



TARANGIRE LION PROJECT (TLP) REPORT

Introduction

The Lion, *Panthera leo*, is the most abundant large predator in African savannah and plains ecosystems after the spotted hyaena (Estes 1993). Depending on prey density, in a given area there can be anywhere from 1 lion/3 mi² to 1 lion/50-100mi² (Estes 1993) (this converts to approximately 1 lion/4.8 km² to 1 lion/80.1-161.3 km²). However, over the past century lion populations have been declining all over Africa and have disappeared all over central Asia (except for those living in the Gir Forest National Park) and the Middle East (*Nowell & Jackson 1996*). In Africa they have disappeared from the northern regions while in the southern areas only few populations are left. In the remaining part of the African continent they are mainly confined to National Parks and the surrounding areas. The main cause of this decline is the loss of wildlife habitat due to the expansion of agriculture and livestock. In some areas unsustainable hunting and poaching are the main limiting factors. This situation threatens the survival of the main African predator by reducing its number and by isolating the lion populations, increasing the risk of inbreeding. Tarangire National Park (TNP) is a relatively small protected area, encompassing 2,600 km² . Prior to achieving national park status, the Tarangire area was quite popular for hunting (Lyogello, 1988), and today the Game Controlled Areas that surround the Park contain several trophy hunting companies (Bayne 1998). Although the rainy season officially runs from November to May, comparatively speaking the total rainfall in the park per year is low, at about 600mm (Lyogello, 1988). Nevertheless, most migratory species such as zebra and wildebeest (Fig 1 and Fig 2) leave the Park at the beginning of the short rains in early November (Snelson, 1992), leaving only the resident species such as impalas, warthogs, and dikdiks behind. Because of these factors: herbivore migration, deterioration of habitat, and nearby hunting camps, it has been said that TNP is not a self-sustaining ecosystem (TLP, 2000). The Park's narrow width (about 40 km at its widest point) means that wildlife, including the resident lion population, often moves in and out of the Park boundaries, thereby interacting with nearby human populations.

The Tarangire Lion Project was started in June 1998 with the aim of collecting reliable data on the status of the lion population with particular awareness to those factors which are essential for the correct management of the species in the surrounding areas. The project focuses on the identification of lion individuals of the Park in order to examine the population structure and dynamics of the lions within

Tarangire National Park to determine the effect of trophy hunting in surrounding areas on the population's demographics. The data are being analyzed in an attempt to extrapolate a population estimate for the future, as well. Since the lion can be considered a key species in Tarangire both for its ecological role and for its value in tourist game viewing and hunting, all factors impacting the lions are obviously extremely important to sustain a healthy population and preserve the species in the Tarangire ecosystem. Clearly, there are many factors that come into play when determining the health and long-term viability of a given population of lions, not the least of which is prey availability. Past research has shown that "population density, cub survival, and dispersal rates of sub-adults are all highest where prey is most abundant" (Hanby, 1995). Craig Packer has found in his research with lactating females that the amount of milk that a female produces depends entirely on the female's food intake and not on her number of cubs, so prey availability clearly influences all dependent young, as well as those individuals that are directly feeding on a kill. Similarly, in *The Safari Companion*, Estes (1993) states that lions will compete fiercely for food amongst themselves, with the smaller and weaker lions often getting very little, resulting in high juvenile mortality rates when prey is not readily available.

Past observations seem to show that the Tarangire lions feed mainly on zebra and wildebeest (Snelson, 1992) both of which migrate out of the Park once the rains begin (Fig 1 and Fig 2). Furthermore, a study conducted by TLP evidenced that lion foraging in Tarangire National Park consists of 39% wildebeest, 34.1% zebra and 17.1% buffalos (Farina, TLP, 2000). Research has shown that lion home ranges can be as small as 20 km² in the best habitat, and as large as 400 km² when there is low prey availability (kingdom, 1997). Range size appears to be inversely correlated with prey abundance when abundance of prey is lowest, and overall lion density in a given area tends to decline when prey disperses (Weldon, 1999).

Many studies have shown that herbivore populations are directly affected by rainfall, due to their reliance on vegetation, thereby indirectly affecting the predators that feed on them as well (Weldon, 1999). For example, P.C. Viljoen's work in Northern Botswana (1993) concluded that in his study area, lion range sizes varied with the seasons, with ranges being approximately 1.7 times larger during the time of year when prey density is lowest.

This particular study seeks to understand how the mass movement and dispersion of the Tarangire lions' main food source once the rains begin affects their own dispersal in and around the Park. It is hypothesized that such a large-scale dispersal of preferred prey out of the Park will force the lion population to respond accordingly, i.e. the lions will need to disperse as well in order to obtain an adequate food supply while prey abundance is low in TNP.

This study has direct applications to the ongoing research being conducted by the Tarangire Lion Project, in that all factors affecting the species' health and survival directly tie in to any sort of long-term management plan that should be developed. The question of how the lions adapt their home ranges when prey becomes scarce has direct implications for population sustainability in the future, because as they move outside the Park's boundaries, the lions potentially become more at risk in regards to hunting and other conflicts with the human population.

Tarangire Manyara Conservation Project (TMCP)
 Istituto Oikos, Tanzania Branch &
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Zebra

Dry and wet season distribution areas

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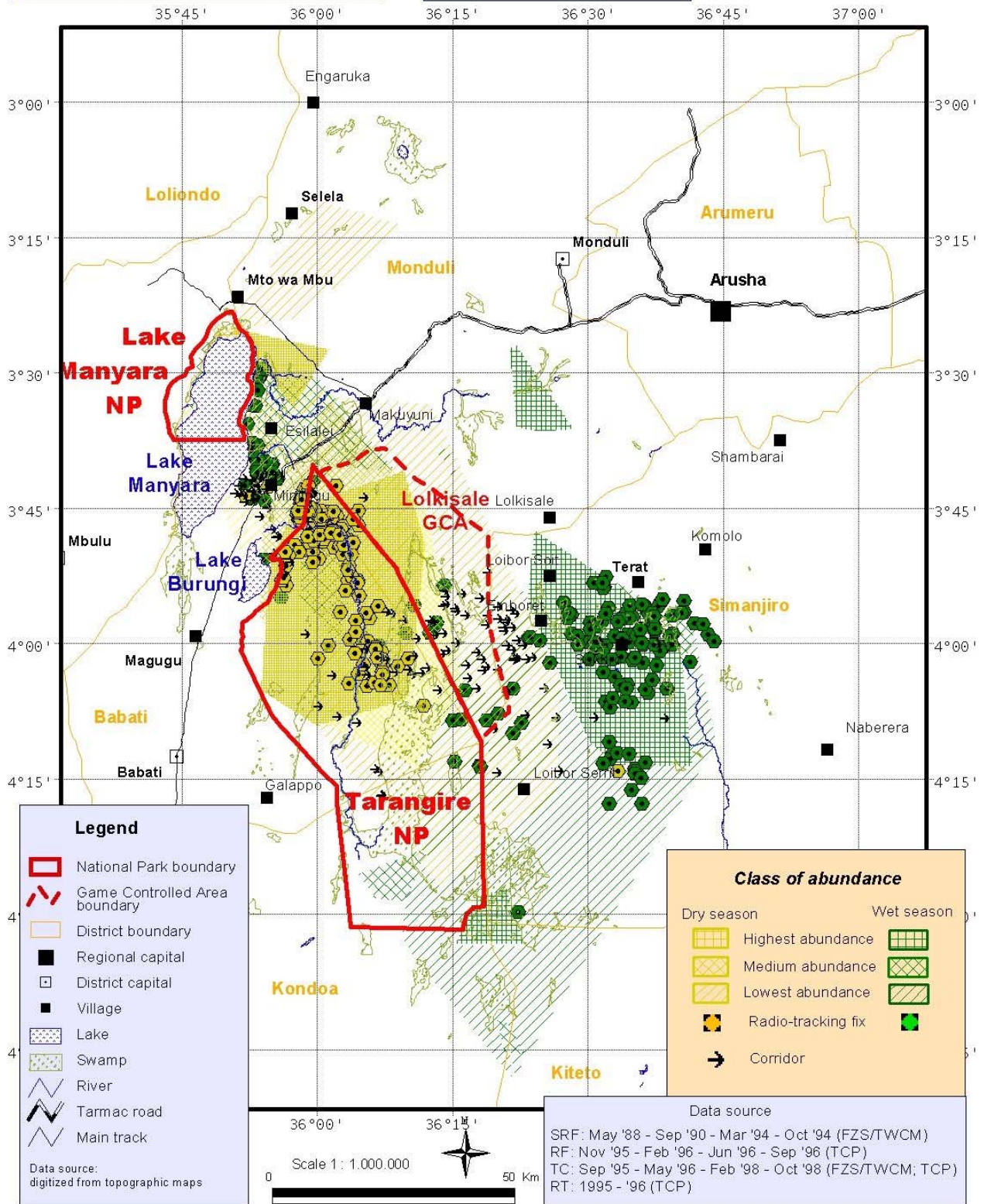


Fig. 1 A map of Tarangire National Park's zebra population distribution as compared between the dry and wet seasons (TMCP 2002)

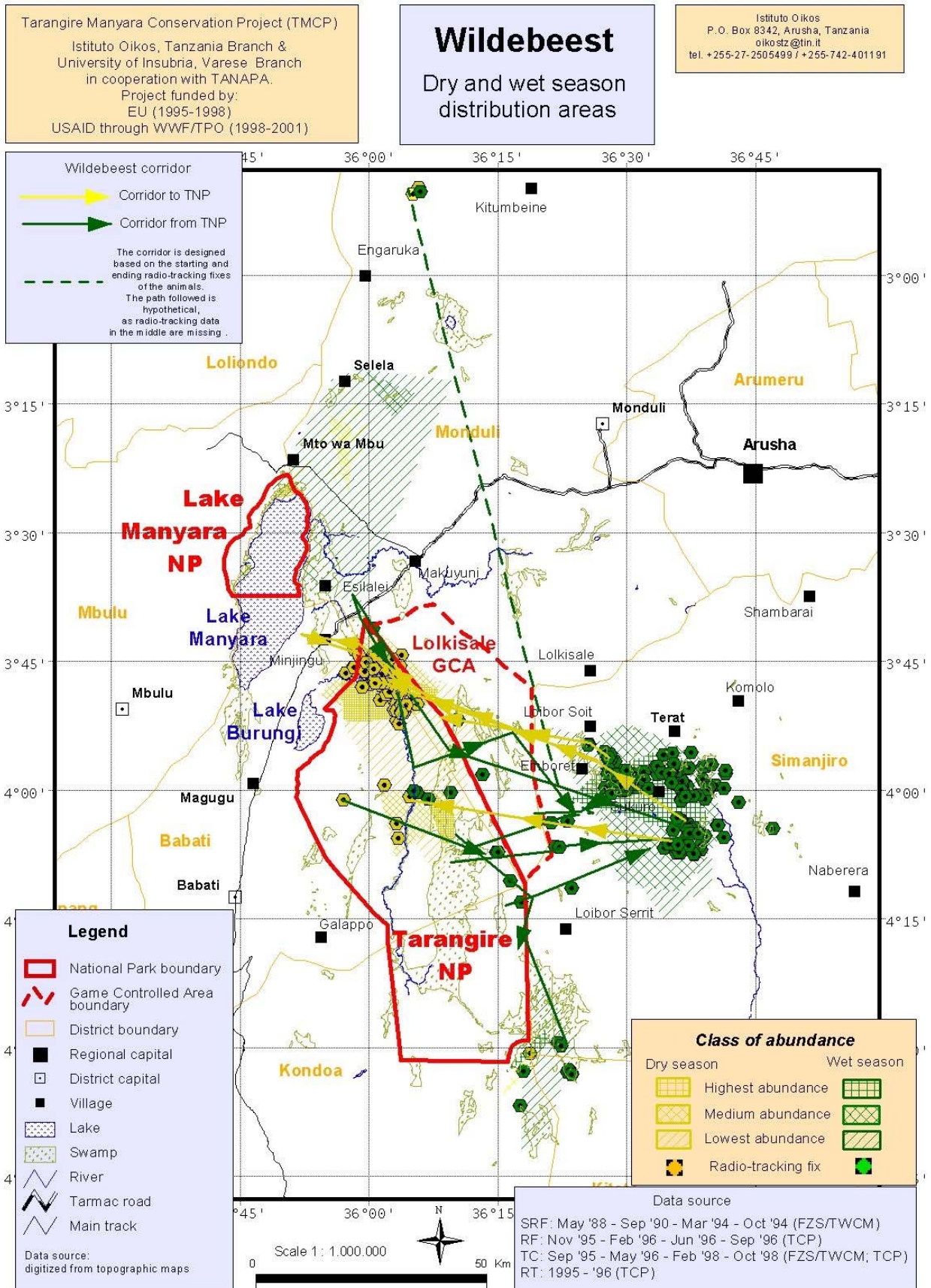


Fig. 2 A map of Tarangire National Park's wildebeest population distribution as compared between the dry and wet seasons. (TMCP 2002)

Study Area

Tarangire National Park covers an area of approximately 2600 km² in northern Tanzania at 3° 50'S and 36° 00'E latitude and longitude respectively. While Tarangire officially achieved National Park status in 1970, from 1957 until 1970 it was considered a Game Reserve. Today the Park is bordered by four Game Controlled Areas (GCA's), which are: Mukungunero GCA in the south, Mto wa Mbu GCA to the north, Simanjiro GCA in the east, and Lolkisale GCA to the northeast. The Park is bordered in the south by Mukungunero Game Controlled Area (GCA), in the east by Simanjiro GCA, in the north-east by Lolkisale GCA and in the north by Mto wa Mbu GCA. Formerly, Tarangire National Park, used to be a Game Reserve which was established in 1957. The National Park was established in 1970.

