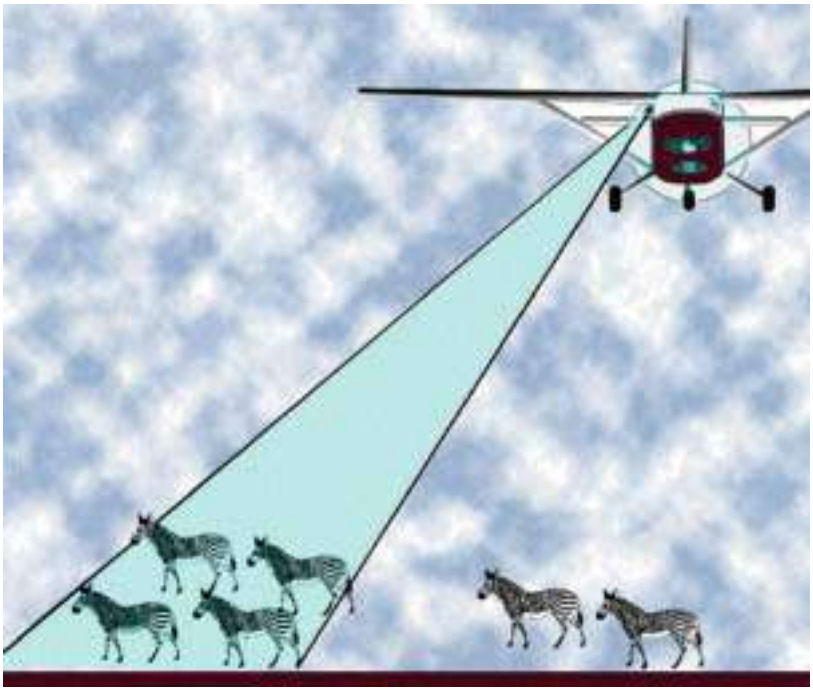
AERIAL CENSUS IN TARANGIRE-MANYARA ECOSYSTEM, TANZANIA

Dry Season 2016

Systematic Reconnaissance Flight (SRF) Census Report

Aerial Census in Tarangire-Manyara Ecosystem, Dry Season 2016



Conducted by

TANZANIA WILDLIFE RESEARCH INSTITUTE

CONSERVATION INFORMATION AND MONITORING UNIT

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COLLABORATION

The successful implementation of the Tarangire-Manyara Ecosystem Aerial Survey was a product of thorough planning, hard work, and good collaboration between government and non-governmental partners. The following partner institutions collaborated with TAWIRI for the successful implementation of this census:

WILDLIFE DIVISION
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Wildlife Division works to conserve, manage and develop wildlife and wetlands resources, and fosters sustainable utilization that will contribute towards poverty reduction.

TANZANIA NATIONAL PARKS
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Tanzania National Parks (TANAPA) was created in 1959 to manage and regulate the use of areas designated as National Parks.

NGORONGORO CONSERVATION AREA AUTHORITY
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Ngorongoro Conservation Area Authority (NCAA) cooperates with NCA indigenous residents to conserve the natural and historical resources of this World Heritage Site while providing optimal social services to residents, staff and visitors.

This report is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of TAWIRI in partnership with The Nature Conservancy, the Wildlife Conservation Society, and NTRI partners and do not necessarily reflect the views of USAID or the United States Government.

EXECUTIVE SUMMARY

A Systematic Reconnaissance Flight (SRF) survey was conducted in the Tarangire-Manyara ecosystem during the dry season from 27th October to 7th November 2016. The main objective of the census was to establish the population status and geographical distribution of large animals within the ecosystem. TAWIRI in collaboration with the Wildlife Division (WD), Tanzania National Parks (TANAPA), Ngorongoro Conservation Area Authority (NCAA) and the Wildlife Conservation Society (WCS) conducted this survey. The census zone covered an area of 16,521 km with 190 transects, with three aircraft flying at an average height of 339 feet above ground and an average speed of 171 km/h. An average transect strip width of 291 meters was maintained for the entire census zone.
A total of twenty-nine wildlife species were counted in this census. The most abundant species were zebra (21,709 ±2,844) followed by wildebeest (13,603 ±3,381) and impala (5,721±687). Seven species showed a stable population trend compared to 2011 using a d-test (values < 1.96 not significantly different from previous survey): wildebeest (*d*=0.20), zebra (d=1.03), impala (*d*=0.99), kongoni (*d*=1.2), Grant's gazelle (*d*=-0.02) and ostrich (*d*=0.24). Several species showed an increasing population trend: eland (d=2.28), giraffe (*d*=4.68), Thomson's gazelle (*d*=4.00), Bohor reedbuck (*d*=3.16), warthog (*d*=2.18), and greater kudu (*d*=3,98). Other species that were counted during this census were buffalo and elephant, but the 2014 total count estimates for those two species are considered more accurate estimates.

Major human activities include cattle with an estimate of 331,013 ±25,504, shoats (sheep and goats) with an estimate of 228,360 ±18,728 and donkeys with an estimate of 4,393 ±703. All livestock show a strongly increasing population trend, doubling from the previous estimate in 2011.

RECOMMENDATIONS

Based on our findings we recommend the following:

- To conduct a study that addresses the influence of land use changes, especially settlements, livestock keeping and agriculture on wildlife numbers and distribution.
- Ground counts are encouraged in Manyara National Park due to difficulties in conducting SRF counts over the forest and escarpment.
- Carnivores, small mammals and primates require specially-designed ground censuses in order to establish their relative abundance.

- The ecosystem used to be a stronghold of species such as gerenuk and oryx. The current population is reduced and restricted to small area within the ecosystem. Consequently, the SRF technique is no longer an appropriate method to enumerate these species, and ground methods should be employed instead.
- In order to protect wildlife outside designated protected areas (dispersal and corridor areas) there is a need to encourage local communities in participatory conservation though strengthening existing Wildlife Management Areas (WMAs).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

The Tarangire-Manyara ecosystem located in northern Tanzania (Figure 1) is among the key areas for conservation of Cape buffalo (*Syncerus cafer*), African elephant (*Loxodonta africana*) and other wildlife species in Tanzania. The ecosystem covers 16,521 km of which more than 60% is outside the core-protected areas (National Parks and Game Reserves). The Tarangire-Manyara ecosystem includes Tarangire and Lake Manyara National Parks, Mkungunero Game Reserve, Simanjiro, Mto wa Mbu and Lolkisale Game Controlled Areas, Burunge, Randilen and Makame Wildlife Management Areas and wildlife corridors of Kwakuchinja, Kibaoni and Manyara Ranch.

Aerial wildlife censuses have been carried out in the ecosystem since 1987 using two methods, Systematic Reconnaissance Flight (SRF) and Total Counts (TC). Total counts in this ecosystem are done only for elephant and buffalo, the last being conducted in 2014 (TAWIRI 2015). For other large mammals the SRF is applied, and the last census was conducted in the dry season of 2011.

1.2 Survey Objectives

The objectives of the aerial wildlife census in the Tarangire-Manyara ecosystem were: (i) to determine the population status of large mammals, (ii) to map their distribution patterns and densities, (iii) to derive their population trends, (iv) to assess abundance and distribution of major human activities, and (v) to document the census data and results in the centralized wildlife database (SISTA) at TAWIRI which allows comparison between current and previous censuses.

The most recent previous SRF census was conducted in the dry season of 2011 (Table 1).

Table 1: Wildlife Surveys in the Tarangire-Manyara Ecosystem 1987-date

Year	Season	Technique	Survey coverage	Area (km²)	Source
1987	Dry	SRF	Tarangire-Manyara Ecosystem	12,150	Campbell (1987)
1988	Wet	SRF	Tarangire-Manyara Ecosystem	11,495	Campbell (1988)
1990	Dry	SRF	Tarangire Ecosystem (Excluding LMNP*)	8,359	TWCM (1991)
1994	Wet	SRF	Tarangire Ecosystem (Excluding LMNP)	12,826	TWCM (1994)
1994	Wet	SRF	Tarangire Ecosystem (Excluding LMNP)	12,389	TWCM (1994)
1995	Dry	TC	Tarangire-Manyara Ecosystem	12,000	TWCM (1995)
1996	Wet	TC	Tarangire Ecosystem (Excluding LMNP)	8,000	TCP (1997)
1997	Wet	SRF	Tarangire-Manyara Ecosystem	12,987	TWCM (1999)
1998	Wet	TC	Tarangire-Manyara Ecosystem	12,000	TWCM (1998)
1999	Dry	SRF	Tarangire Ecosystem (Excluding LMNP)	8,385	TWCM (2000)
2000	Dry	TC	Tarangire-Manyara Ecosystem	9,500	TWCM (2000)
2001	Wet	SRF	Tarangire-Manyara Ecosystem	12,000	TAWIRI (2004)
2001	Wet	TC	Tarangire-Manyara Ecosystem	12,612	TAWIRI (2004)
2004	Dry	TC	Tarangire-Manyara Ecosystem	12,000	TAWIRI (2004)
2004	Dry	SRF	Tarangire-Manyara Ecosystem	12,972	TAWIRI (2004)
2006	Dry	TC	Tarangire-Manyara Ecosystem	12,766	TAWIRI (2006)
2007	Dry	SRF	Tarangire-Manyara Ecosystem	12,971	TAWIRI (2007)
2009	Dry	TC	Tarangire-Manyara Ecosystem	12,958	TAWIRI (2009)
2011	Dry	SRF	Tarangire-Manyara Ecosystem	12,958	TAWIRI (2011)
2014	Dry	TC	Tarangire-Manyara Ecosystem	16,135	TAWIRI (2015)
2016	Dry	SRF	Tarangire-Manyara Ecosystem	16,521	TAWIRI (2016)

*LMNP = Lake Manyara National Park

1.3 Survey area

1.3.1 Location

The Tarangire-Manyara census conducted in 2016 covered a total area of 16,521km . The ecosystem lies in northern Tanzania between 3° 22' 00" to 5° 12' 20" South and 35° 40' 53" to 37° 5' 22" East (Figure 1).

