need the support of Governments and the communities that are often found on the periphery of the countries.

Finally, it would be fitting when making management suggestions to quote from the introduction of the Zimbabwe Conservation and Action Plan for lions since this document was commissioned and sanctioned by the Ministry of Environment and Tourism and embodies the African perspective of lions:

> “The lion *Panthera leo* is a powerful cultural symbol of Africa and is an important indicator of an area’s wildness qualities where it occurs. It is also a key species for tourism, research and trophy hunting, the last embedded in mythology and reflecting the pinnacle of success in a classical African hunting safari.”

LARGE MAMMALS FOUND IN THE MANA POOLS NATIONAL PARK, ZIMBABWE

Common name	Scientific name
Baboon (Chacma)	*Papio hamadryas*
Buffalo	*Syncerus caffer*
Bush buck	*Tragelaphus scriptus*
Bushpig	*Potamochoerus larvatus*
Caracal	*Caracal caracal*
Cheetah	*Acinonyx jubatus*
Duiker (common)	*Sylvicapra grimmia*
Eland	*Tragelaphus oryx*
Elephant	*Loxodonta africana*
Giraffe	*Giraffa camelopardalis*
Hyaena (spotted)	*Crocuta crocuta*
Impala	*Aepyceros melampus*
Kudu	*Tragelaphus strepsiceros*
Leopard	*Panthera pardus*
Lion	*Panthera leo*
Monkey (vervet)	*Cercopithecus pygerythrus*
Nyala	*Tragelaphus angasii*
Oribi	*Ourebia ourebi*
Reedbuck (Southern)	*Redunca arundinum*
Sable	*Hippotragus niger*
Steenbuck	*Raphicerus campestris*
Warthog	*Phacochoerus africanus*
Waterbuck	*Kobus ellipsiprymnus*
Wildebeest (blue)	*Connochaetes taurinus*
Zebra (Plains)	*Equus quagga*

APPENDIX 2

ABSTRACT

THE DEMOGRAPHY AND POPULATION STATUS OF LIONS (*Panthera leo)* IN THE MANA POOLS NATIONAL PARK, ZIMBABWE

by

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Demographics of the lion population in the Mana Pools National Park were studied between 2001 and 2007. No detailed work had previously been carried out on this subject in the park. Demographic data was obtained from six prides, with two prides (Chitake and Jesse) being on the Zambezi Valley floor at the base of the Zambezi Escarpment in the south, and four prides on the Zambezi floodplain in the north. The Zambezi floodplain in the Mana Pools National Park is 95.5 km² in extent and in area comprises 11.2% of the park. Approximately 46% of the adult lion population occurs on the floodplain where approximately 63% of the lion prey base in the park is found. Not all prides could be studied at the same intensity, however, demographic data was obtained for all six prides. The Nyamepi pride on the floodplain was the most intensely studied.

A population estimate of 67 adult and sub-adult lions was made for the Mana Pools National Park. Overall density throughout the park was 3.05 lions/100 km². Density ranged from 0.65/100 km² in the escarpment which held 0.3% of the prey species taken by lions to 12.7/100 km² on the floodplain. There were 1.8 adult males to 3.3 adult females and all prides were attended by a male. Mean group size (adults and sub-adults) was 7.8 (range 5-11). The adult and sub-adult age class made up 70.7% of the population and large and small cubs made up 29.3% of the population. Cub survival to one year of age was 66.7%.

Females produced their first litter between 43-53 months of age and cohorts of cubs were produced on average every 38.5 months. Pride males had an average tenure with the pride of 33.25 months and sub-adult males dispersed from the pride between 36-57 months with a mean of 39.8 months.

Home ranges varied on the floodplain from 28.1 km² to 278 km² and from 50.2 km² to 379.3 km² on the valley floor. The floodplain Nyamepi pride males had a home range two and a half times that of the females. Only the Valley floor lions had differences in dry and wet season home range size (dry season 57.7 km² and wet season 379.3 km²).

Demographic variables, when compared to other lion populations in similar habitat in protected areas in Africa, did not differ and the Mana Pools National Park lion population appears to be normal. The Mana Pools National Park is surrounded in the west and east by Safari areas (administered by ZPWLMA) and has no man-made or natural barriers between them. No work was carried out on lions in the surrounding Safari areas but it was found that males frequently made excursions into the Safari areas (one collared male was shot in Chewore Safari area 80 km from the darting site in Mana Pools). Lions also frequently crossed the Zambezi River into the Lower Zambezi National Park, Zambia. It is presumed that there is a two-way movement between the Mana Pools National Park and Safari areas and the Park and the Lower Zambezi National Park, but could not be confirmed in this study.