Tarangire National Park is characterised by an arid and undulating landscape (mean altitude of 1200 mts a.s.l.), with a rocky area and high plains in the South-east and has been eroded by the Tarangire River which bisects the Park from South to North. During the dry season the river is reduced to some deep pools. Swamps are created during the wet season, from November until May with a peak in March.

The so-called short rains begin in the Park in November, with heavier rains continuing on through May resulting in an average annual rainfall of 650 mm (Davison, 1991), and with an annual evapotranspiration of 1500-2500 mm (Peterson,1978). The area is classified as Eco-climatic Zone V, arid rangeland (*Pratt & Gwynne,1977*) and it belongs to the “ East African Woodland/ Savannah (3.05.04) Bio-geographical Province ” (Udvardy, 1975).

The Tarangire River provides a water source for many animals in the area during the dry season. Tarangire's predominant features include nine different vegetation zones (Lyogello, 1988), Lake Burungi in the northwest, Tarangire Hill in the centre, a rocky area and high plains in the South-east, Silale swamp in the east and, of course, the Tarangire River.

The study area to conduct lion research was chosen due to the presence of several hunting concessions in the area which may be placing excessive pressure on the lion population residing in and around Tarangire National Park. The Project's study area encompasses an area of 1350km² primarily in the northern section of the Park. The Tarangire area is an ideal location for this specific study, due to the seasonal migration of the Park's herbivore population out of the Park once the rains begin. This in turn directly affects the lions' ability to access adequate amounts of food during this period of time. The main road network inside Tarangire National Park along which the data are collected is shown in figure 3. The map shows in red the roads which are travelled over 20 times per year, in orange those between 11 – 20 times and in yellow the least travelled ones.

There are 3 key routes by which wildlife moves from TNP into its surrounding areas, the most critically threatened of which is most probably the area leading to the Lolkisale GCA as the majority of the migration corridors pass through it. Also the Kwa Kuchinja corridor located to the northwest of TNP, leading to Manyara National Park, is currently at risk because of the rapid growth of agricultural development and human settlement in this area.

Wildlife

Most of the larger African mammals of the East African Plains inhabit the Tarangire National Park, such as elephant (*Loxodonta Africana*), buffalo (*Syncerus caffer*), impala (*Aepyceros melampus*), giraffe (*Giraffa camelopardalis*), zebra (*Equus burchelli*), wildebeest (*Connochaetes taurinus*), lesser kudu (*Tragelaphus imberbis*), eland (*Taurotragus oryx*) and fringe-eared oryx (*Oryx gazzella callotis*). Carnivores include lion (*Panthera leo*), leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), spotted hyaena (*Crocuta crocuta*) and wild dog (*Lycaon pictus*).

For some species, such as zebra, wildebeest, buffalo, elephant, oryx and eland, Tarangire National Park represents a refuge in the dry season. At the beginning of wet season the majority of these species migrate to the Maasailand. There are 2,300 elephants in the Tarangire Ecosystem (*TWCM/TCP, 1995*), the greatest elephant population in northern Tanzania; 6800 buffalo (*TWCM/TCP, 1995*); 32,000 zebra and 37,000 wildebeest (*TWCM, 1990*).

A small population of wild dogs present in the area (although it hasn't been sighted in the last couple of years inside the Park but a pack was seen in year 2002 in Manyara Ranch area) and a considerable lion population are the carnivore species of greatest conservation value in Tarangire.

ROADS OF TARANGIRE NATIONAL PARK

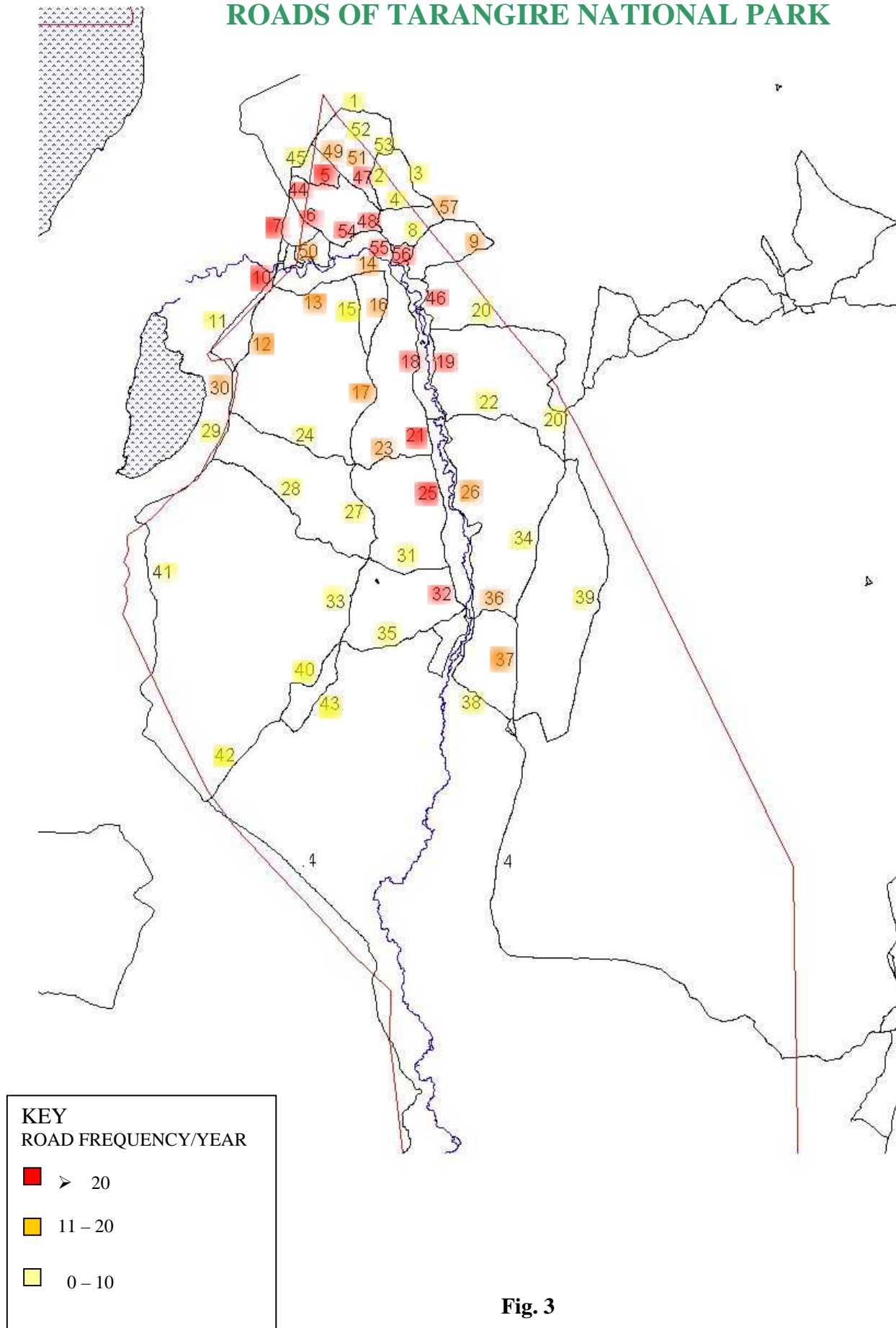


Fig. 3

Methodology

Data collection started in July 1998 and has been conducted daily until February 2003, with breaks during the wet seasons (February – June)

Photo-identification

ID cards have been made for each individual encountered using the photo-identification technique. Lions were found whilst driving around the park, using information from Park personnel and tourist drivers. Lion tracks that were found along the roads were examined to determine the direction, how many individuals they belonged to and how old they were and were followed where possible. In some cases lions have been found in this way. Vultures, which scavenge animals preyed by carnivores, were observed as well. Whenever they were sighted in congregations they were followed and the area thoroughly searched for remains of carcasses. If the remains were found they were examined to verify if they were lion kills in such case the surrounding area was searched for lions. Observation of prey animals was sometimes helpful in finding lions. Whenever a behaviour of alert, alarm calls, run away or look in a specific direction was noticed the search for lions in that particular area would become more attentive. For each animal a sighting data-sheet was completed. Using the method described by *Pennycuick & Rudnai (1970)* through the patterns of vibrissa-spots (Fig. 4, D,1,2,3,4 and Fig. 5), permanent scars and ear notches (Fig.4, A); it has been possible to recognise each single individual. Age has been estimated using body size (*Smuts et al. 1978; Bertram 1975*), percentage of blackness of the nose (fig. 4, F) (*Creel & Creel 1997*) and by the amount of tooth wear (fig.4, E) (*Smuts et. Al. 1978*). Filling the ID cards each individual's age been estimated as precisely as possible, especially for juvenile and sub-adults.

The following criteria were used to estimate age:

- | | |
|--------------|---|
| Young Lions: | size in relation to the mother, appearance of mane hairs in males, childhood spots (presence or absence-they fade with age), milk teeth |
| Adult males: | development of mane, size or length of mane, childhood spots disappear around 7 years of age |
| All adults: | teeth discolouration, wear and tear |