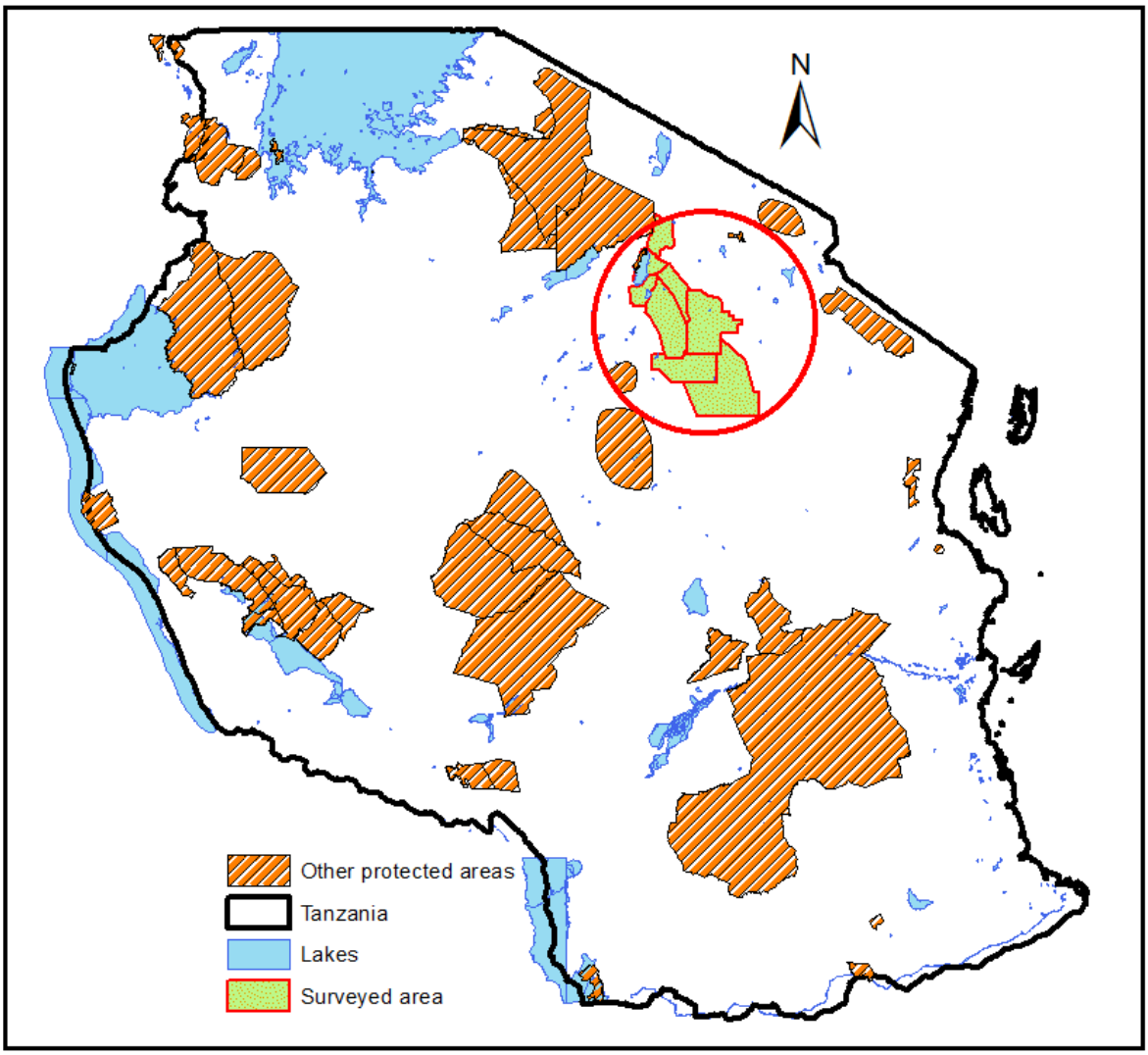

Figure 1: Location of Tarangire-Manyara ecosystem in relation to other protected areas in Tanzania

1.3.2 Administrative Areas of the Tarangire-Manyara Ecosystem

Administrative areas covered by this survey include Tarangire and Lake Manyara National Parks, Mkungunero Game Reserve, Lolkisale Game Controlled Area (and Randilen WMA), Simanjiro plains, Mto wa Mbu, Kwakuchinja Open Area, Kibaoni Open Area, Burunge WMA and Manyara Ranch, and Outside south (Makame WMA). The relative area covered by these administrative areas is shown in Table 2 and Figure 2.

Table 2: Surveyed areas of Tarangire-Manyara ecosystem

Admin block	Area (km²)
Burunge WMA	618
Kibaoni	156
Kwa Kuchinja	488
Lake Manyara NP	58
Lolkisale	1,068
Makame WMA	4,348
Mkungunero	1,507
Mto wa Mbu	982
Out west	103
Outside South	866
Simanjiro	3,545
Tarangire NP	2,783

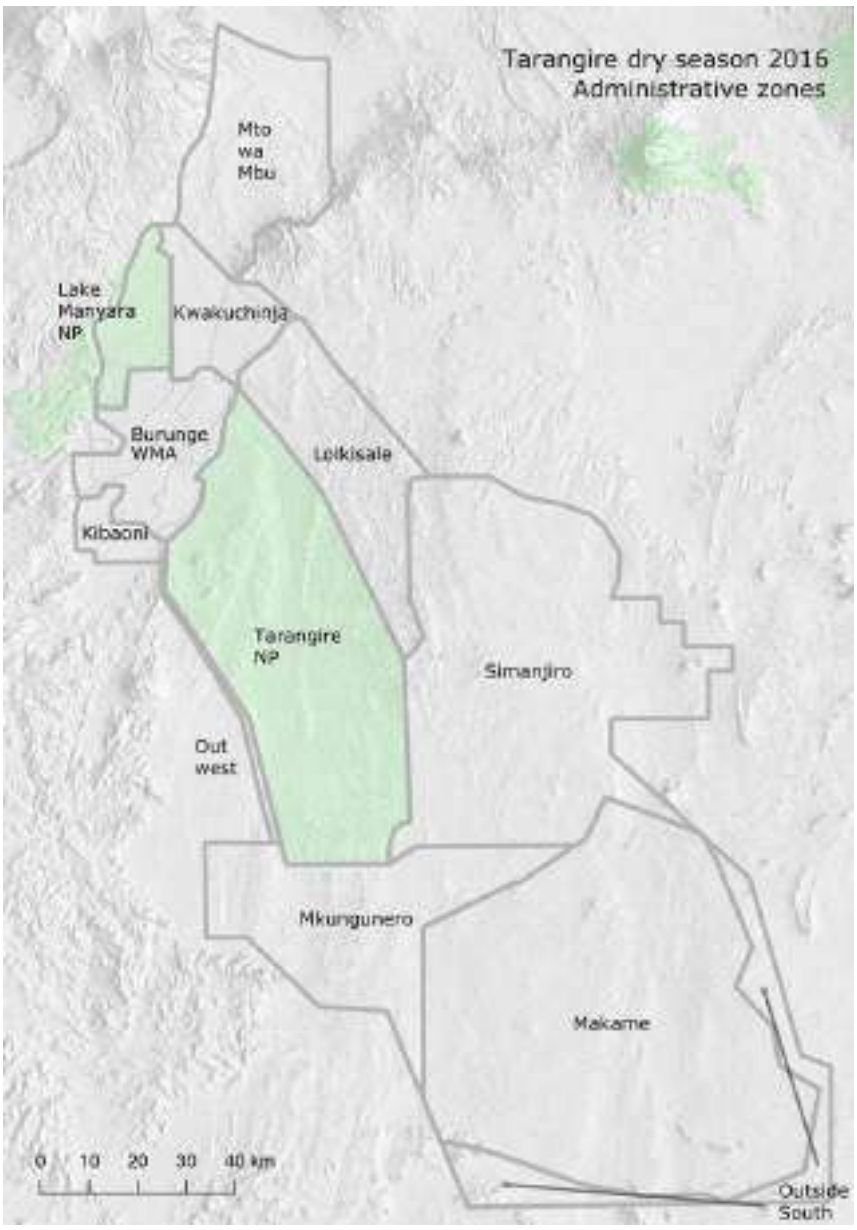

Figure 2: Administrative areas in the Tarangire-Manyara ecosystem.

1.3.3 Climate

The average rainfall in Tarangire-Manyara ecosystem is approximately 600-650 mm per year (Galanti *et al*, 2000), and the area is lying just within the arid climatic zone (Pratt & Gwynne, 1997). Monthly figures show that March and April are the wettest months, and June to October is very dry, often with no rain. The rainy season can be divided into two periods, with the short rains falling from November to February, and the long rains from March to May.

1.3.4 Vegetation

The ecosystem has a relatively rich floristic diversity, consisting mainly of *Combretum-Dalbergia* and *Acacia-Commiphora* woodlands, grasslands, and flood-plains (Lamprey, 1963), and *Acacia-Themeda* wooded grassland (Peterson, 1978). In the arid lowlands (1000 m above sea level) there are small moist enclaves in a generally dry environment (ground water forest near Lake Manyara and some areas bordering Tarangire River), that are covered by extended grasslands where drainage is poor owing to volcanic ash, and by bush thickets and *Acacia* woodlands. Dominant grass species include *Sporobolus spicatus, robustus, marginatus, Cyperus laevigatus, Themeda triandra, Panicum* sp., *Hyparrhenia* sp., *Digitaria* sp., and *Pennisetum* sp. (Pratt & Gwynne, 1977).

1.3.5 Socio-economic status

The traditional pastoral Maasai and Waarusha people traditionally co-existed relatively peacefully with wildlife. However, over the last 25 years there has been a major immigration of other groups, mainly non-pastoralists, into the area (TCP, 1997). Traditionally, agriculture was subsistence-based, but now also includes market-driven production. Large-scale farms, mainly for seed-bean export, were started in 1971 in Lolkisale (Borner, 1985). The highest rate of agriculture expansion occurred in the 1980's (Davison, 1991). The boom in agriculture would suggest that the area is well-suited to farming, but the area's low and erratic rainfall, high temperatures, and infertile soil indicate that it is only marginally suited for agriculture (Davison, 1991).

2 METHODS

The aerial census was conducted following the systematic reconnaissance flight (SRF) technique as described by Norton-Griffiths (Norton-Griffiths 1978), and a smaller area of total count (TC) in Lake Manyara National Park where transect flying is inappropriate due to the narrowness of the block and terrain (Norton-Griffiths 1978). Three aircrafts (5H-TPK, 5H-TPM and 5H-MPK) were flying at a target height of 350 ft. (~109m) above ground and a target ground speed of 180 km/h.

SRF is a sample method, based on sampling narrow strips along transects (long flight lines), where the average density of each species in the samples is then multiplied by the total area to produce an estimate for the total survey area. The method depends on the samples being representative of the whole population – not that the animals themselves are evenly distributed, but that the samples are allocated without reference to the distribution of animals; in the case of SRF, the samples are allocated systematically according to a predefined map. More information on method is provided in Appendix 7. Total counts rely on searching and enumerating all target species in a survey area. It is appropriate for a limited set of highly-visible species and small areas that can be counted in a single flight session.

Normally only buffalo and elephant are counted in total counts (highly visible and aggregated species), but other species (impala size and larger) were also counted due to the small sample block size; however, it is likely that these smaller species were undercounted in the Manyara block.

2.1 Transect design and flight plan

Transects were spaced at 2.5km and 5km intervals with variable orientations due to the nature of terrain, ecological gradient and aiming at maximizing number of samples (Figure 3). Transects were *a priori* evenly subdivided into subunits between 2.1 and 2.5 km in length (typically around 40 seconds of flying time) and uploaded onto GPS units. Geo-referencing of aircraft on transect was determined by GPS (Garmin 60Csx or 296).

An aerial total count method was used over the escarpment in the Lake Manyara National Park.