The spotted hyaena population in the Mana Pools National Park was found to be in the low-medium category when compared to other populations in protected areas in Africa (Purchase, 1999). All data accrued during the present study showed that this population do not pose a threat to lion conservation in and around the Mana Pools National Park.

OPSOMMING

THE DEMOGRAPHY AND POPULATION STATUS OF LIONS (*Panthera leo)* IN THE MANA POOLS NATIONAL PARK, ZIMBABWE

deur

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Die demografie van die leeupopulasie in die Mana Pools Nasionale Park is vanaf 2001 tot 2007 bestudeer. Geen gedetaileerde studie oor hierdie onderwerp is nog voorheen in die park uitgevoer nie. Demografiese data is van ses troppe versamel, met twee troppe (Chitake en Jesse) op die Zambezi-vallei se bodem teen die basis van die Zambezi platorand in die suide, en vier troppe op die Zambezi vloedvlakte in die noorde. Die Zambezi vloedvlakte in die Mana Pools Nasionale Park is 95.5 km² en beslaan 11.2% van die park. Ongeveer 46% van die volwasse leeupopulasie kom op die vloedvlakte voor waar ongeveer 63% van die leeus se prooidiere in die park te vinde is. Nie al die troppe kon met dieselfde intensiteit bestudeer word nie, maar demografiese data kon vir al ses troppe ingesamel word. Die Nyamepi trop op die vloedvlakte is die intensiefste bestudeer.

Die leeupopulasie vir die Mana Pools Nasionale Park is beraam op 67 volwasse en sub-volwasse leeus. Die digtheid in die park was 3.05 leeus/100 km². Die digtheid het gewissel van 0.65/100 km² vir leeus van die platorand waar 0.3% van die leeus se prooi spesies voorkom tot 12.7/100 km² op die vloedvlakte. Daar was 1.8 volwasse mannetjies vir elke 3.3 volwasse wyfies en al die troppe het een mannetjie gehad. Gemiddelde grootte van groepe (volwasse en sub-volwassenes) was 7.8 (reeks 5-11). Die volwasse en sub-volwassene

ouderdomsgroep maak 70.7% van die populasie uit en groot en klein welpies 29.3% van die populasie. Oorlewing van welpies tot op ouderdom een jaar was 66.7%.

Wyfies lewer hulle eerste werpsel tussen die ouderdom van 43-53 maande en groepe van welpies is gemiddeld elke 38.5 gebore. Mannetjies behou hulle troppe gemiddeld vir 33.25 maande en sub-volwasse mannetjies versprei tussen 36-57 maande, met 'n gemiddeld van 39.8 maande.

Tuisgebiede wissel tussen 28.1 km² en 278 km² op die vloedvlakte en tussen 50.2 km² en 379.3 km² op die bodem van die Vallei. Die mannetjies van die vloedvlakte se Nyamepi trop se tuisgebied is twee en 'n half maal groter as die wyfies se tuisgebied. Slegs die leeus op die Vallei het verskillende tuisgebiede tussen die droë (57.7 km²) en die nat (379.3 km²) seisoene gehad.

Gemeet teen ander leeupopulasies van vergelykbare beskermde gebiede in Afrika stem die demografiese veranderlikes in die Mana Pools Nasionale Park grootliks ooreen en skyn die populasie normaal te wees. Die Mana Pools Nasionale Park word in die weste en die ooste begrens deur Safari gebiede (onder administrasie van die ZPWLMA) met geen mensgemaakte skeiding tussen die gebiede nie. Geen navorsing is op die leeus in die omringende Safari gebiede uitgevoer nie, maar mannetjies maak dikwels ekskursies in die Safari gebiede ('n mannetjie met 'n halsband is in die Chewore Safari area geskiet, sowat 80 km vanwaar hy in die Mana Pools gepyl is). Leeus steek ook dikwels die Zambezirivier oor na die Lower Zambezi Nasionale Park in Zambië. Daar word aanvaar daar is 'n tweerigting beweging tussen die Mana Pools Nasionale Park en die Safari gebiede en die Park en die Laer Zambezi Nasionale Park, maar dit kon nie in die studie bevestig word nie.

Die gevlekte hiëna populasie in die Mana Pools Nasionale Park is in die laag-medium kategorie indien dit vergelyk word met die ander populasies in die beskermde gebiede in Afrika (Purchase, 1999). Al die data wat in die huidige studie ingesamel is toon dat die populasie nie 'n bedreiging vir die bewaring van leeus in en rondom die Mana Pools Nasionale Park inhou nie.

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