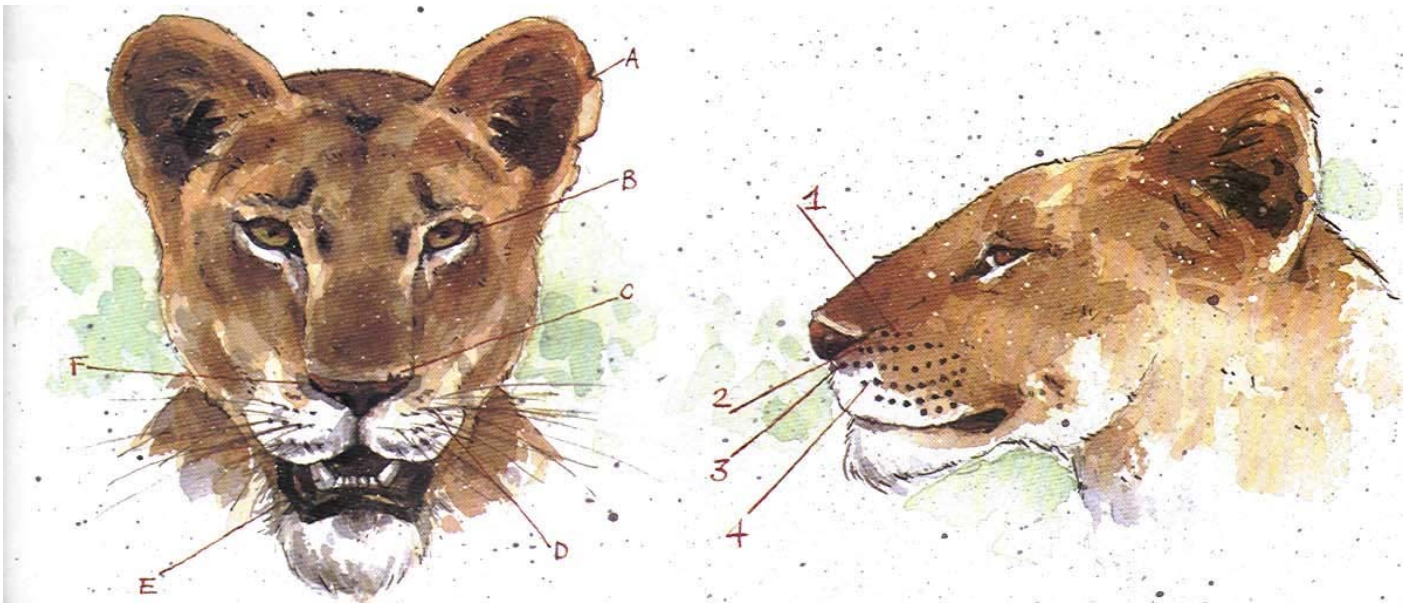


Fig. 4

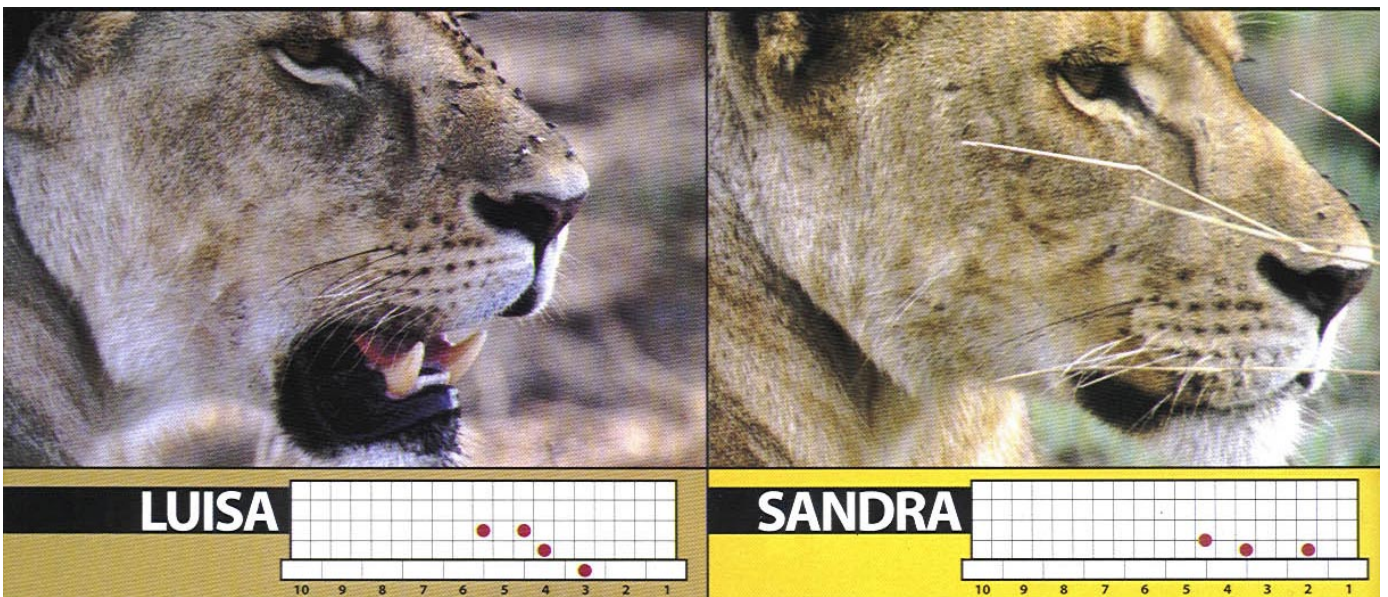


Fig. 5 - comparison between 2 adult females in Tarangire National Park

Playback

To facilitate data collection, the play-back method has been used. A tape with a record of a dying wildebeest calf bleat and hyenas squabbling at a kill was played in order to attract predators. The sound system consisted of a tape recorder Sony XRS-22SW3, an amplifier Pioneer GM-X 404 and two 200 Watt Sony loud speakers. The map of the Park was divided by a grid of 10x10 Km to avoid overlapping and having the same lions responding to the calls from different positions on the grid. In fact, the distance at which lions respond was estimated to be 3 Km from one calibration done in Tarangire N.P. and from studies conducted in other areas

(*K. Whitman pers. comm.*) A 5 Km distance has been chosen to be sure not to overlap the tape to the same lions.

Due to landscape's characteristics it was not always possible to reach the planned position of the grid with the vehicle. Occasionally some extra grid playbacks were broadcasted in places where roaring was heard the previous night. Starting at 6.00 in the morning the vocalisations were played until lions came or for a maximum of 45 minutes. A maximum of three playbacks were played in a morning in neighbouring positions on the grid and occasionally one playback was done in the late afternoon. Playbacks were not performed during the day because, due to the heat, lions would have not responded. Each time lions responded, the vocalisations have not been played in the same area for at least 4 weeks, to avoid the habituation of the animals. On each playback session a data-sheet was completed.

Rarely a tape with a record of a male lion's roar was used instead but just in areas in which we were sure no females with cubs were around to avoid them running away.

Analysis

Data analysis have been conducted in Italy. All the pictures taken during the field work were cross checked with the ID cards of the animals previously identified. The database for each individual consists of the location of the sighting, date, time, pride, group composition, activity and whenever animals are eating prey is also considered. The cartographic software used to produce the mapping system is the GIS ArcView 3.1. The GIS system allows to produce multilayer maps, connected to the data base, with the distribution for all the different prides, seasons etc. Areas and densities can also be calculated by the software, particularly using Kernel and MCP analysis.

The examination and the analysis of the interacting factors that place a population or a species at risk is called population viability analysis or PVA (Burgman *et al.* 1993, Lacy 1993). PVA was carried out to identify the threats faced by lions in Tarangire National Park and to evaluate the likelihood that it will

persist for a given time into the future. This type of analysis is often oriented towards the conservation and management of rare and threatened species, with the goal of applying the principles of population ecology to improve their chances of survival. Threatened species management has two broad objectives. The short term objective is to minimize the risk of extinction. The longer term objective is to promote conditions in which species retain their potential for evolutionary change without intensive management. Within this context, PVA may be used to address three aspects of threatened species management:

1. **Planning research and data collection.** PVA may reveal that population viability is insensitive to particular parameters. Research may be guided by targeting factors that may have an important impact on extinction probabilities or on the rank order of management options.
2. **Assessing vulnerability.** Together with cultural priorities, economic imperatives and taxonomic uniqueness, PVA may be used to set policy and priorities for allocating scarce conservation resources.
3. **Ranking management options.** PVA may be used to predict the likely response of species to reintroduction, captive breeding, prescribed burning, weed control, habitat rehabilitation, or different designs for nature reserves or corridor networks.

Computer simulation modelling provides a tool for exploring the viability of populations subjected to many complex, interacting deterministic (eg. over-harvest, habitat destruction, competition or predation from introduced species) and stochastic processes (random variation of demographic and genetic events and the effect of environmental variation on demographic and genetic events).

Natural populations are influenced by different types of processes and these variables can be incorporated in the simulation modelling (Shaffer 1981):

- **Basic life history of the species,** (its ecology, breeding system, birth rate, mortality pattern, social system) sets the context upon which other processes act and determines how and whether a population can respond to changing circumstances. However, chance processes play an essential role in determining the fate of a population especially if it's a small population and the model may fail to reflect this.

- **Demographic stochasticity.** This is random variation in population size as a consequence of chance variations in birth or survival rates. This process is entirely intrinsic to the population and can lead to extinction even when average population growth rates are positive.
- **Genetic variation.** In small populations genetic variation is lost rapidly. Inputs from mutation are negligible and if exchanges with neighbouring populations are limited lost variation is unlikely to be regained. Genetic factors are most problematic for the smallest populations and can become significant over a long period especially for species that are facing environmental changes.
- **Environmental variation and catastrophes.** These are external forces acting on populations. Natural populations experience continuing variation and often progressive deterioration of the habitat. These have significant impacts on viability both through restricting the total amount of habitat and through increasing fragmentation. In addition to changes in habitat there may be periodic rare events with major effect which can reduce survival or fecundity. These catastrophes include diseases, storms droughts or harvest as in our specific case.

We used the VORTEX simulation model (Lacy, R. C., K. A. Hughes, and P. S. Miller. 1995). VORTEX is an individual-based model that simulates birth and death processes as discrete, sequential events, with probabilistic outcomes. The model generates random numbers to determine whether individual animals lives or dies and the number of progeny produced by each female each year. The model can simulate inbreeding depression as a decrease in viability of inbred animals.

There is no single recipe to follow when doing a PVA, because each case is different in so many respects. A variety of model scenarios were developed to examine the relative importance of the different threatening processes and those which are particularly significant for the lions' viability.

The P.V.A. analysis was carried considering a 50 year period and each run consisted of 500 simulations.

Discussion

The Tarangire Lion Project has been concentrated on the northern section of the park, from Silale swamp northward, in order to assess the lion population structure of this area of the Park.

From June 1998 to February 2003, 1479 lions have been sighted corresponding to 294 specific individual lions. The number of direct sightings increases during the dry season mainly due to the fact that fires and grazers shorten the grass down improving visibility whilst the playback method becomes less effective. Other studies have shown a correlation between playback success and prey availability in areas where a migratory movement of great herbivores is present (*K. Whitman, Pers. Comm; Ogutu & Dublin 1998*). In fact the great abundance of prey lowers dramatically the response to the vocalisations broadcasted. Although the playback method has not been greatly effective especially in the last two years it must still be considered of great help. In fact it is very useful at the beginning of the dry season when the grass is still very tall and when the migratory species have not yet returned to the Park. Furthermore it has been efficient to attract those individuals which are non-habituated to vehicles and which would be very difficult to observe otherwise.

In the 5 year study period 11 prides have been recognised for a total of 294 lions of which 239 individuals have a complete ID card. Tab. 1 shows the different lion prides resident in the Park identified from July 1998 until December 2002. Just 6 groups of lions were seen all 5 years (Lodge, River, Wazi, Tarangire Hill, Kuro and Silale) although in some cases, such as Silale in the year 2000 and Poacher's Hide in 2001, only a couple of individuals and not the entire pride were found.

1998	1999	2000	2001	2002
Lodge	Lodge	Lodge	Lodge	Lodge
Wazi	Wazi	Wazi	Wazi	Wazi
River	River	River	River	River
Tarangire Hill	Tarangire Hill	Tarangire Hill	Tarangire Hill	Tarangire Hill
Kuro	Kuro	Kuro	Kuro	Kuro
Silale	Silale	Silale	Silale	Silale
	Altipiano	Altipiano		Altipiano
		Old Silale	Old Silale	Old Silale
		Poacher's Hide	Poacher's Hide	
		New Silale	New Silale	
			Silale NE	

Tab.1 prides of Tarangire from July 1998 to December 2002

This is probably the major issue in Tarangire: where do lions go? And to which areas do they move to when they are not found? Are they still inside the Park or do they travel outside as well? We have considered and compared the sightings and re-sightings of the 5 years of study and only 10 animals (4.2% of the 239 lions identified), all of which are females, were sighted every year for the entire 5 year study period (Tab. 2 and Fig. 6). Most lions were sighted just during one year and were never sighted again (51.5%), 52 lions, corresponding to the 21.8% of the total identified, were sighted in 2 different years of the study period and not necessarily in 2 subsequent years. In fact, in some cases, lions that were sighted the first year of study reappeared after 2 – 3 years.