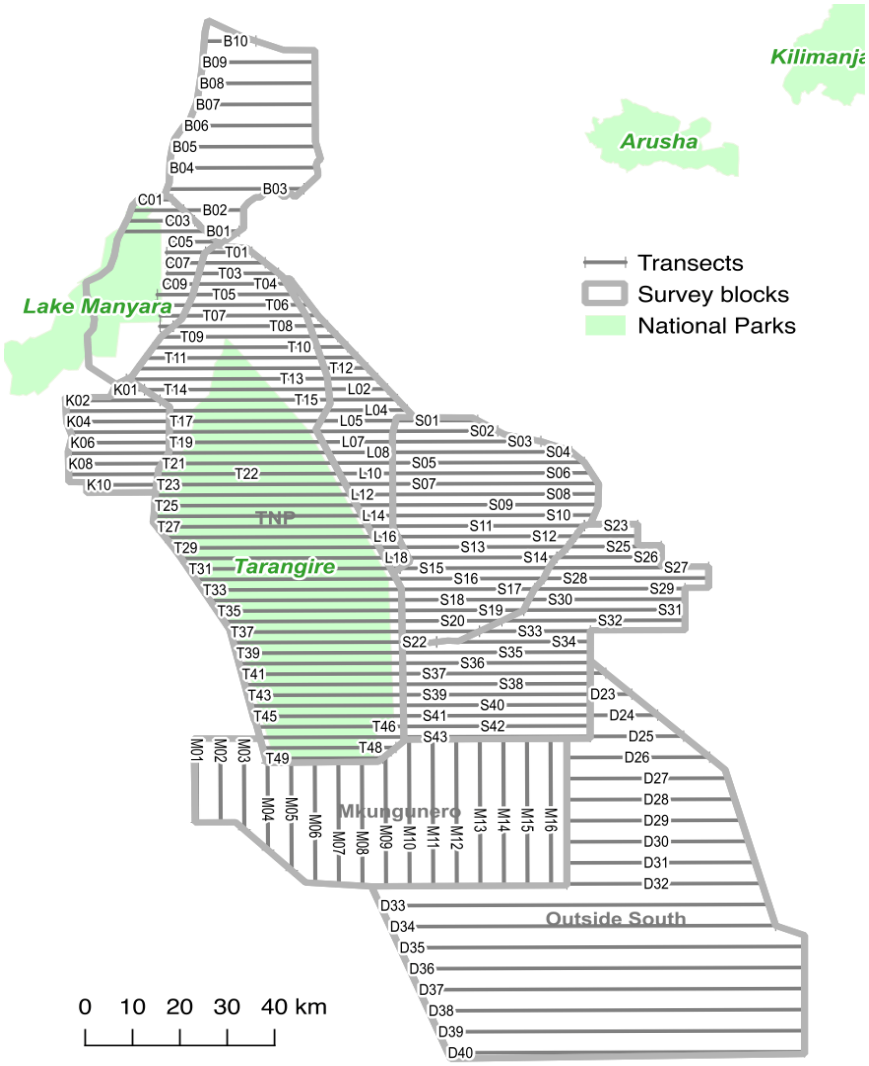

Figure 3: Map of Tarangire-Manyara Ecosystem showing planned transects

2.2 Data Collection

The survey crew consisted of four individuals in each aircraft (Appendix 1). The pilot navigated the aircraft following a survey plan that was loaded into the GPS prior to the flight. **Front Seat Observer (FSO)** was responsible for the inflight recording of transect metadata including the beginning and end points of each transect, the beginning and end time of each transect, flight height above ground using a radar or laser altimeter in each subunit, predominant vegetation, presence or absence of water and extent of burnt areas. The FSO also announced the subunit identification numbers to the rear seat observers.

Left and right **Rear Seat Observers (RSOs)** counted and recorded on digital recorders all observations of animals and human activities sighted in each sub-unit. Photos were taken of large groups with more than ten individuals. The RSOs transcribed recorded data on to data-sheets after each flight session. Counting was confined within a sample area defined by streamers attached on the wing strut on each side of the aircraft with a target width of 150m on the ground. Geographical position of every subunit as called-out by the FSO was recorded together with its observations and subsequently transcribed on data sheets.

For the total count area, a single session with two RSOs, FSO (recorder) and pilot was flown, counting all species above impala size, with the FSO marking all observations on a GPS and datasheet.

2.3 Track Log and Parameters

A total area of 16,521km^2 was covered by 190 transects as shown in Table 3. On average, all aircrafts flew at 339 ft. above ground at average speed of 171 km/h. The transect strip width was maintained at 291m on average for the entire census zone. A track log was maintained for each session flown by each aircraft (

Figure 4). The majority of transects were flown in an east-west direction, but Mkungunero Block was flown north-south. The Lake Manyara National Park escarpment was flown as a total count due to the terrain being too difficult for SRF (

Figure 4). One transect was omitted on the last day in the southern block as the aircraft exceeded its endurance; this has little effect on estimates.

Table 3: Parameters

Parameters	5H-TPM	5H-MPK	5H-TPK	COMBINED
Survey area (km²)	9,812	982	5,727	16,521
Sample Areas (km²)	1,002	52	442	1,495
Transect distance	3,227	192	1,828	5,247
Total number of transects	102	9	79	190
Total number of subunits	1,342	84	768	2,194
Sample Fraction %	10.20%	5.30%	7.70%	9.10%
Flying height:				
Mean	343	321	333	339
Standard Deviation	55	79	34	51
Minimum	130	190	184	130
Maximum	848	510	423	848
Strip width				
Left	153	129	134	
Right	153	129	134	
Total	306	257	267	291
Ground speed (km/h)	163	201	179	171

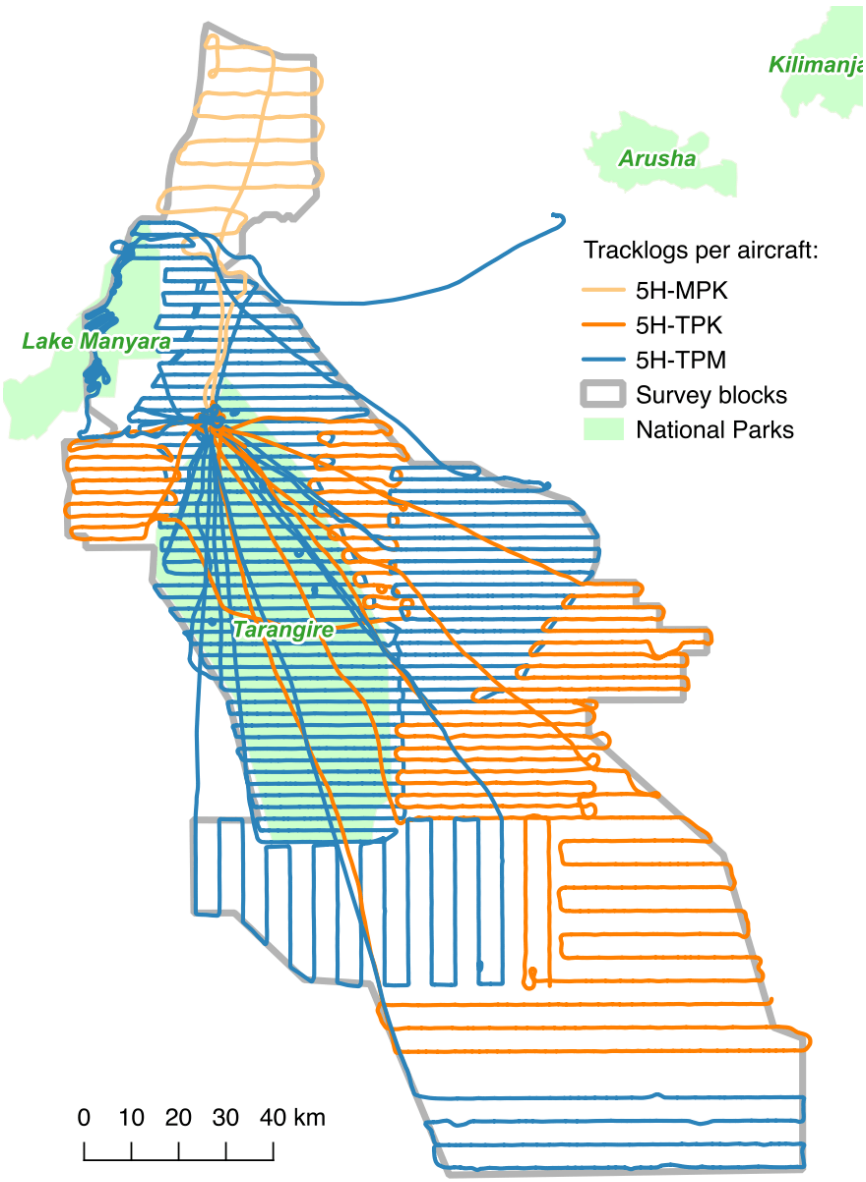

Figure 4: Map showing flight logs in the Tarangire - Manyara ecosystem, dry season 2016

2.4 Data analysis

Collected data were analysed using Jolly's unequal sample size method 2 (Jolly, 1969; Norton-Griffith, 1978) to calculate the population estimates with a script in R. Population trends were generated and *d*-test was used to determine whether the change was significant (Cochran, 1954). Species densities and distribution as well as human activities were mapped using the QGIS 2.14 software.

3 RESULTS

3.1 Wildlife estimates for the Tarangire-Manyara ecosystem

Twenty-nine wildlife species were recorded in the surveyed area of which the estimates are presented in Table 4. The most abundant species include zebra (21,709 ±2,844), followed by wildebeest (13,603 ±3,381) and impala (5,721 ±687). Population estimates of buffalo and elephant are presented in Table 4 in *grey italics* but the 2014 total count data are more reliable for these species; estimates for species with fewer than 10 observations (and correspondingly low accuracy) are also in *grey italics* in the following Table 4. Statistics in Table 4 include number of individuals observed per species (N. obs), the extrapolated estimate (Est), and a measure of variability (standard error, SE). The total count (TC) method only reports the estimate (absolute number counted), and the total estimate (ecosystem-wide) figure is a combination of the SRF and TC figures.

Table 4: Wildlife estimates in the Tarangire-Manyara ecosystem

	SRF				TC	Total
Species	No. obs	Count	Est.	±SE	Obs.	Est.
Baboon	5	80	*635*	*384*		
Buffalo	35	2,377	**19,225**	7,065		
Bush pig	7	16	*275*	*106*		
Bushbuck	5	8	*98*	*40*		
Duiker spp	26	37	**493**	197		
Elephant	40	919	**7,882**	1,237	66	*7,948*
El. carcass 2*	20	25	**220**	46		
El. carcass 3*	8	8	*87*	*31*	3	*90*
El. carcass 4*	15	18	**165**	40		
Eland	45	279	**2,543**	438		
Gerenuk	4	5	*50*	25		
Giraffe	99	371	**3,904**	507	31	*3,935*
Grants Gazelle	40	452	**4,307**	712		
Hippopotamus					**8**	**8**
Impala	79	630	**5,721**	687		
Kongoni	35	212	**1,731**	381		
Kudu, greater	22	47	**645**	157		
Kudu, lesser	2	3	*24*	*17*		
Kudu spp (aggregate)	24	50	**669**	158		
Oryx	1	2	*17*	*16*		
Ostrich	58	155	**1,413**	194	8	*1,421*
Reedbuck	16	47	**382**	115		
Steenbok	8	81	*914*	*594*		
Thomson's gazelle	33	209	**1,974**	394		
Vervet monkey	3	17	*179*	*99*		
Warthogs	35	106	**1,039**	203		
Waterbuck	15	82	**710**	391	3	*713*
Wildebeest	33	1,629	**13,603**	3,381	368	*13,971*
Zebra	74	2,625	**21,709**	2,844	245	*21,954*

Columns indicate number of individual observations (N. obs), individuals counted (count), estimated numbers (Est.), and standard error (±SE). Data include Lake Manyara block total count.
* Elephant carcasses are categorised according to four stages, as per Douglas-Hamilton & Hillman (1991): 1 – fresh, body intact with rounded appearance or still with rot patch; 2 – recent, body decayed but skeleton not scattered, rot patch dried; 3 – rot patch regrown, white bones and skull visible; 4 – bones widely scattered and decayed, often only the skull visible.

3.2 Wildlife Estimates Per Administrative Area

Population estimates for each individual species per administrative area has been generated and presented in Table 5. The zebra was the most abundant species in the surveyed area, with the largest number observed in Tarangire National Park (14,206 ±2,477), followed by Lolkisale (2,093 ±868) and the Simanjiro (2,041 ±756). Wildebeest was the second most numerous species in Tarangire-Manyara ecosystem; the highest estimate was recorded in Tarangire National Park (9,140 ±2,919) followed by Simanjiro with an estimate of (1,557 ±1,488), Kwakuchinja (926±616) and Burunge WMA (630 ±357). Impala was the third highest observed species recorded in the surveyed area, with again, the largest estimate recorded in Tarangire National Park (1,844 ±452), followed by the Simanjiro with an estimate of (1,808±339) and Mto wa Mbu with an estimate of (794 ±211), Table 5.

Table 5: Wildlife estimates per administrative area

	Burunge WMA				Kibaoni				Kwa Kuchinja				Lolkisale				Makame WMA				Mkungunero			
Species	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE
Baboon									1	5	**40**	39												
Buffalo	1	1	**9**	8													1	8	**144**	143				
Bush pig																	5	13	**234**	100	1	2	**33**	34
Bushbuck																								
Duiker spp	1	1	**9**	9					2	3	**24**	15	2	2	**18**	11	5	6	**108**	43	2	2	**33**	22
Elephant	2	25	**216**	197					2	31	**250**	197	7	104	**922**	436	1	41	**739**	731				
El. carcass 2									1	1	**8**	7					2	2	**36**	24				
El. carcass 3																	2	2	**36**	25				
El. carcass 4	1	1	**9**	8													1	1	**18**	18				
Eland	1	17	**147**	145					1	1	**8**	7	1	2	**18**	16	9	26	**469**	180				
Gerenuk																					1	1	**16**	17
Giraffe	4	10	**86**	51					6	34	**274**	113	17	38	**337**	84	12	48	**857**	307	1	2	**33**	31
Grants Gazelle									2	33	**266**	222	1	1	**9**	8	2	9	**162**	143	2	5	**82**	63
Hippopotamus																								
Impala	2	16	**138**	87					6	61	**491**	271	12	61	**541**	160	4	5	**90**	45				
Kongoni													6	15	**133**	59	1	2	**36**	36				
Kudu, greater																	7	16	**288**	94	3	8	**131**	92
Kudu, lesser																								
Oryx																								
Ostrich	2	6	**52**	35					3	7	**56**	31	5	7	**62**	28					3	4	**66**	38
Reedbuck																	1	1	**18**	18				
Steenbok	1	3	**26**	24	2	8	**70**	47									4	68	**801**	591				
Thomson's gazelle	1	20	**172**	161					4	13	**105**	63	1	3	**27**	25	1	1	**18**	18	1	11	**180**	171
Vervet monkey													1	1	**9**	8								
Warthogs	1	1	**9**	8					1	4	**32**	29	4	6	**53**	26	5	11	**198**	97	2	3	**49**	36
Waterbuck	2	47	**405**	377									1	7	**62**	59					1	1	**16**	16
Wildebeest	4	73	**630**	357					2	115	**926**	616	5	36	**319**	183					1	5	**82**	78
Zebra	7	84	**724**	263					6	213	**1,715**	707	14	236	**2,093**	868					1	7	**115**	109
Flamingo	8	1,333	**11,495**	5,200					3	485	**3,905**	2,664												
Ground hornbill	1	32	**276**	251																				
Marabou stork									1	2	**16**	16												
Pelican spp.	4	568	**4,898**	3,036																				

	Mto wa Mbu				Out west				Outside South				Simanjiro				Tarangire NP				Lake Manyara NP					
Species	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	TC	Total
Baboon													2	6	**52**	42	1	17	**134**	127	1	52	**409**	358		
Buffalo					1	1	**9**	8					12	165	**1,427**	581	19	2,188	**17,239**	7,039	1	14	**110**	96	*287*	**397**
Bush pig																	1	1	**8**	7						
Bushbuck									2	4	**66**	35					3	4	**32**	18						
Duiker spp	1	10	**189**	188					1	1	**17**	15	2	2	**17**	11	10	10	**79**	20						
Elephant	1	3	**57**	56													25	699	**5,507**	847	2	16	**126**	82	*66*	**192**
El. carcass 2																	14	19	**150**	37						
El. carcass 3																	5	5	**39**	16					*3*	**3**
El. carcass 4	1	1	**19**	19													11	14	**110**	27						
Eland					1	7	**61**	58					14	78	**675**	218	18	148	**1,166**	295						
Gerenuk													2	3	**26**	18	1	1	**8**	7						
Giraffe	4	26	**492**	269	2	5	**44**	29	2	2	**33**	23	27	123	**1,064**	175	24	83	**654**	186					*31*	**31**
Grants Gazelle	4	32	**605**	375									24	328	**2,837**	517	4	30	**236**	125	1	14	**110**	96		
Hippopotamus																									*8*	**8**
Impala	7	42	**794**	211									25	209	**1,808**	339	22	234	**1,844**	452	1	2	**16**	14		
Kongoni													10	33	**285**	98	18	162	**1,276**	361						
Kudu, greater									3	4	**66**	48	4	12	**104**	67	5	7	**55**	23						
Kudu, lesser													1	1	**9**	8	1	2	**16**	15						
Oryx													1	2	**17**	16										
Ostrich	2	7	**132**	85					1	1	**17**	18	19	67	**579**	134	23	56	**441**	87					*8*	**8**
Reedbuck					1	1	**9**	8					1	1	**9**	8	13	44	**347**	112						
Steenbok													1	2	**17**	16										
Thomson's gazelle	3	9	**170**	90									19	135	**1,168**	282	3	17	**134**	88						
Vervet monkey									1	5	**83**	56					1	11	**87**	81						
Warthogs					1	1	**9**	8	1	4	**66**	70	10	31	**268**	88	10	45	**355**	127						
Waterbuck	1	1	**19**	18									3	3	**26**	14	7	23	**181**	84						
Wildebeest	1	10	**189**	177									1	180	**1,557**	1,488	18	1,160	**9,140**	2,919	1	50	**393**	345	*368*	**761**
Zebra	4	17	**321**	158	3	23	**201**	153					11	236	**2,041**	756	27	1,803	**14,206**	2,477	1	6	**47**	41	*245*	**292**
Flamingo																					2	720	**5,658**	2,048		
Ground hornbill													1	3	**26**	24										
Marabou stork																										
Pelican spp.																	1	74	**583**	540						

3.3 Wildlife population trends

Population trends of wildlife species were generated by comparing the estimates of the previous aerial survey conducted during the dry season of 2011 with the current census estimates by using a *d*-test. The *d*-test compares estimates, with a critical value greater than 1.96 or less than -1.96 indicating that the estimates are significantly different statistically. Seven species showed a stable population trend compared to 2011: these are wildebeest (*d*=0.15), zebra (*d*=0.99), impala (*d*=0.99), kongoni (*d*=1.2), eland (*d*=1.4), Grant's gazelle (*d*=-0.02) and ostrich (*d*=0.02). Four species showed an increasing population trend, these are giraffe (*d*=4.62), Thomson's gazelle (*d*=4.0), reedbuck (*d*=3.16) and warthog (*d*=2.18). Greater kudu (*d*=3.98) showed an increase, but there is concern over ID issues between Greater and Lesser kudu and the historical trends may be reworked in the future to look at these species in aggregate; estimates are also a result of better observer training and vary year by year. Population trends are indicated for most species in section 3.4, with illustrative trend lines showing either linear or moving averages (not representative of a statistical model). Population estimates are shown as circles with the standard error bars extending above and below. A linear trend line is shown to illustrate the longer-term trends.

While elephant and buffalo are included for reference in Table 6, their estimates are best analysed in the 2014 total count.

Table 6: Wildlife population trends, comparing SRF counts, in the Tarangire-Manyara Ecosystem, 1990 to 2016

	1990		1994		2004		2007		2011		2016		2007/04	2011/07	2016/11
Species Name	**Estimate**	SE	**Estimate**	SE	**Estimate**	SE	**Estimate**	SE	**Estimate**	SE	**Estimate**	SE	d-test	d-test	d-test
Buffalo	**7,219**	3,961	**9,455**	4,665	**6,250**	5,615	**3,828**	1,735	**15,678**	7,693	**19,225**	7,065	-0.41	1.50	0.34
Dik dik	**-**	-	**173**	60	**128**	82	**79**	56	**-**	-					
Eland	**2,825**	925	**726**	240	**1,138**	410	**2,673**	772	**841**	647	**2,543**	372	1.76	-1.82	**2.28**
Elephant	**2,641**	917	**12,138**	3812	**14,357**	8440	**11,901**	2638	**10,895**	2679	**7,882**	1,237	-0.28	-0.27	-1.02
L/Kudu	**84**	56	**110**	57	**272**	124	**-**	-	**122**	64	**24**	17	**-2.19**	1.91	-1.48
G/Kudu	**50**	35	**205**	73	**32**	31	**-**	-	**16**	15	**645**	157	-1.02	1.07	**3.98**
(Kudu total)	***134***	*66*	***315***	*93*	***304***	*128*	***0***	*0*	***138***	*66*	***669***	*158*	-1.02	1.07	**3.10**
Giraffe	**1,387**	334	**4,230**	479	**3,365**	582	**2,228**	506	**1,253**	253	**3,904**	507	-1.47	-1.72	**4.68**
Grant gazelle	**1,922**	584	**8,744**	891	**368**	205	**3,461**	1121	**4,340**	1131	**4,307**	721	**2.71**	0.55	-0.02
Hartebeest	**3,726**	968	**2,620**	291	**1,138**	475	**3,120**	1156	**1,100**	360	**1,731**	381	1.59	-1.67	1.20
Impala	**6,217**	1,924	**6,487**	241	**7,227**	2,912	**6,056**	1,732	**3,728**	1,897	**5,721**	687	-0.35	-0.91	0.99
Oryx	**100**	67	**2636**	601	**656**	553	**-**	-	**321**	162	**17**	16	-1.19	**1.98**	-1.87
Ostrich	**635**	172	**4230**	640	**2308**	496	**3068**	747	**1314**	363	**1,413**	194	0.85	**-2.11**	0.24
Reedbuck	**134**	51	**78**	39	**80**	64	**79**	55	**16**	15	**382**	115	-0.01	-1.11	**3.16**
T/gazelle	**786**	503	**489**	225	**1314**	363	**1363**	696	**290**	148	**1,974**	394	0.06	-1.51	**4.00**
Topi	**-**	-	**31**	31	**240**	235	**26**	25	**-**	-	**0**	0	-0.91	-1.04	
Warthog	**535**	157	**299**	122	**272**	146	**210**	160	**367**	232	**1,039**	203	-0.29	0.56	**2.18**
Waterbuck	**67**	66	**410**	197	**384**	248	**79**	77	**321**	186	**710**	391	-1.17	1.20	0.90
Wild dog	**-**	-	**-**	-	**-**	-	**-**	-	**31**	29					-1.07
Wildebeest	**44,534**	27,037	**43,140**	9,591	**9,567**	4,389	**10,696**	7,017	**11,934**	7,702	**13,603**	3,381	0.14	0.12	0.20
Zebra	**31,617**	8,513	**41,278**	7,839	**33,330**	11,254	**16,594**	5,434	**15,662**	5,118	**21,709**	2,844	-1.34	-0.12	1.03

**d-tests (right three columns) compare succeeding surveys: 2004 and 2007, 2007 and 2011, 2011 and 2016. Significant values are shown in dark bold.*

3.4 Distribution and density of wildlife

Distribution maps and trends are shown in this section.

Population estimates are shown as circles with the standard error bars extending above and below. A linear trend line is shown to illustrate the longer-term trends.

3.4.1 Zebra distribution and density

Zebra were the most abundant species recorded in the Tarangire-Manyara ecosystem during the 2016 dry season census. The species was distributed throughout the census zone with high pockets of concentration in the northern and central parts of Tarangire National Park. Relatively low concentrations were found in Kibaoni, Mto wa Mbu and Simanjiro areas (Table 5).

Zebra are stable or increasing in recent surveys (the past decade), but show a decline (~50%) from 1990 (Figure 5).