	YEARS				
	1	2	3	4	5
M	52	23	13	6	0
F	71	29	21	14	10
TOTAL	123	52	34	20	10
% of total identified	51.5	21.8	14.2	8.4	4.2

Tab.2 Lions sighted and re-sighted between July 1998 to December 2002

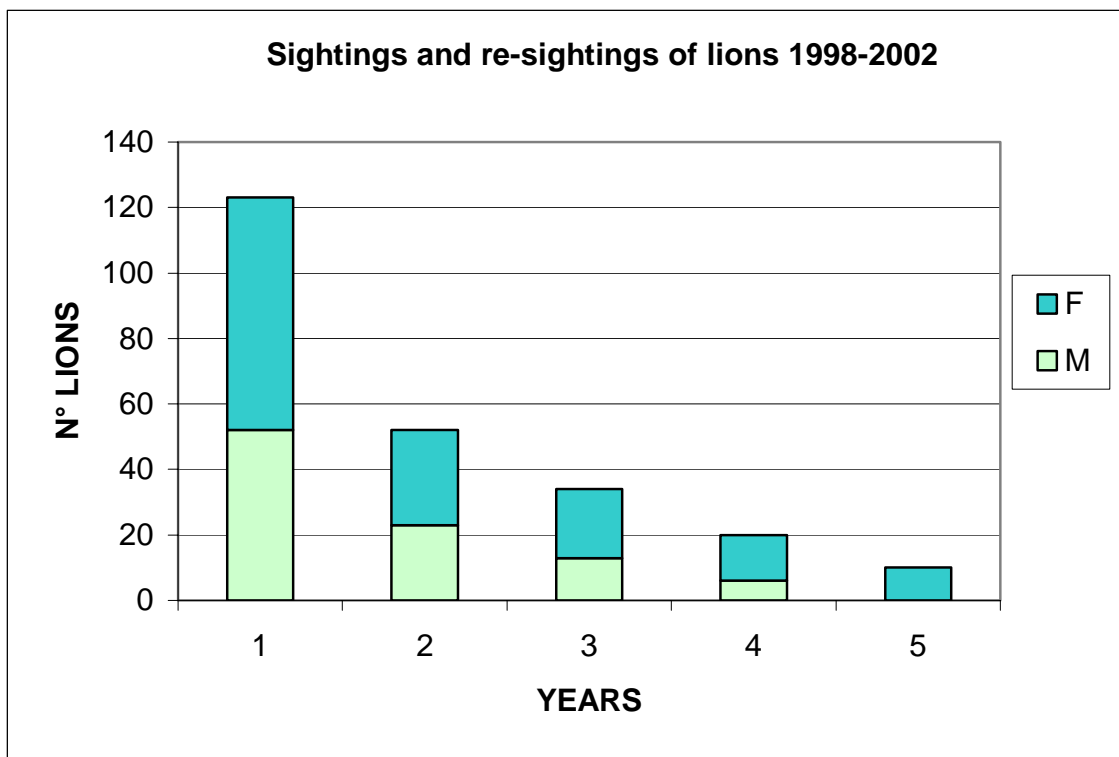


Fig.6 Lions sighted and re-sighted between July 1998 to December 2002

The largest pride size observed was 30 (Tarangire Hill, 2002) with an average of 10.7 (Tab.3). The greatest number of females in a pride was 9 (Lodge, 1999) with an average of 4.22. The biggest male coalition observed consisted of 5 young males that were chased away from their original pride (Silale) and have moved from the south of the Park to the northern areas where they have been seen mating with the adult females of the Lodge pride between August 2002 and February 2003. Although they are still quite young (4 – 5 years old) they managed to chase away the 2 adult males that were resident in the area around the lodge and establish in that region. The 2 older males have been seen just once in the past year and far away from their habitual territories. This made us assume that they had been chased away by the new incomers. Other 2 adult males were present in the same area around the lodge but have never been sighted during the last study period.. In most cases, as in the latter, it is very difficult to tell whether the males that aren't seen for long periods of time have moved to other areas because of the arrival of new males or if they have been killed by hunters and maasai outside the protected areas.

Of the 239 lions that were identified most of them reside in prides. In fact, only 58 were considered nomads because seen just once and / or never seen within any other known pride

The largest pride, group of females and male coalition are all highlighted in table 3.

Population structure for the 5 years is shown in Tab 4 and grouped in age classes (0-2 years = juvenilia; 2 - 4 years = sub-adult; >4 years = adult) in Tab. 6 and Fig. 2. The mean for the whole study period, after normalization, can be seen in Tab. 5. Sex ratios at birth and for each year and for each age class can be seen in Tab. 7 and Fig. 3.

Tab.3 Pride size and structure between July 1998 to December 2002

PRIDE	YEAR	ADULTS		SUBADULTS		JUVENILIA		TOTAL
		M	F	M	F	M	F	
KURO	1998	4	4			1	2	11
	1999		4			3	1	8
	2000		4	3	3			10
	2001		3	2	1			6
	2002	2	6					8
LODGE	1998	1	4	2	7		2	16
	1999	3	9		2	5	2	21
	2000	2	4			2		8
	2001	4	5	3		1	4	17
	2002	2	3					5
RIVER	1998		5	2	1	3	2	13
	1999		3			1		4
	2000	1	4	1	1	5	3	15
	2001		3				4	7
	2002	3	5				4	12
SILALE	1998	2	8			5	4	19
	1999	2	8			6	5	21
	2000							0
	2001	1	5	5	5	2	4	22
	2002	5	4		4		1	14
TAR.HILL	1998		4			3	5	12
	1999		2			1	1	4
	2000	1	1	1	3			6
	2001	3	5	2				10
	2002	3	7			12	8	30
WAZI	1998	1	5		8			14
	1999	1	7		2			10
	2000	1	2					3
	2001						6	6
	2002		4		2	1	5	12
ALTIPIANO	1998							0
	1999		2	1			2	5
	2000		2	1		1	3	7
	2001							0
	2002	1	4	1	1	2		9
POACHER'S HIDE	1999							0
	2000		3	1	9	1	2	16
	2001		1					1
	2002							0
OLD SILALE	1998							0
	1999							0
	2000		5				4	9
	2001							0
	2002							0
NEW SILALE	1998							0
	1999							0
	2000		4	3				7
	2001		3	5	1			9
	2002							0
SILALE NE	2001	1	2		1	2	2	8
TOTAL		44	154	33	51	57	76	415

AGE	1998		1999		2000		2001		2002	
	males	females	males	females	males	females	males	females	males	females
0-1	10	8	4	3	1	3	8	9	11	7
1-2	3	7	12	11	9	15	2	6	3	7
2-3	5	6	1	3	14	9	9	10	3	3
3-4	3	15		2	3	4	18	10	6	9
4-5	2	3		9	2	2	4	4	8	7
5-6	2	7		2	1	5	4	1	5	5
6-7		7	4	5		2	0	6		4
7-8	5	9		6	3	6	1	2		3
8-9		7	5	6	1	8	5	9	1	2
9-10	1	1		5	4	3	0	13	3	4
10-11		2	1	1		3	2	0	0	7
11-12		1				1	0	2	0	2
12-13						1	0	2	0	3
13-14							0	0	0	1
>14						1	0	0	0	0
TOTAL	31	73	27	53	38	63	53	74	40	64

Tab.4 Lion population structure in Tarangire - July 1998 to December 2002

Age class	1998		1999		2000		2001		2002	
	males	females	males	females	males	females	males	females	males	females
Juvenilia	13	15	16	14	10	16	10	15	14	14
Subadults	8	21	1	5	17	15	25	19	9	12
Adults	10	37	10	34	11	32	18	40	17	38

Tab.5 Lion population structure in Tarangire - July 1998 to December 2002

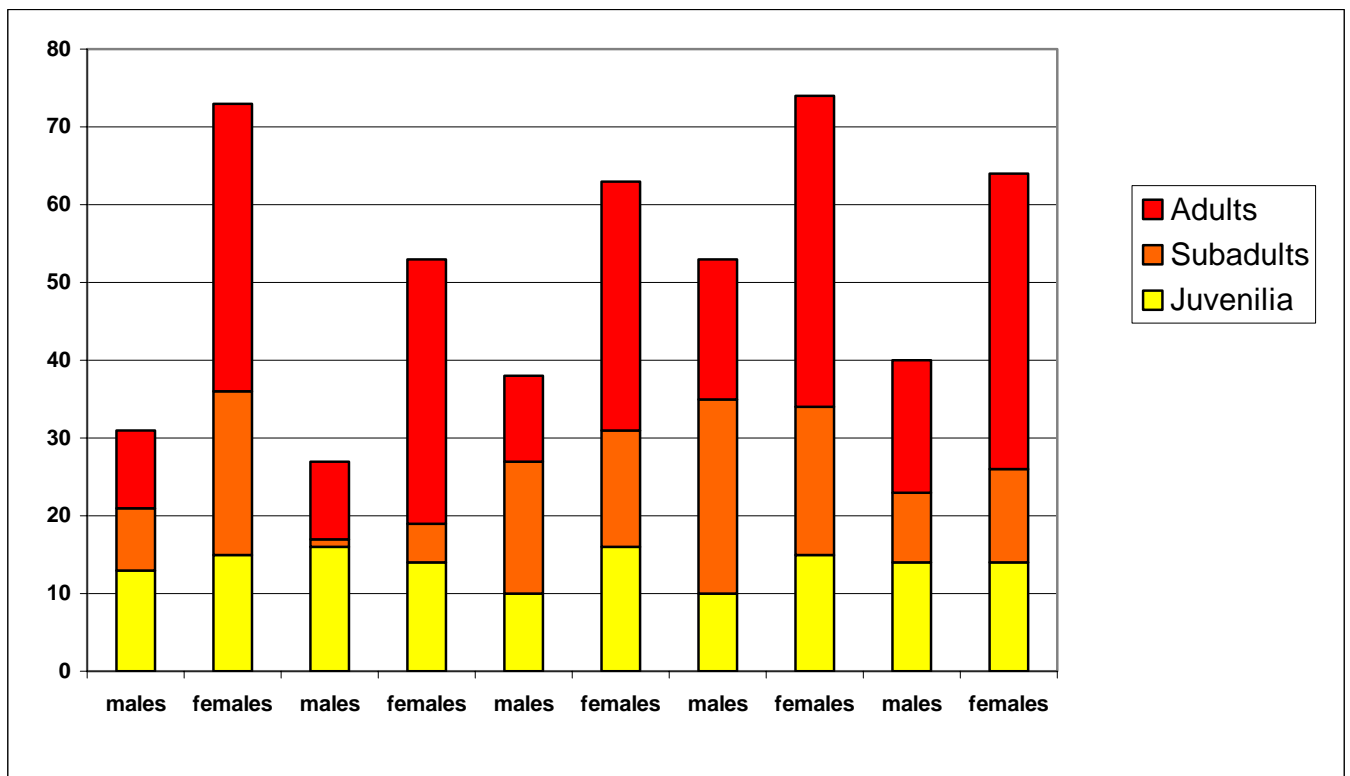


Fig.2 Lion population structure in Tarangire - July 1998 to December 2002

Age	1998	1999	2000	2001	2002	Mean
0-1	17,31	8,75	3,96	13,39	17,31	12,14
1-2	9,62	28,75	23,76	6,30	9,62	15,61
2-3	10,58	5,00	22,77	14,96	5,77	11,82
3-4	17,31	2,50	6,93	22,05	14,42	12,64
4-5	4,81	11,25	3,96	6,30	14,42	8,15
5-6	8,65	2,50	5,94	3,94	9,62	6,13
6-7	6,73	11,25	1,98	4,72	3,85	5,71
7-8	13,46	7,50	8,91	2,36	2,88	7,02
8-9	6,73	13,75	8,91	11,02	2,88	8,66
9-10	1,92	6,25	6,93	10,24	6,73	6,41
10-11	1,92	2,50	2,97	1,57	6,73	3,14
11-12	0,96	0,00	0,99	1,57	1,92	1,09
12-13	0,00	0,00	0,99	1,57	2,88	1,09
13-14	0,00	0,00	0,00	0,00	0,96	0,19
>14	0,00	0,00	0,99	0,00	0,00	0,20
TOTAL	100,00	100,00	100,00	100,00	100,00	100,00

Tab.6 normalized population structure - July 1998 to December 2002

SEX RATIO %M	1998	1999	2000	2001	2002	Mean
Juvenilia	46,43	53,33	38,46	40	50	45,64
Subadults	27,59	16,66	53,13	56,81	42,86	39,41
Adults	21,28	22,73	25,58	31,03	30,9	26,30

Tab. 7 sex ratio expressed in terms of % of males on the total for each age class