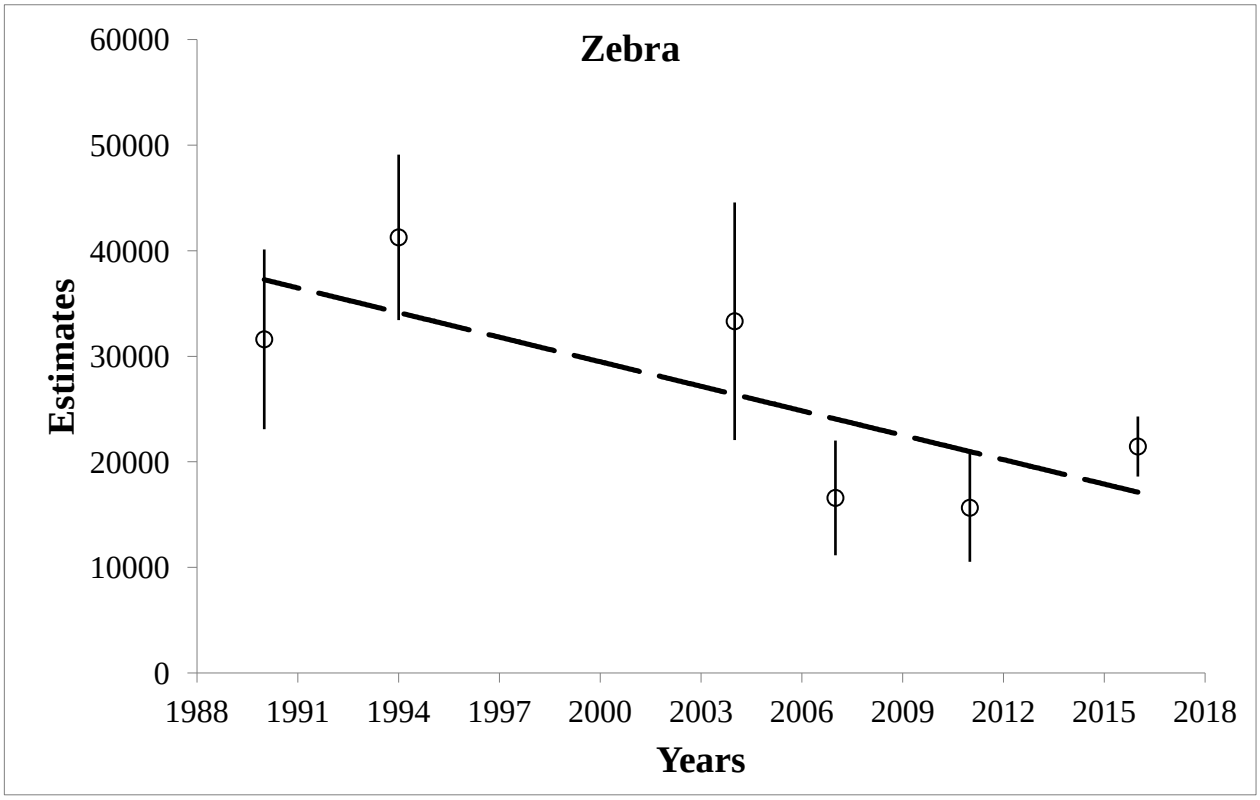

Figure 5: Zebra population trend in Tarangire-Manyara ecosystem, comparing SRF aerial counts from 1990 to 2016.

Population estimates are shown as circles with the standard error bars extending above and below. A linear trend line is shown to illustrate the longer-term trends.

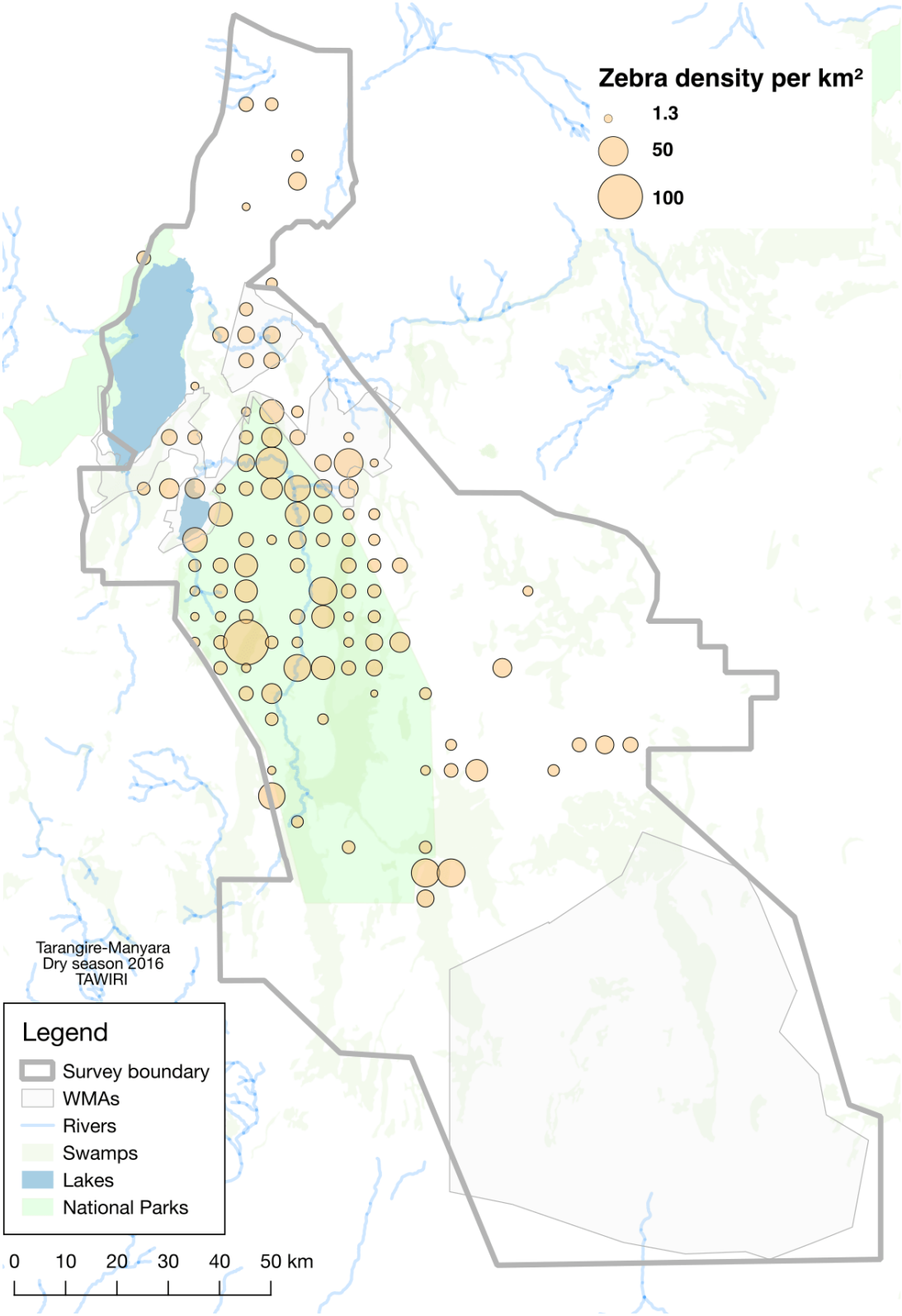

Figure 6: Zebra distribution and density in the Tarangire - Manyara ecosystem, dry season 2016

3.4.2 Buffalo distribution and density

Buffalo were widely distributed in Tarangire NP, Simanjiro, Mkungunero and Lake Manyara National Park. The highest concentration of this species was observed in Tarangire National Park. Relatively low concentrations were observed in Simanjiro, Makame and Lake Manyara National Park (Figure 7).

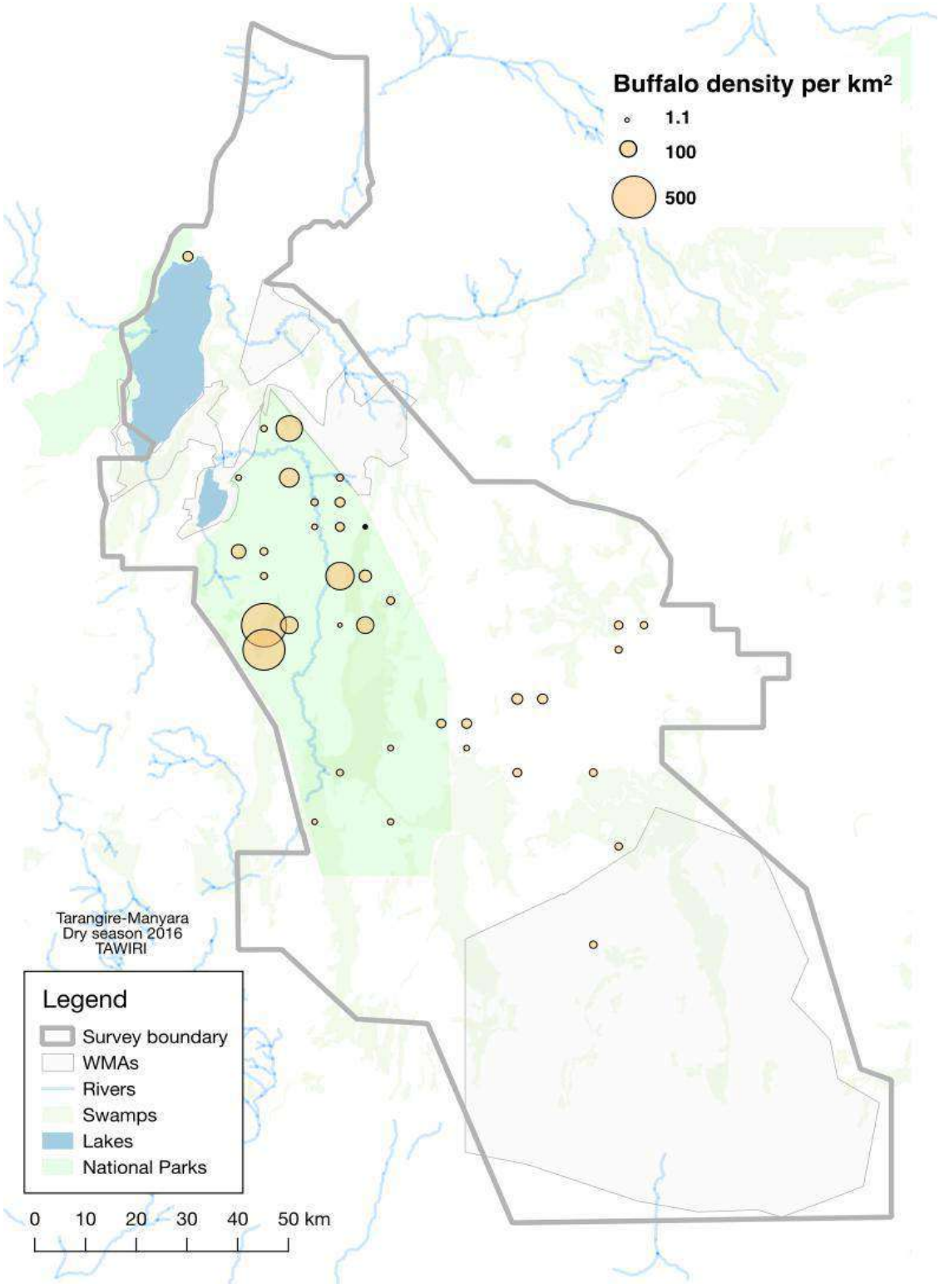

Figure 7: Buffalo distribution and density in the Tarangire-Manyara Ecosystem, dry season 2016

3.4.3 Wildebeest distribution and density

Wildebeest was the second most abundant species recorded in the Tarangire-Manyara Ecosystem. The distribution pattern of the species shows that the highest concentrations are found in the northern and central parts of Tarangire National Park. Other areas where this species was recorded includes Mto wa Mbu, Kwakuchinja, Kibaoni, Lake Manyara NP and Mkungunero (Figure 9).

Wildebeest are stable in the short term (d < 0.2 from 2007 onwards), but declined dramatically from populations greater than 40,000 individuals in the early 1990s (Figure 8).

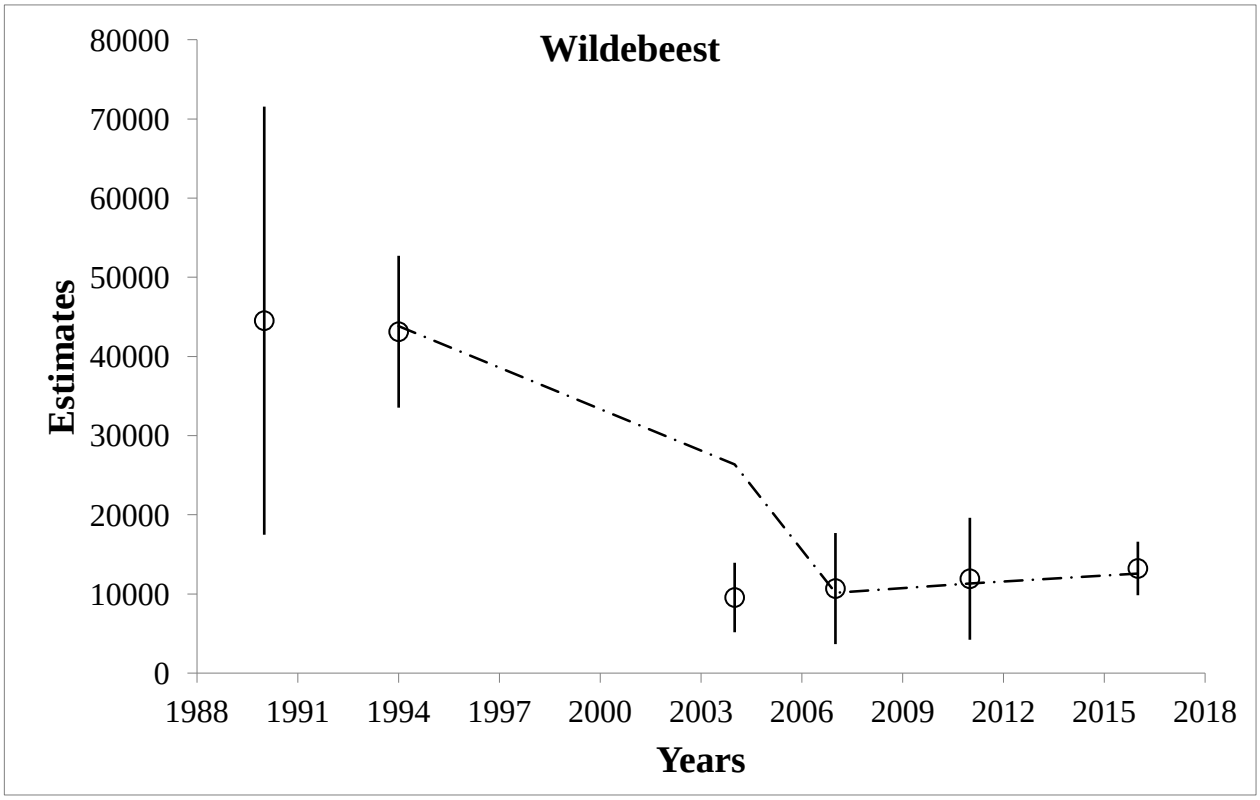

Figure 8: Wildebeest population trend in Tarangire-Manyara Ecosystem, comparing SRF aerial counts from 1990 to 2016.

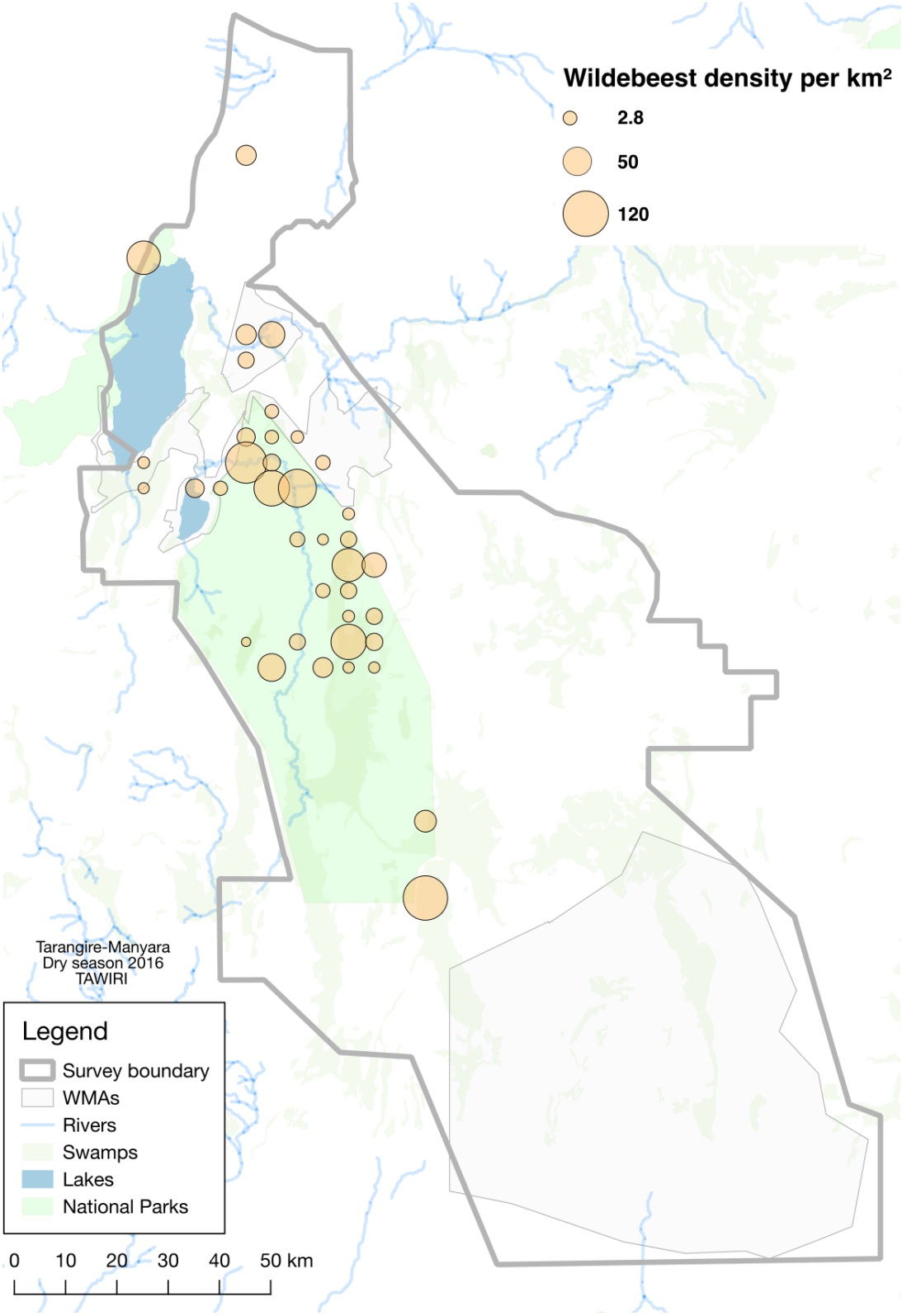

Figure 9: Wildebeest distribution and density in the Tarangire - Manyara ecosystem, dry season 2016

3.4.4 Elephant and carcass distribution and density

The distribution pattern of elephants shows high concentration in Tarangire NP, followed by Kwakuchinja, Lolkisale and Makame. Relatively low concentration was recorded in all other surveyed areas (
Figure 10).

Elephant populations in Tarangire are often highly aggregated with occasional large herds, which leads to misrepresentations (typically over-estimating) when using a SRF aerial count to assess numbers. The 2014 aerial total count results are considered more reliable, with the long-term population increasing from the early 1990s (2,300) to an estimated 4,202 individuals in 2014. This survey estimated 7,948 (SRF 7,882 ± 1,237SE, TC 66) elephants, a likely overestimate due to encounters with large herds.

Elephant carcasses were widely distributed throughout the ecosystem, mostly older carcasses of stage 3 and 4 but with some relatively fresh (stage 2). The carcass ratio (live + dead / live) for this SRF survey is 5.2%, which would represent a value in the range of normal mortality – however, given that the likely true population (from the 2014 aerial total count) is much lower (estimate 4,202), the carcass ratio is probably closer to 9%, which is a potential cause for concern.

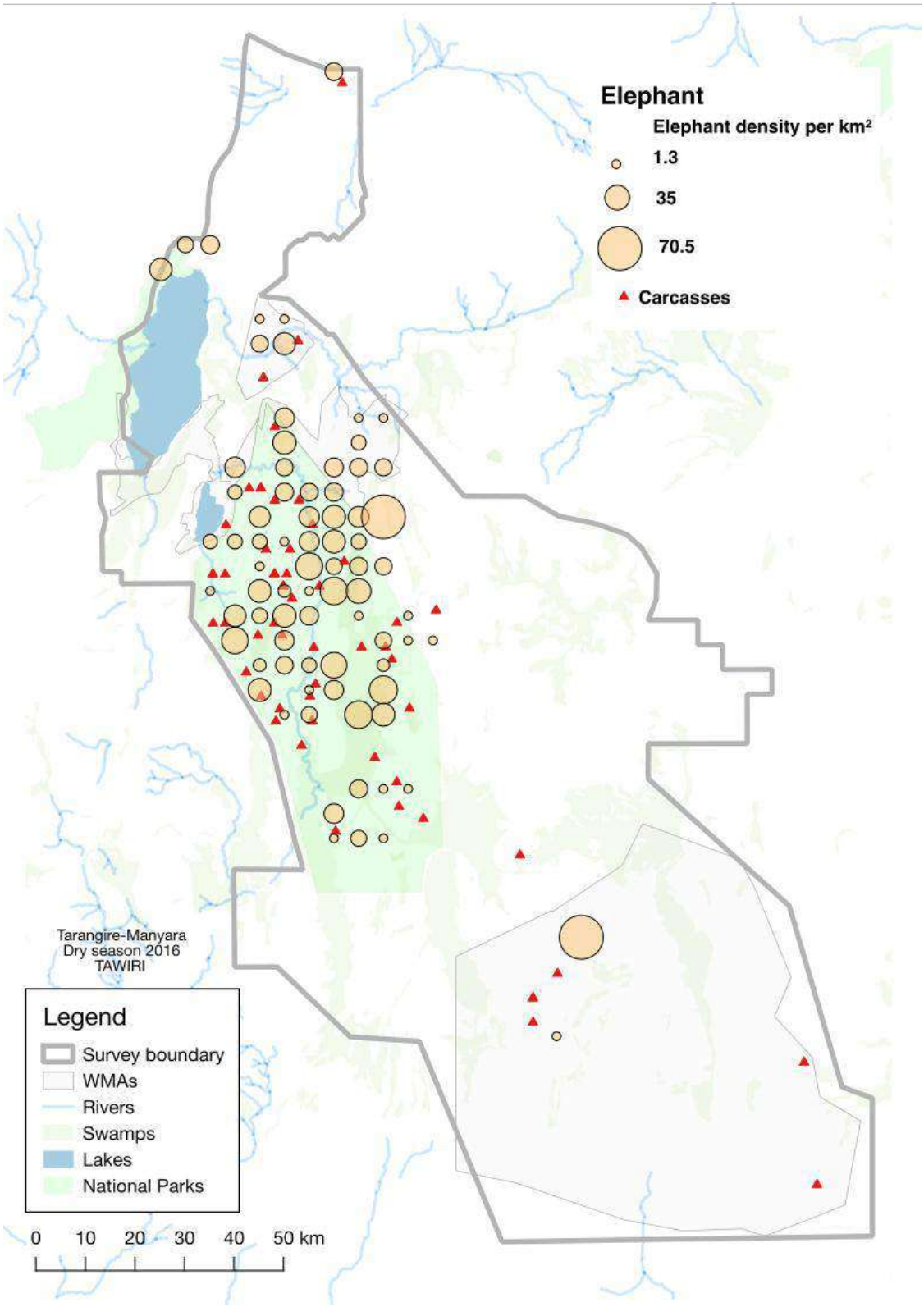

Figure 10: Elephant and carcass distribution and density in the Tarangire-Manyara Ecosystem, dry season 2016

3.4.5 Impala distribution and density

This species was widely distributed throughout the census zone; highest concentrations were found in northern Tarangire Nation Park, Simanjiro, Lolkisale, Mto wa Mbu and Kibaoni. Relatively low concentrations were observed in the Outside South/Makame WMA area (
Figure 12).