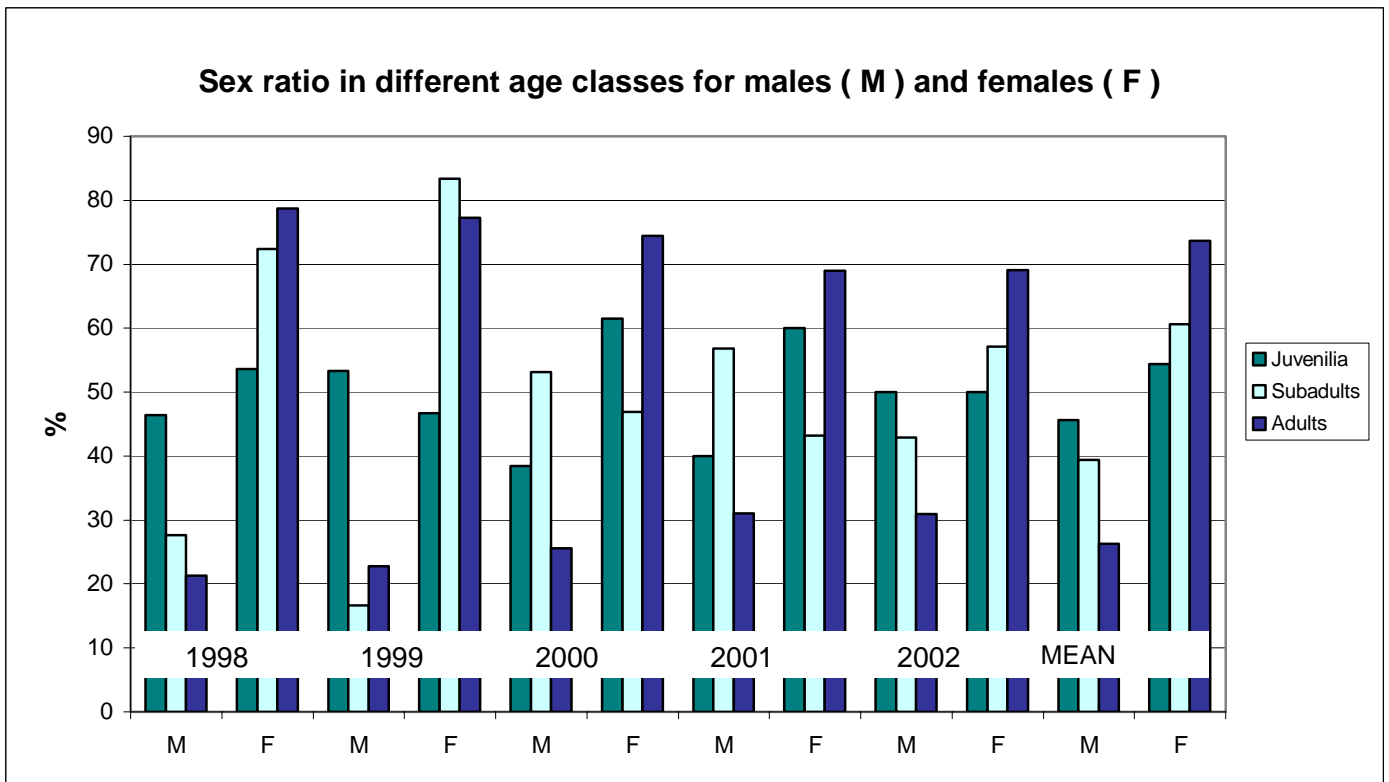


Fig. 3. sex ratio for each age class and mean values for the 5 year study period

Distribution of the number of cubs for each female has been calculated for each year in two different ways because it is not always possible to see cubs as soon as they are born due to the fact that the mothers often keep them hidden. The first method considers direct observations of the cubs and the females (Tab. 8, method 1) which are seen within the year of study. The second method considers both direct observations, as described for method 1, as well as indirect ones i.e. consequent observations in the following years after birth (Tab. 9, method 2). Therefore, if a cub was not seen in the year of interest but it was instead sighted the following years it was in any case inserted in the correct year of birth / interest backwards. For obvious reasons, this type of analysis was not possible for the year 2002. The mean values of the data obtained for the whole study period with the two methods are shown in Tab. 8, 9 and Fig. 4.

Mean litter size has been calculated for each year considering both methods 1 and 2 and the mean values for the entire 5 year study period are 1,99 and 2,03 respectively (Tab. 8, 9).

Mortality rate for cubs has been calculated from one age class to the other considering the exact age of the cubs when first and last sighted and approximated into various age classes. Tab. 10 and Tab. 11 show the number of cubs sighted in each age class which survived to the next considering males and females together in order to increase the sample size. However, we have also considered them separately as shown in Tab. 12 and Tab. 13.

Areas occupied and densities for adults have been calculated for each year of study and examining the whole study period together using the GIS software Arc View (Tab. 14). Kernel and MCP analysis have been carried out as shown in Fig. 5. The same diagram shows all the lion sightings between July 1998 and December 2002 and their distribution mainly along the Tarangire river.

The final objective of the project is to verify the dynamics and the trend of the population and to do so a preliminary Population Viability Analysis (PVA) has been conducted using data collected in Tarangire. Whenever input data was not available, mainly due to the little size of the sample, data from bibliography was used instead.

N° cubs	N° Females	% F on total	% reproductive F	Tot cubs
1	3,40	10,63	32,67	3,40
2	3,60	11,14	41,72	7,20
3	1,60	4,95	18,94	4,80
4	0,60	1,75	6,67	2,40
0	23,00	71,53	0,00	0,00
TOTAL FEMALES	32,20	100,00	100,00	17,80
% F riprod	28,47			

Mean litter size
1,99

Tab. 8 N° of cubs per litter, mean values: N° of females producing each litter, % of females producing each litter on the total number of females in the population, % of reproductive females producing each litter class, N° of cubs produced in each litter between July 1998 and December 2002 calculated considering method 1 (see text)

N° cubs	N° Females	% F on total	% reproductive F	Tot cubs
1	4,50	11,49	34,75	4,50
2	4,25	10,47	35,22	8,50
3	2,75	6,86	22,15	8,25
4	1,00	2,34	7,88	4,00
0	28,25	68,84	0,00	0,00
TOTAL FEMALES	40,75	100,00	100,00	25,25
% F riprod	31,16			

Mean litter size
2,03

Tab. 9 N° of cubs per litter, mean values: N° of females producing each litter, % of females producing each litter on the total number of females in the population, % of reproductive females producing each litter class, N° of cubs produced in each litter between July 1998 and December 2002 calculated considering method 2 (see text)

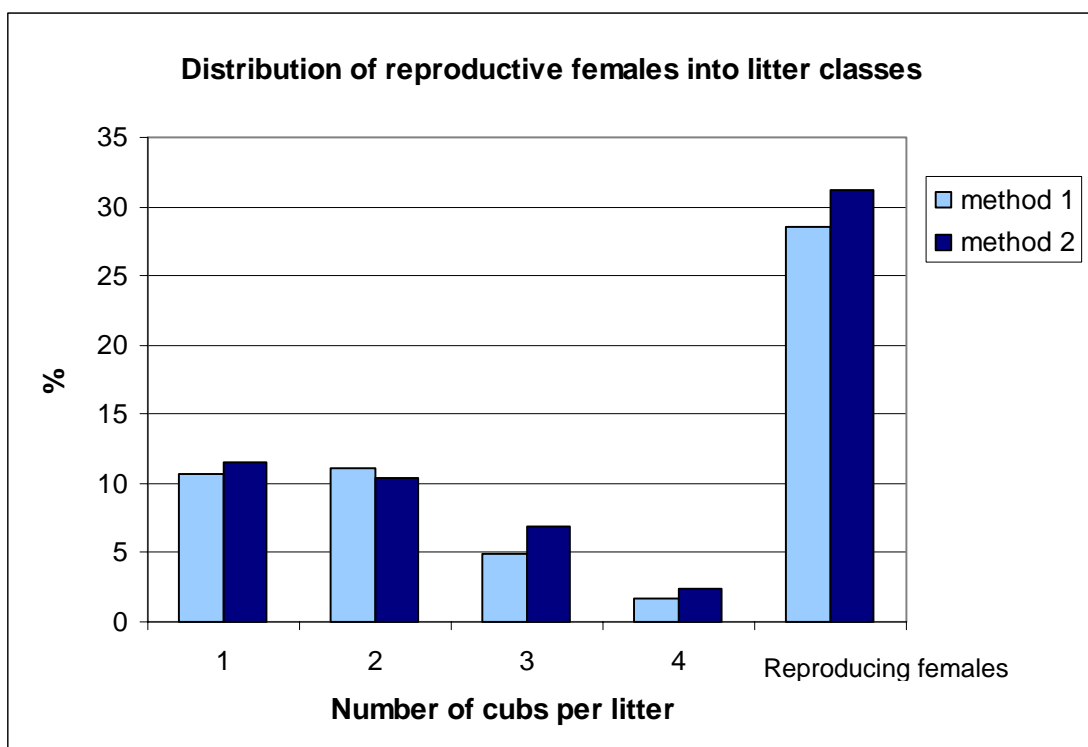


Fig.4 Distribution of reproducing females into litter classes – methods 1 and 2

MONTHS								
0	6	12	18	24	30	36	42	48
9	6							
	46	32						
		45	38					
			49	42				
				50	45			
					53	49		
						49	43	
							33	27

Tab 10 Number of cubs sighted in each age class which survived to the next (M and F together)

%MORTALITY

0-6 months	6-12 months	12-18 months	18-24 months
30	30,43	15,55	14,28

Tab 11 Mortality rate (%) for each age class (M and F together)

MONTHS									
0		6		12		18		24	
M	F	M	F	M	F	M	F	M	F
2	7	1	5						
		21	25	14	18				
				19	26	16	22		
						19	30	15	27
								22	28

Tab 12 Number of cubs sighted in each age class which survived to the next (M and F separately)

%MORTALITY

0-6 months		6-12 months		12-18 months		18-24 months	
M	F	M	F	M	F	M	F
50	28,57	33,33	28	15,79	15,38	21,05	10

Tab 13 Mortality rate (%) for each age class (M and F separately)

	1998	1999	2000	2001	2002	mean
Tot n° adults M+F	44	43	39	49	50	43,75
Area occupied Kernel 95% (SqKm)	450	429	327	344	277	387,5

Ad. density /100SqKm	9,78	10,02	11,93	14,24	18,05	11,49
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Tab 14 Total n° of adults and areas occupied by lions between 1998 – 2002 calculated with Kernel

Lion sightings from 1998 to 2002

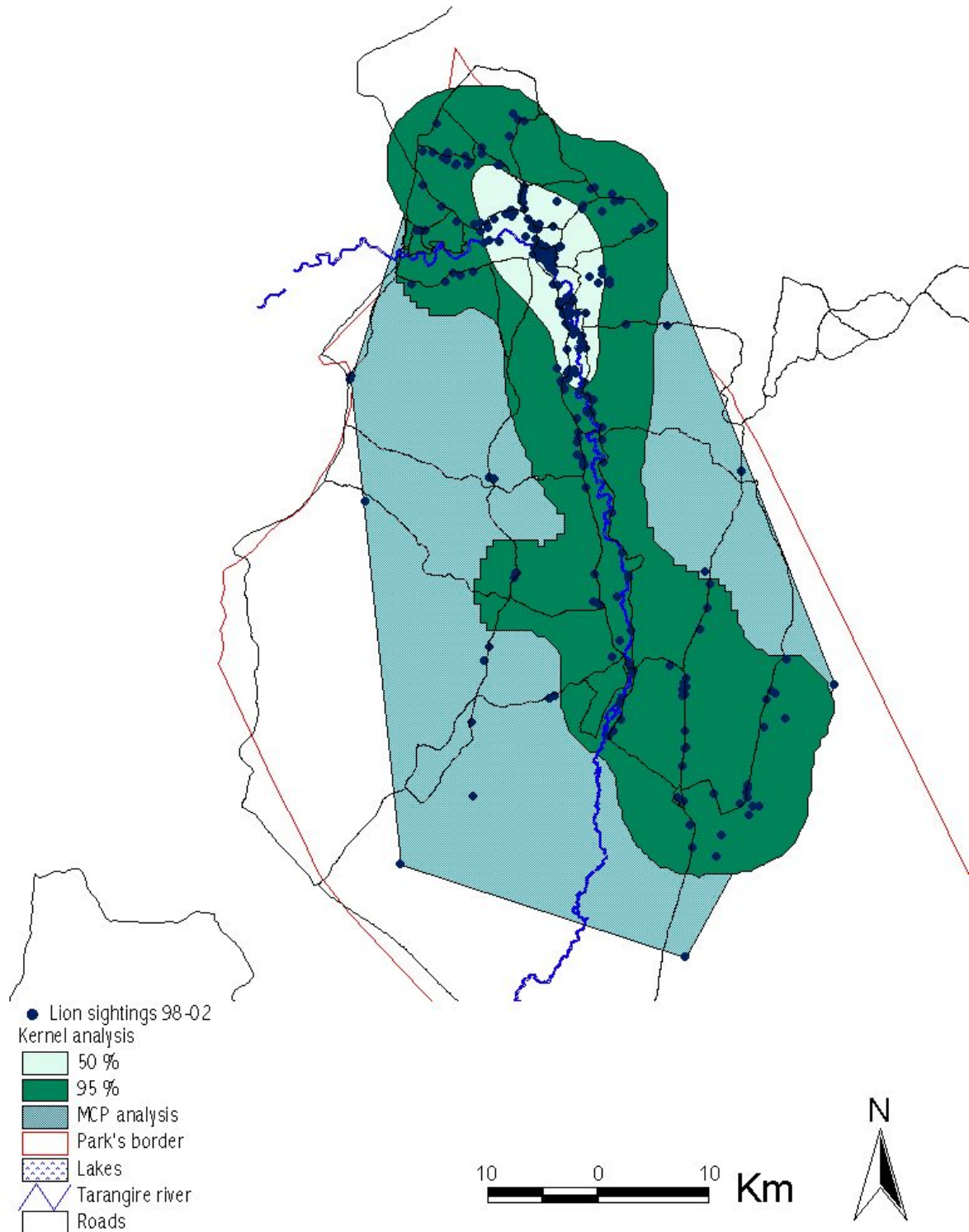


Fig 5 Areas occupied by lions sighted between 1998 – 2002 (kernel and MCP analysis)

We modeled the Tarangire Lion population as a single interbreeding population with no ingress from or egress to other populations. All data used as input for the model is based on the field study carried out between July 1998 and December 2002. All details are shown in the PVA data form in Appendix A. We run 42 different simulations each of which considers 500 hypothetical populations over a time period of 50 years. Six results obtained from running different model scenarios are shown in Fig. 7.