Impala have been generally stable in the long term (
Figure 11).

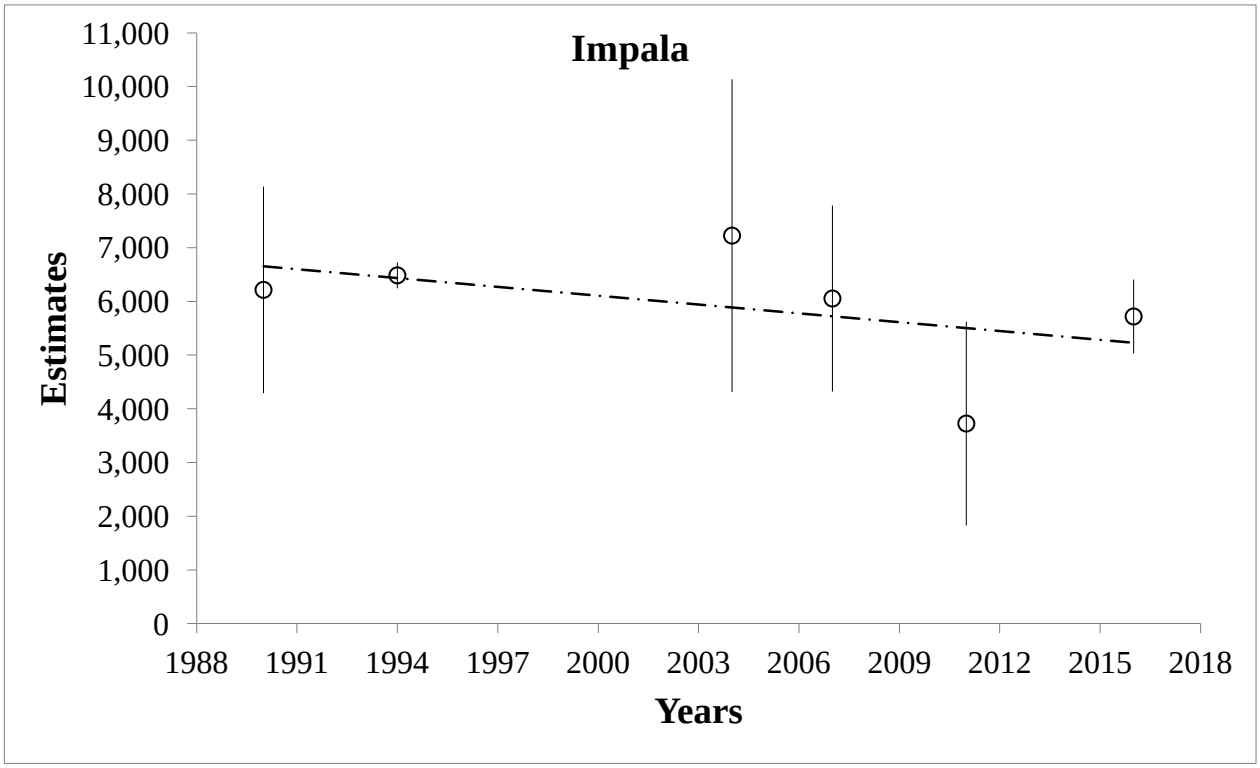

Figure 11: Impala population trend in Tarangire-Manyara Ecosystem, comparing SRF aerial counts from 1990 to 2016.

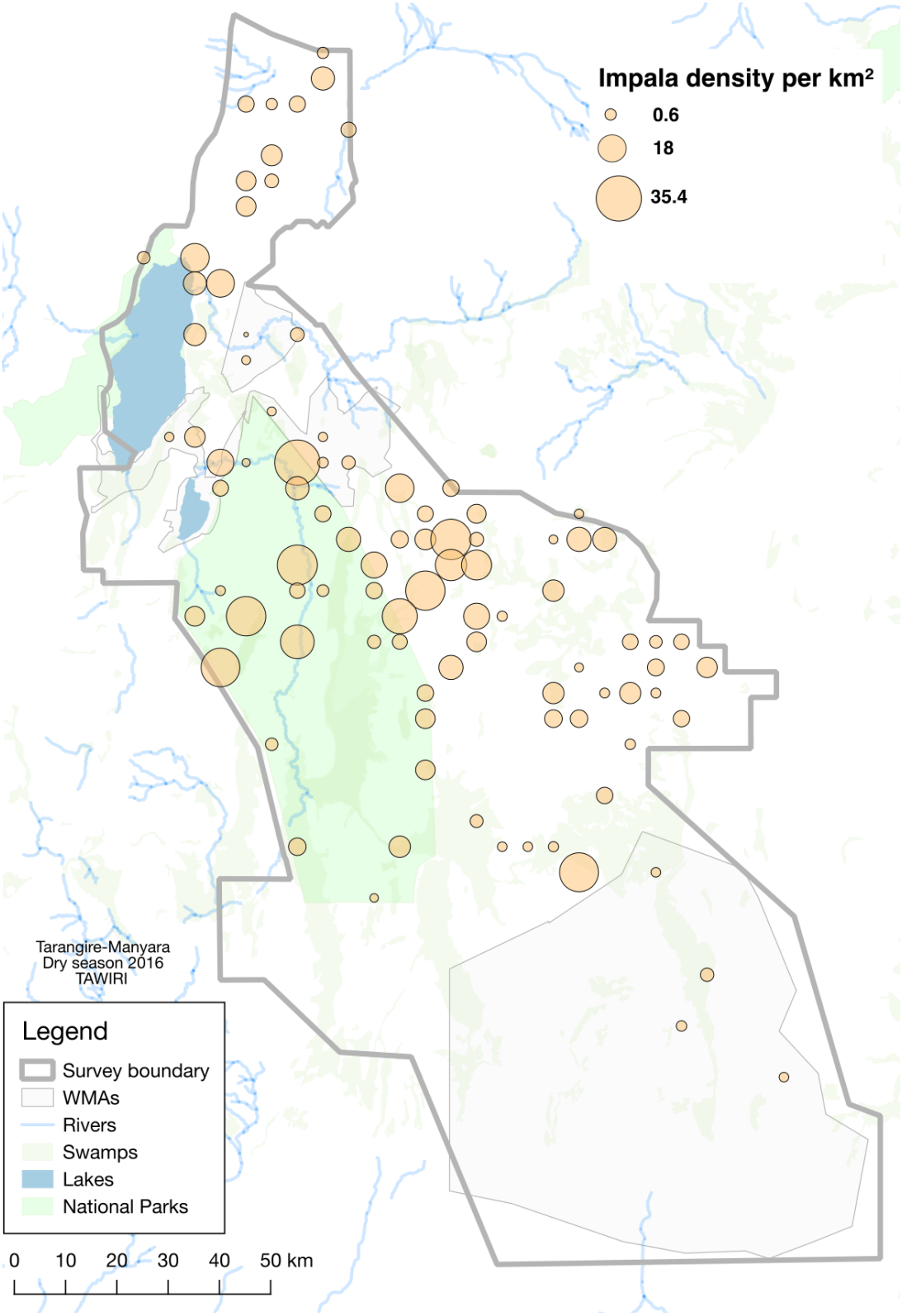

Figure 12: Impala distribution and density in the Tarangire-Manyara Ecosystem, dry season 2016

3.4.6 Grant's gazelle distribution and density

The distribution pattern of Grant's gazelle shows high concentrations in the Simanjiro area and Mto wa Mbu. Relatively low concentrations were recorded in all other surveyed area except Kibaoni, which had no observations (
Figure 14).

Over the long term, Grant's gazelles show high variability which may reflect identity confusion during the aerial counts with Thomson's gazelles; in recent surveys the population has been stable around 4,000 (
Figure 13).

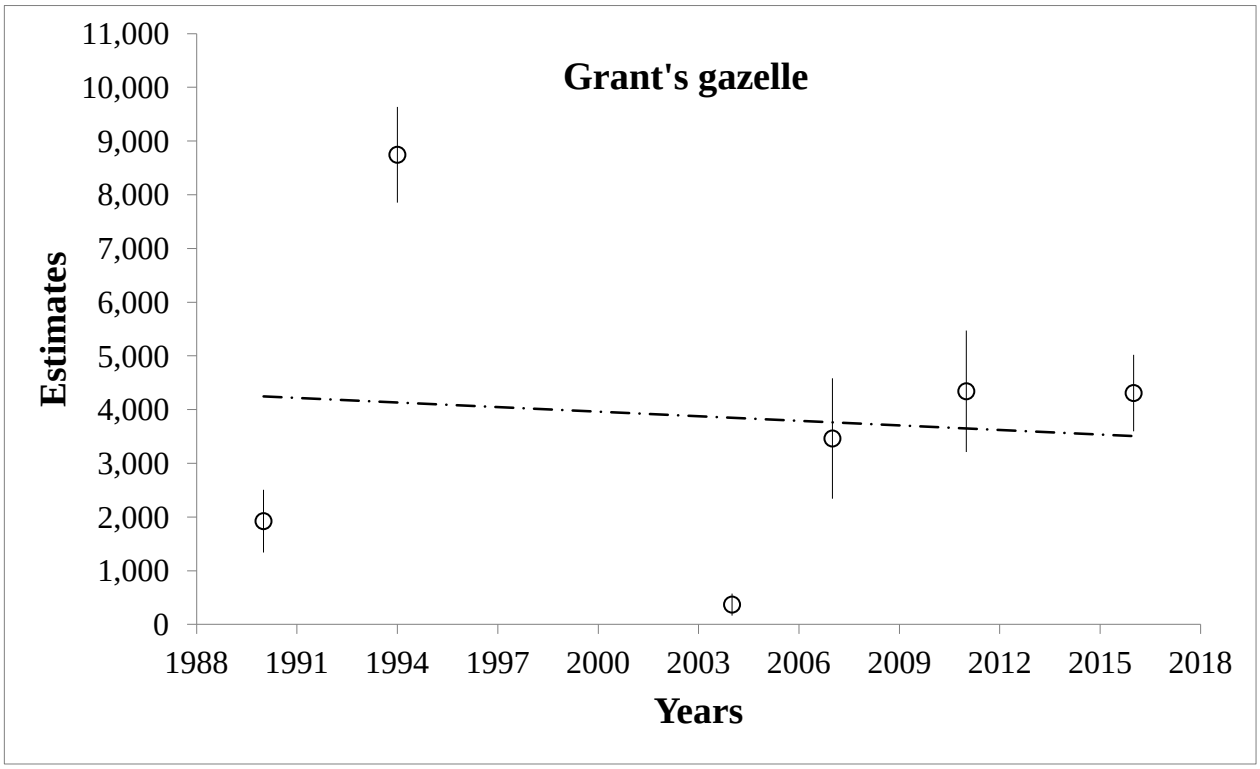

Figure 13: Grant's gazelle population trend in Tarangire-Manyara Ecosystem, comparing SRF aerial counts from 1990 to 2016.