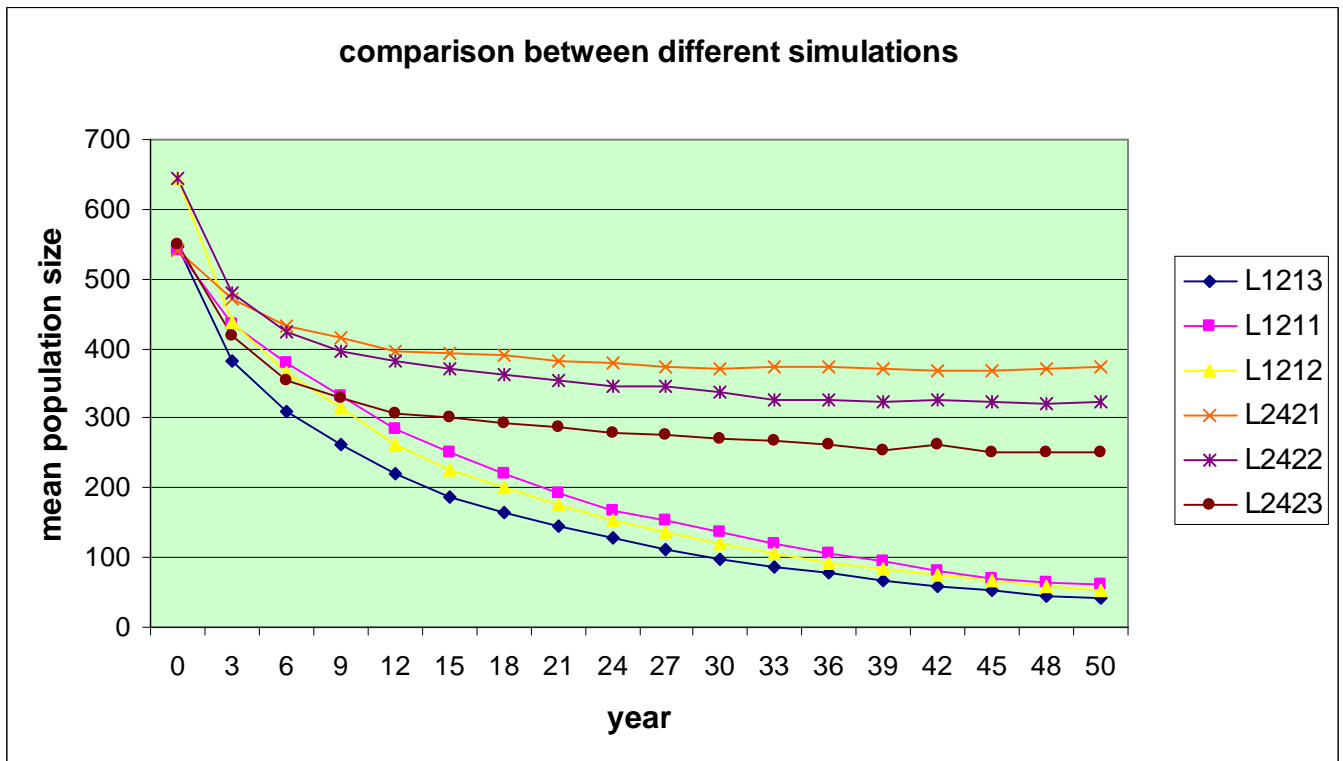


Fig. 7

Most of the input data to run the software was the same for all the simulations although percent of reproductive rate of females, juvenilia/sub-adult mortality rates, adult female and male mortality rates, carrying capacity (K) and harvest were the variables in the modeling scenarios.

Inbreeding depression has not been considered in the simulations because considered irrelevant to the viability of the population (TLP, 2000).

Mortality in age class 1 (0 – 1 year) was calculated in two ways either by considering the age classes 0 - 6 months and 6 months - 12 months separately (codes Lx1xx and Lx2xx) or by considering it as a whole, 0 – 12 months, because of the small sample (codes Lx3xx and Lx4xx). In all the other age classes mortality has been calculated by comparing the values of one age class with the next and considering the number of individuals that have not reached the following age class (6 months interval and then calculated on year basis). Just for the age class 3 – 4 years the difference was assumed as mortality or dispersion for

the age class 36 – 48 months. An individual has been considered dead if not seen for more than 2 years after the date of its last sighting. Simulations have been conducted in two different ways, either by calculating the mortality rate for females and males together (code Lx2xx), or by considering them separately (code Lx1xx). Due to the small size of the sample the two sexes were added together in each age class and the same comparison as above has been made.

Adult female mortality was either found in bibliography (code Lxx1x) or an arbitrary value close to zero was assumed (code Lxx2x). Fig. 8 shows the output scenarios between three models which consider bibliographic mortality (L1213, L1211 and L1212) and three which consider a low arbitrary value (L1221, L1222 and L1223). Although in all cases the population decreases a higher adult female mortality value has a major impact.

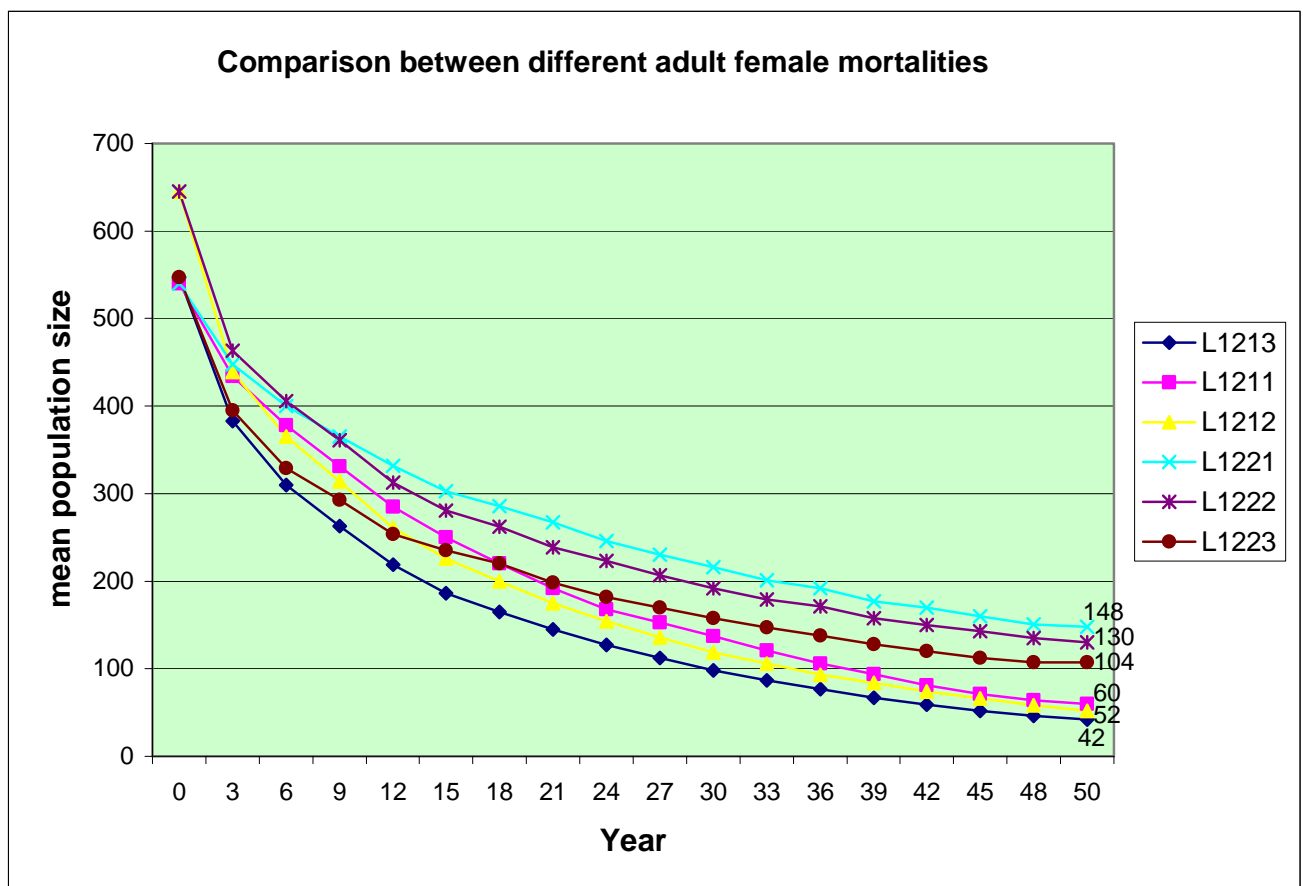


Fig. 8

Carrying capacity (K) has been calculated in three different ways although in all cases the density of lions in the North of the Park was assumed to be unlike that of the South where prey availability is low and water is scarce. K1 (code Lxxx1) was found by adding the number of adults in the North of the Park, calculated considering the mean density of the 5 years in study area, to the estimated number of adults in the south of Tarangire National Park assuming a density value of 7 adults per 100 sqKm (the lowest in bibliography). To the total population the corresponding percentage of juvenilia was then added. K2 (code Lxxx2) was extrapolated from the highest lion density obtained in the 5 year study (Tab. 14: in 2002 18 /100 sqKm) and it may be considered as the highest carrying capacity value for Tarangire National Park to which the corresponding percentage of juvenilia was added. K3 (code Lxxx3) was calculated not considering just the mean of adults for the 5 year study period but the entire population (juvenilia and subadults). Therefore, the corresponding percentage of juvenilia and subadults was added year per year and subsequently the final mean value was calculated. The latter is probably the most correct because it considers the entire population although it has a very high standard deviation. Presumably K1 is the most reliable value for this reason, because the standard deviation is smaller due to the fact that, in calculating it, the juvenilia don't influence much as they are added after the adults' density has been found.

When possible standard deviation has been calculated otherwise it has been estimated as default to a value of 25% of the mean.

It has to be underlined that all carrying capacity values are overestimates of the effective number because calculated according to densities found during the dry season when animals are highly concentrated within the park borders. Most probably as the herbivore population migrates outside the park the lions become much more scattered reducing their density within Tarangire. However, no data has yet been collected during the wet season.

A comparison between 3 equal scenarios which consider K1 (540), K2 (645) and K3 (550) as possible carrying capacity values (Fig. 9), has shown that the trend of the population is not affected greatly by the initial value of K.

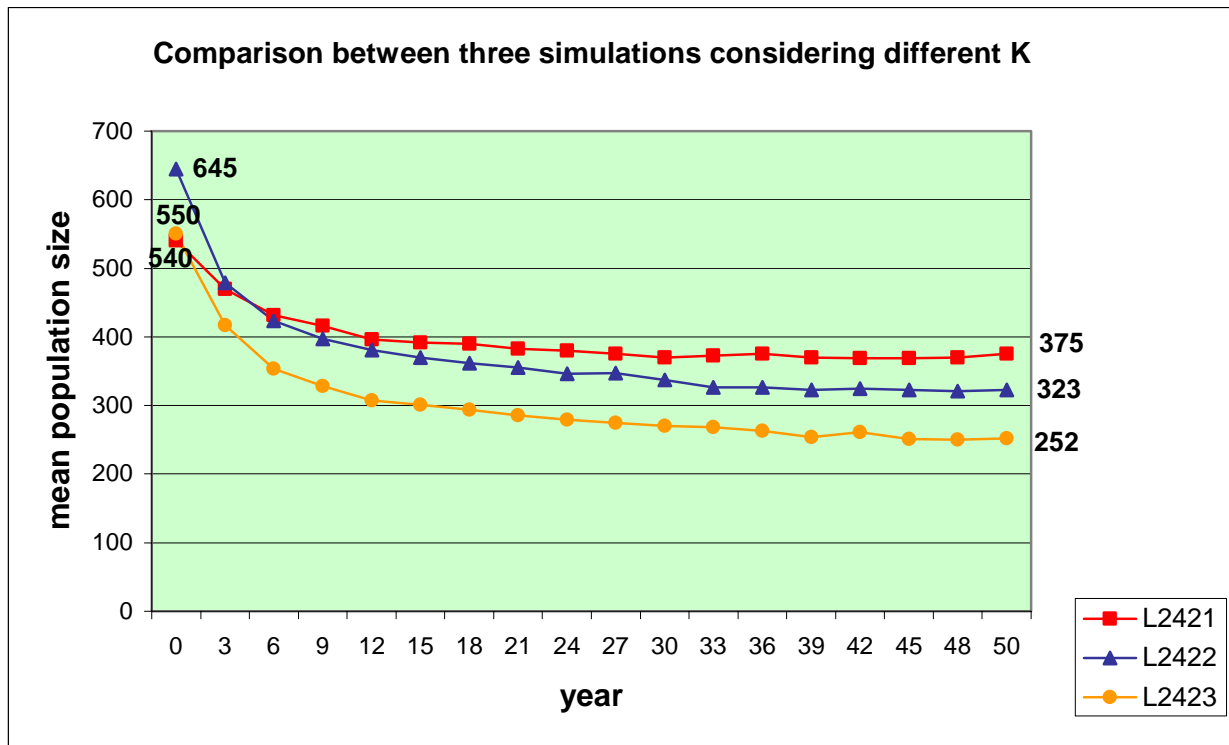


Fig. 9

The output scenarios of some variables were much more significant and had a major impact on viability than others. The most optimistic and most pessimistic simulations are compared in Fig. 10 Although we should consider these outputs as the results of two extreme hypothetical scenarios.

Most likely the scenarios given by codes L2311 and L2411 in Fig. 11 are the most realistic. These models consider cub natality calculated according to method 2 (code L2xxx, see text), bibliographic female adult mortality (code Lxx1x) and K1 as carrying capacity (code Lxxx1, see text). The two models differ in the cub mortality value which was calculated considering in both the interval 0 – 12 months but either males and females separately (code Lx3xx) or together (code Lx4xx).

Since PVA simulation models may include variables such as external forces that act on populations and have significant impact on viability we run the last two models (L1213 and L2421) with an additional harvest of 1 adult male resident in Tarangire National Park (Fig. 12). In this model the harvest effect on cubs has been considered as an induced “turnover” and 4 cubs have been subtracted to the population, 2 males and 2 females,

(Tab. 4, ratio at birth M : F ~ 1 : 1). Such value has been calculated as the mean of cubs under 18 months present per year within each pride. In fact, when an adult resident male is subtracted from his pride and a new one takes over, all the cubs under 18 months of age most probably will be killed by the incoming male.

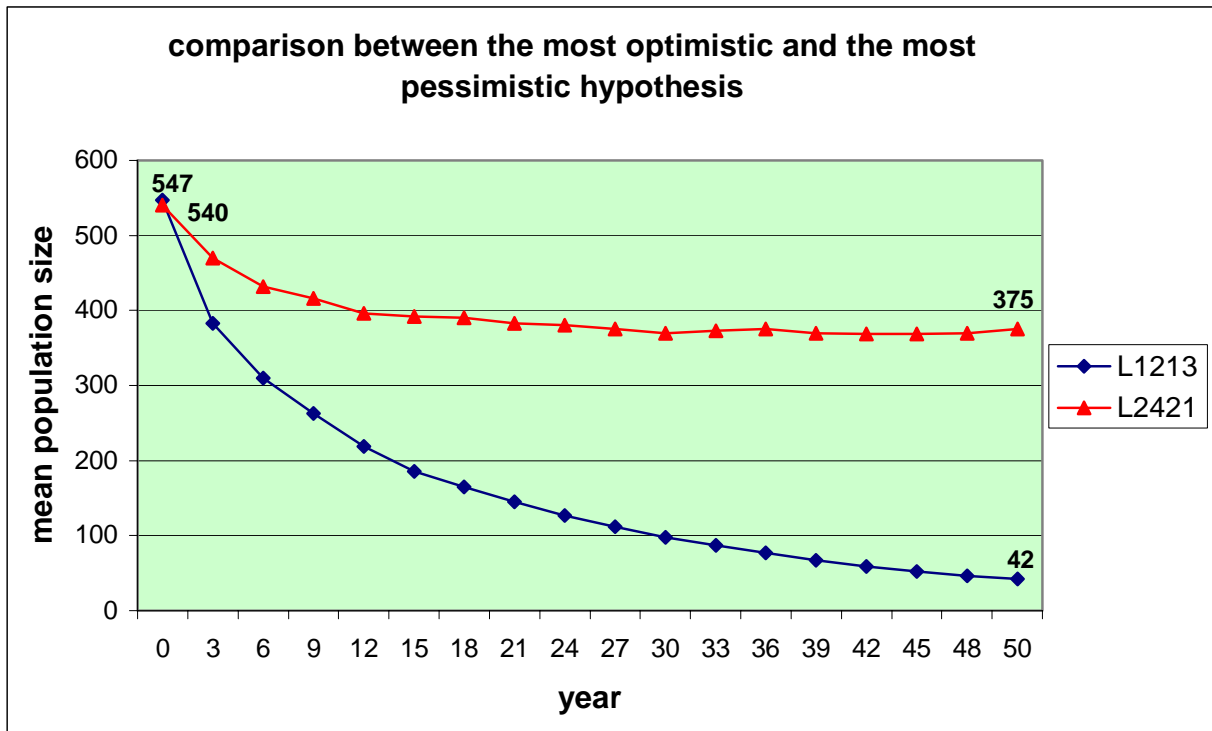


Fig. 10

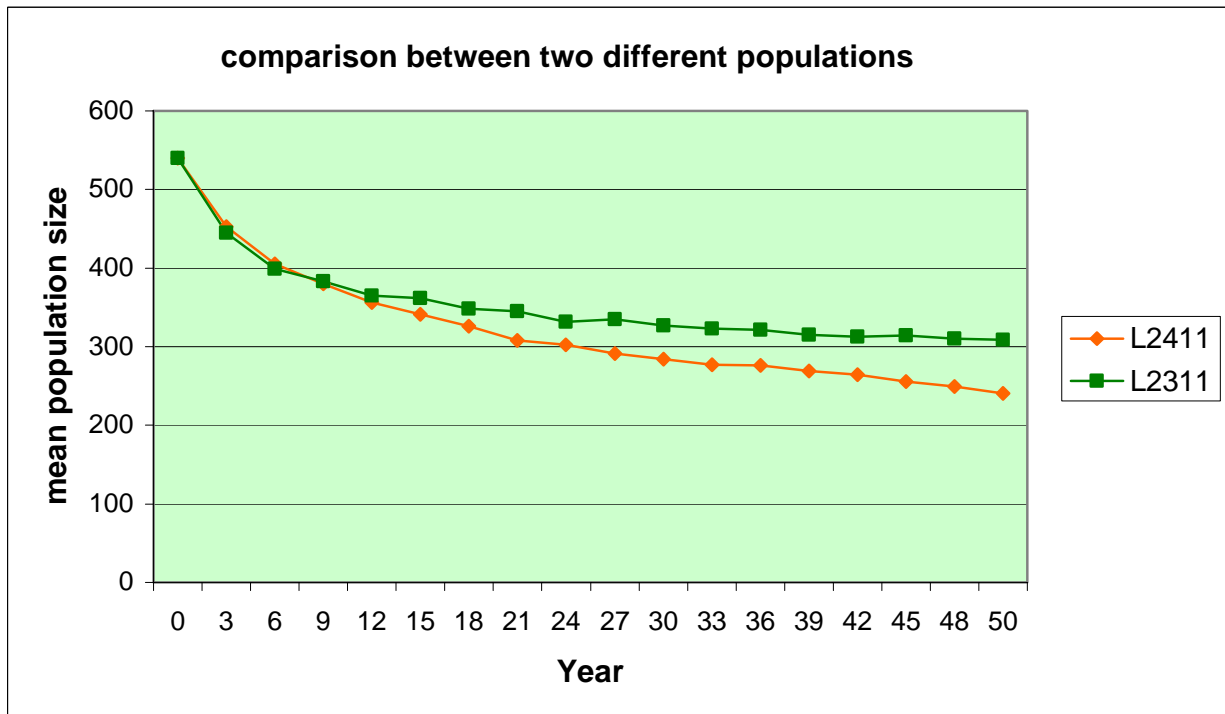


Fig. 11

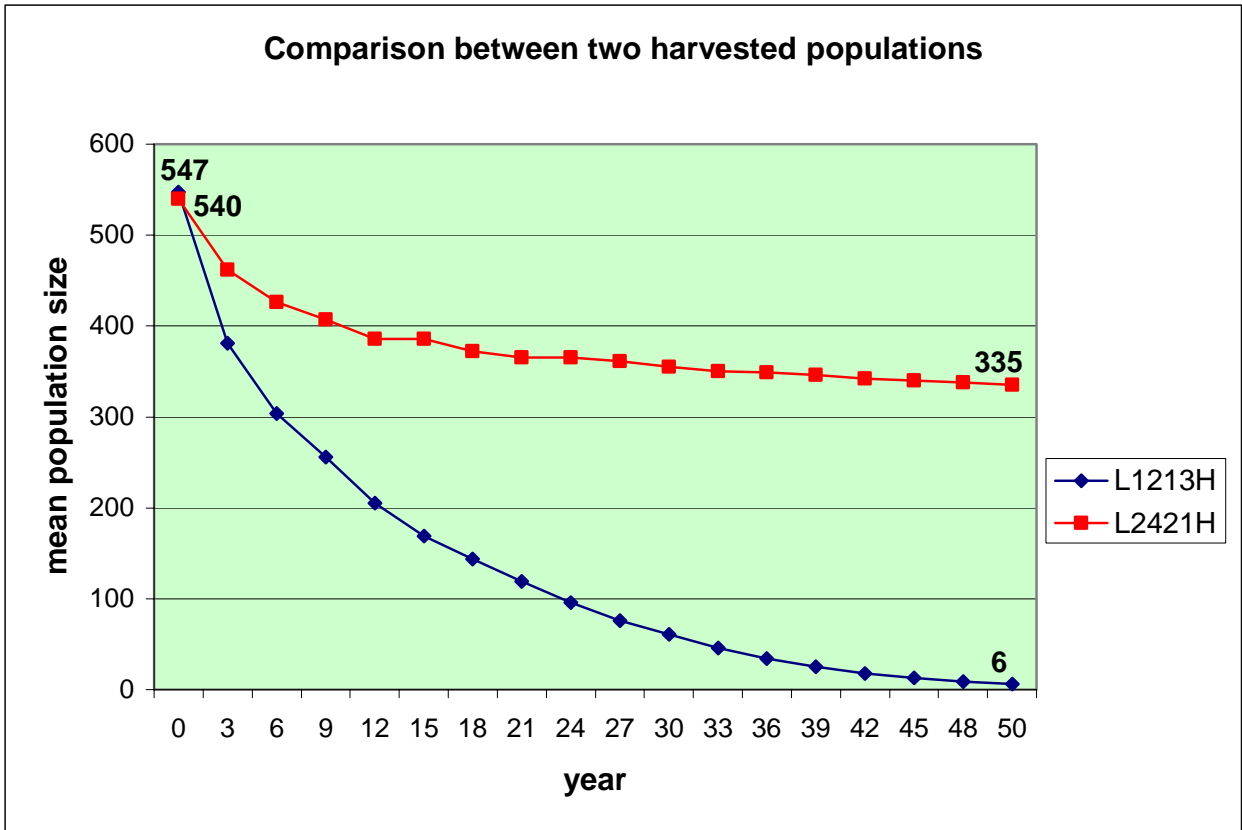


Fig 12

Conclusions

Comparing the ratio of adult males to adult females in Tarangire N.P as a mean of the five years of study (1 : 2,8) with the ratio found between 1998 and 2000 (1 : 3,34 TLP, 2000), the disproportion doesn't seem so relevant as it used to be. The results obtained after the first 3 years suggested that the number of males in Tarangire was far too low compared to the number of females, aspect which is not so evident after 5 years. However, we must consider the fact that our adult male sample is very small (10 - 12 adult males per year) and when a big coalition, such as the one of 5 males that moved from Silale to the North in the year 2002 (see text) turns to adult it has a significant impact on the overall sex ratio. It would be interesting to compare this male increase with the number of adult males harvested during the same period of time in order to verify whether less lions have been killed. Available hunting data give as the most significant year 1995 therefore it could be hypothesized that the lion population took several years to recover. Furthermore, previous studies have shown that sex ratio at birth is biased towards males as a signal of frequent turnover. This could easily be true in all those areas where hunting persists but in our case the results would suggest that sex ratio at birth is not affected. In fact, the mean between 1998 – 2002 of the sex ratio at birth Males : Females is almost 1: 1 (Tab. 7 and

Fig. 3). However according to our results 58.8% of cub mortality is most certainly a consequence of turnover within the first 12 months (4 males out of 8 and 6 females out of 9 died) and 54.5% if we consider 18 months instead (5 males out of 10 and 7 females out of 12 died). In these cases females with cubs were in fact sighted with new males at the same time of cub disappearance.

Although adult males are hardly ever seen within prides and are infrequently sighted, according to our data the mean length of pride tenure has been of 28 months (SD 15.8 months). Only 7 prides out of 11 have been sighted with adult males and just 1 pride has been sighted with adult males every year for the entire study period. In two cases pride tenure has been of 48 and 52 months long, in other two around 24 months (22 and 28) and in the last three less than 18 months (17, 13 and 16). Of the latter in one case we have observed a male coalition of 4 moving spontaneously from one pride (River) to another (Lodge) and what's most interesting is the fact that no other male has succeeded in the River pride for the following two years. An explanation could be related to the 1995 hunting season during which a very high number of adult males has been harvested and which probably made the number of males collapse within the population. This could explicate the fact that no males were around to get hold of a pride, as in the River case, and the long period of pride tenure observed in the Silale and Lodge prides. After the first years of data collection probably the number of males has increased, as it is confirmed by the sex-ratio, and consequently pride tenure has decreased and turnovers have been more frequent. In fact, the only prides in which cubs have grown to adults have been the ones with the longest tenure (Silale:52 months, Lodge:48

months and Kuro: 28 months) or in cases where the pride has been left by the male coalition (River: 13 months) but not replaced by new incomers for a couple of years that could have caused infanticide. In all other cases observed during the study period the entire litter has died.

Cub mortality seems to be very impacting in the output scenarios (see below) and, as the outcomes of the turnover process appear so relevant, it would be very important to verify its extent and effects on the long term.

The question remains: is the lion population of Tarangire National Park threatened? And if it is what are the external factors that affect its viability?

The PVA output scenarios show that the main trend is a remarkable decrease of the population showing that the population is significantly affected by one or more variables.

Earlier studies have shown that conservation of a species has to be looked more in depth. Conservation biology has emphasized that preservation of endangered species cannot be based only on protecting the species and their habitat. It also requires a very careful analysis of their needs and sometimes direct management to overcome the effects of threatening processes (Caughley and Gunn, 1996). It becomes therefore essential to identify all those processes that have a direct impact on the viability of the species in exam. It is necessary to recognize all the variables that have a significant effect on the long term in order to intervene where possible and minimize the effect. The PVA allows to do so. The model scenarios consent to find all the interacting factors that place a population or a species at risk. Some simulations stabilise under a certain level of the carrying capacity, probably because we have considered the actual population size as the maximum sustainable by the Tarangire ecosystem whilst others drop further down (Fig. 7). Though, carrying capacity doesn't have a great effect on the output scenarios (Fig. 9). The main interfering process on viability seems to be related to cub mortality (code Lx2xx in Figs 7, 8, 10 and 12) and to adult female mortality (code Lxx1x in Figs 7, 8, 10 and 12). The sample of cubs is probably still too low to have exact values on mortality especially if we consider the fact that they are kept hidden during the first couple of months and mortality rates are based only on direct observations and extrapolation from successive sightings. In both cases, whether cub mortality values were found considering males and females separately or together to increase the sample, the PVA evidenced a significant decrease especially in the second case (code Lx2xx, Figs 7, 8).

If we have a close look at the mean growth rate values of the different output scenarios it is positive in the most optimistic ($r = 0.0207$) and negative in the most pessimistic hypothesis ($r = -0.45$) as expected. However, if we assume that they are extreme outputs and analyse the growth rate values of the two most probable scenarios instead (Fig. 11) we get a positive value ($r = 0.0062$ in L2311) and a negative one ($r = -0.0033$ in L2411) underlining the worrying picture of Tarangire's lion population.

Female adult mortality has some effect too especially when it is combined, within the same model, with high cub mortality (code Lx2xx, see text). We had to use bibliographic data (Fig. 8, code Lxx1x) because without radiocollars it is very difficult to establish whether an adult individual has moved or died and we compared the same models choosing an arbitrary low value instead

(Fig.8, code Lxx2x.). In both cases the population drops however when the females' adult mortality was chosen to be very low, the decrease wasn't as outstanding. Comparing the output scenarios considering the same value of carrying capacity and cub mortality but different adult female mortalities, the population may drop from 547 individuals to 42 in the first case and from 547 to 104 in the second.

As cub mortality seems to be the limiting factor, the main question and objective for further studies will be focused on trying to verify whether it is related to frequent turnovers because of hunting or if there are other factors which could have a significant impact. Although other processes could be highly responsible (Tarangire has a very high elephant density, could these large pachyderms affect cub mortality ?) most probably cub mortality is a consequence of frequent turnovers due to hunting.

If we consider cub mortality in relation to what was observed in these 5 years of study, at least 50% can be attributed to turnovers. In fact, in several cases the disappearance of cubs coincided with the arrival of new adult males within a pride.

Although in Tarangire National Park hunting is not permitted it must be kept in mind that, due to the relatively narrow shape of the Park, lions can easily move outside the borders. Adding to both the most optimistic and pessimistic simulations shown in Fig. 10 an hypothetical harvest of 1 adult resident male per year (and 4 cubs, see text) for the next 50 years a particularly worrying scenario is evidenced especially in the second case. Of the 500 hypothetical populations 0 went extinct in the most optimistic analysis and 429 in the most pessimistic which gives a probability of extinction of 0 % and 85.8 % respectively. In both cases the mean population size decreases from 540 to 335 in the first and from 547 to 6 in the second.

The major issue in Tarangire is trying to find out where do animals move to when they are not seen for long periods of time. The very low percentage of animals that have been re-sighted every year during the entire study period (just 4.2% of the total, Tab. 2 and Fig. 6) suggests that the application of radiocollars is necessary for any further study. Furthermore, the very negative outputs obtained considering the harvest on adult males would recommend the application of radiocollars on males. This has to be taken in serious consideration because males patrol big areas and are much more mobile than females allowing the identification of the territories used within the park but, most important, would help us find whether they move outside the boundaries and into the hunting areas or masaaï land as well.

From these results it becomes necessary to continue the study in order to increase the size of the sample and be able to obtain more consistent results and eventually verify the sustainability of the hunting quotas allocated. (Caro *et. Al.* 1998). In August 2003 the Tarangire Lion Project will put 6 radiocollars to facilitate

the collection of data regarding population structure, cubs and adult mortality and population density. The main factors which have an impact on the lion population in Tarangire National Park have been hypothesised but it is necessary to enlarge the sample and improve the PVA models to obtain more reliable output scenarios.

Since the risks faced by the lions of Tarangire are not yet entirely known it is extremely important to continue the data collection which will be essential in choosing the correct management plan for the conservation of the species.

Appendix A Vortex input data form

LEO1111.IN ***Output Filename***

Graphing Files?

N ***Details each Iteration?***

500 ***Simulations***

50 ***Years***

3 ***Reporting Interval***

0 ***Definition of Extinction***

1 ***Populations***

N ***Inbreeding Depression?***

Y ***EV concordance between repro and surv?***

0 ***Types Of Catastrophes***

P *Monogamous, Polygynous, or Hermaphroditic***

4 ***Female Breeding Age***

4 ***Male Breeding Age***

14 ***Maximum Breeding Age***

51.660000 ***Sex Ratio (percent males)***

4 ***Maximum Litter Size (0 = normal distribution) *****

N ***Density Dependent Breeding?***

Pop1

28.47 **breeding

10.25 **EV-breeding

32.670000 ***Pop1: Percent Litter Size 1***

41.720000 ***Pop1: Percent Litter Size 2***

18.940000 ***Pop1: Percent Litter Size 3***

48.570000 *FMort age 0

20.000000 ***EV

23.840000 *FMort age 1

LEO2222.IN ***Output Filename***

Y ***Graphing Files?***

N ***Details each Iteration?***

500 ***Simulations***

50 ***Years***

3 ***Reporting Interval***

0 ***Definition of Extinction***

1 ***Populations***

N ***Inbreeding Depression?***

Y **EV concordance between repro and surv?***

0 ***Types Of Catastrophes***

P *Monogamous, Polygynous, or Hermaphroditic*

4 ***Female Breeding Age***

4 ***Male Breeding Age***

14 ***Maximum Breeding Age***

51.660000 ***Sex Ratio (percent males)***

4 *Maximum Litter Size (0 = normal distrib.) *

N ***Density Dependent Breeding?***

Pop1

31.16 **breeding

11.00 **EV-breeding

34.750000 ***Pop1: Percent Litter Size 1***

35.220000 ***Pop1: Percent Litter Size 2***

22.150000 ***Pop1: Percent Litter Size 3***

51.300000 *FMort age 0

20.000000 ***EV

27.610000 *FMort age 1

3.000000 ***EV
 13.130000 *FMort age 2
 3.000000 ***EV
 18.640000 *FMort age 3
 3.000000 ***EV
 4.500000 *Adult FMort
 3.000000 ***EV
 33.330000 *MMort age 0
 20.000000 ***EV
 33.520000 *MMort age 1
 3.000000 ***EV
 21.490000 *MMort age 2
 3.000000 ***EV
 6.250000 *MMort age 3
 3.000000 ***EV
 20.900000 *Adult MMort
 14.090000 ***EV
 N ***All Males Breeders?***
 Y ***Answer--A--Known?***
 84.380000 ***Percent Males In Breeding Pool***
 N ***Start At Stable Age Distribution?***
 30 ***Initial Females Age 1***
 51 ***Initial Females Age 2***
 32 ***Initial Females Age 3***
 40 ***Initial Females Age 4***
 28 ***Initial Females Age 5***
 21 ***Initial Females Age 6***
 25 ***Initial Females Age 7***
 29 ***Initial Females Age 8***

3.000000 ***EV
 16.790000 *FMort age 2
 3.000000 ***EV
 14.090000 *FMort age 3
 3.000000 ***EV
 0.500000 *Adult FMort
 0.025000 ***EV
 51.300000 *MMort age 0
 20.000000 ***EV
 27.610000 *MMort age 1
 3.000000 ***EV
 16.790000 *MMort age 2
 3.000000 ***EV
 14.090000 *MMort age 3
 3.000000 ***EV
 20.900000 *Adult MMort
 14.090000 ***EV
 N ***All Males Breeders?***
 Y ***Answer--A--Known?***
 84.380000 Percent Males In Breeding Pool
 N ***Start At Stable Age Distribution?***
 30 ***Initial Females Age 1***
 51 ***Initial Females Age 2***
 32 ***Initial Females Age 3***
 40 ***Initial Females Age 4***
 28 ***Initial Females Age 5***
 21 ***Initial Females Age 6***
 25 ***Initial Females Age 7***
 29 ***Initial Females Age 8***

34 ***Initial Females Age 9***
26 ***Initial Females Age 10***
14 ***Initial Females Age 11***
6 ***Initial Females Age 12***
6 ***Initial Females Age 13***
1 ***Initial Females Age 14***
35 ***Initial Males Age 1***
34 ***Initial Males Age 2***
32 ***Initial Males Age 3***
28 ***Initial Males Age 4***
16 ***Initial Males Age 5***
12 ***Initial Males Age 6***
5 ***Initial Males Age 7***
9 ***Initial Males Age 8***
13 ***Initial Males Age 9***
8 ***Initial Males Age 10***
3 ***Initial Males Age 11***
0 ***Initial Males Age 12***
0 ***Initial Males Age 13***
0 ***Initial Males Age 14***
547 ***K***
143.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***

34 ***Initial Females Age 9***
26 ***Initial Females Age 10***
14 ***Initial Females Age 11***
6 ***Initial Females Age 12***
6 ***Initial Females Age 13***
1 ***Initial Females Age 14***
35 ***Initial Males Age 1***
34 ***Initial Males Age 2***
32 ***Initial Males Age 3***
28 ***Initial Males Age 4***
16 ***Initial Males Age 5***
12 ***Initial Males Age 6***
5 ***Initial Males Age 7***
9 ***Initial Males Age 8***
13 ***Initial Males Age 9***
8 ***Initial Males Age 10***
3 ***Initial Males Age 11***
0 ***Initial Males Age 12***
0 ***Initial Males Age 13***
0 ***Initial Males Age 14***
645 ***K***
161.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***

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