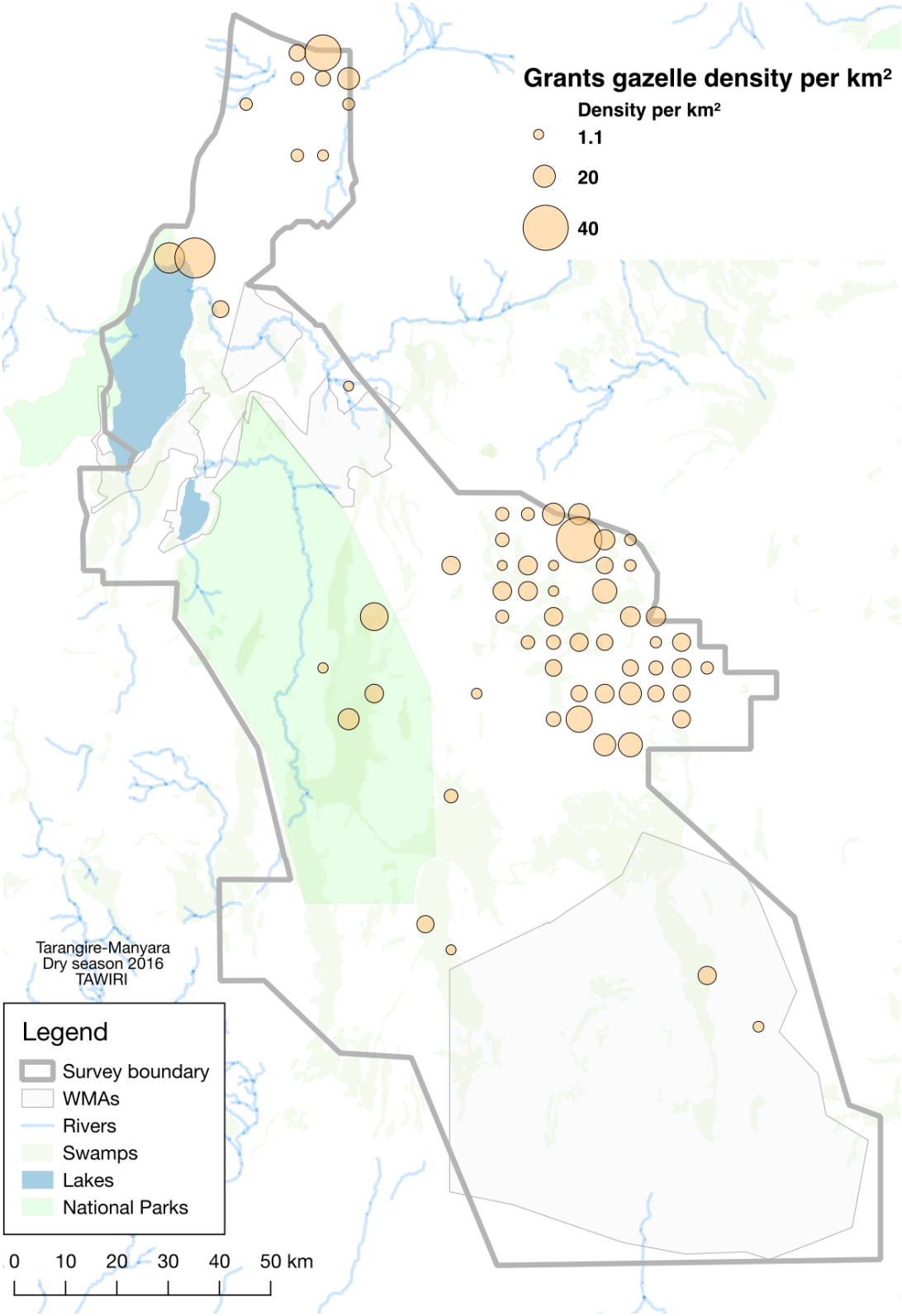

Figure 14: Grant's gazelle distribution and density in the Tarangire - Manyara ecosystem, dry season 2016

3.4.7 Giraffe distribution and density

The 2016 aerial census in the Tarangire-Manyara ecosystem shows that Giraffe were widely distributed over the census zone. The highest concentrations were found in Tarangire National Park, Simanjiro, Lolkisale, and Kwakuchinja areas. Relatively low concentrations were recorded in Mto wa Mbu, Mkungunero, Kibaoni and Outside South (
Figure 16).

Giraffe show an apparent strong increase (~4x) from 2011 which is extremely unlikely ecologically (Figure 15). Lee and Bond (2016) note that aerial surveys in dry seasons have had strong negative biases based on data from Tarangire – the current estimate from 2016 matches closely the estimate from Lee and Bond's ground surveys in 2015, which may reflect better observer training and attention to flight performance.

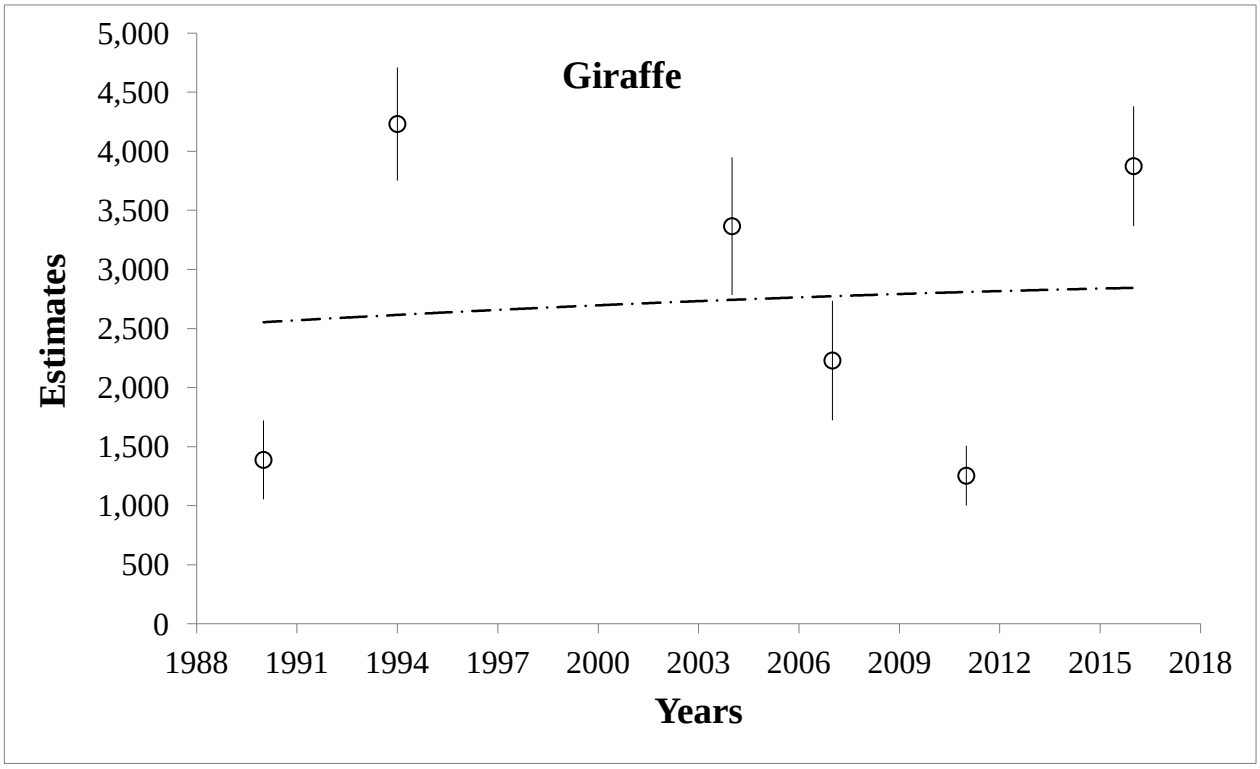

Figure 15: Giraffe population trend in Tarangire-Manyara Ecosystem, comparing SRF aerial counts from 1990 to 2016.

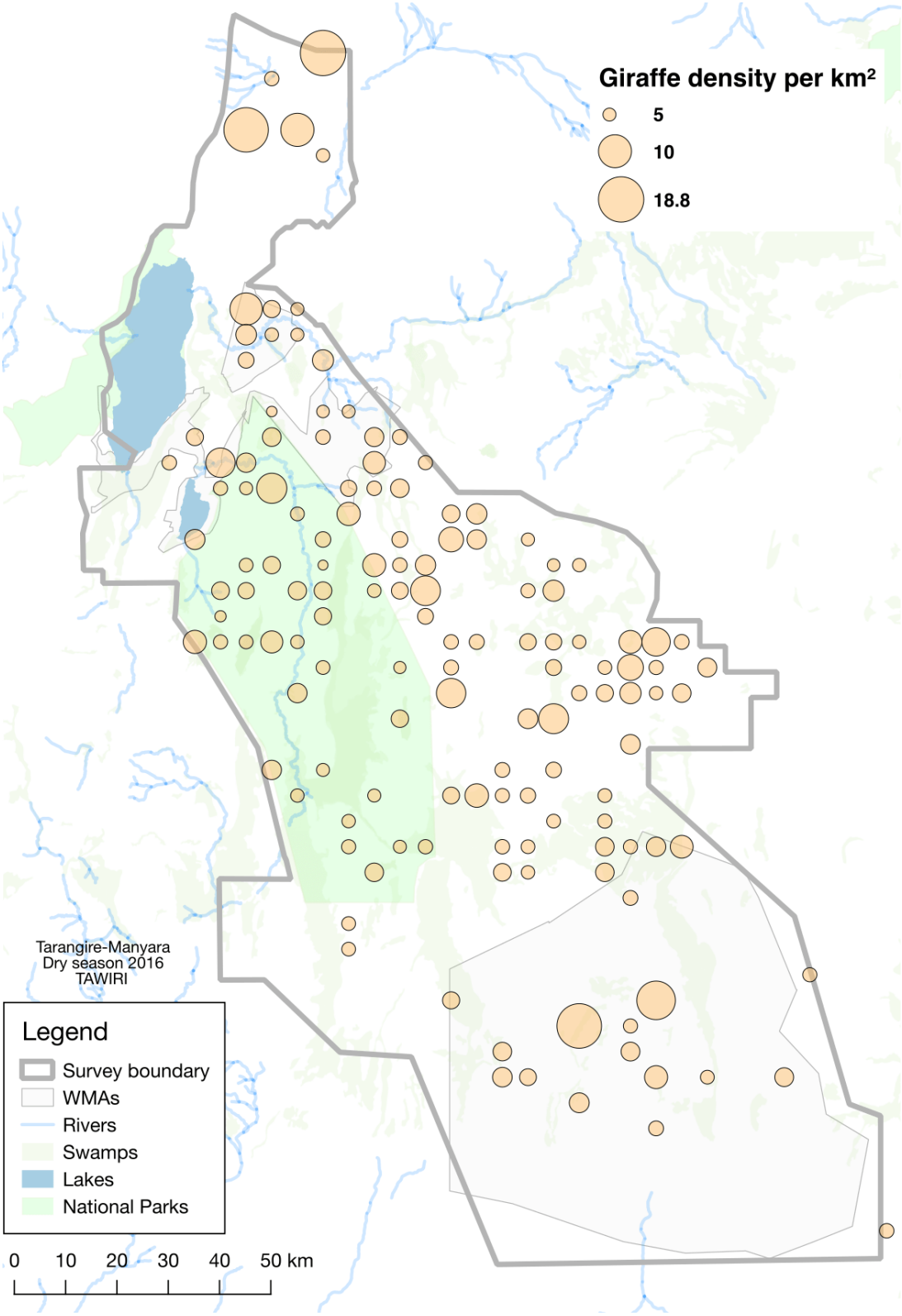

Figure 16: Giraffe distribution and density in the Tarangire - Manyara ecosystem, dry season 2016

3.4.8 Kongoni distribution and density

The 2016 aerial census of Tarangire-Manyara ecosystem shows that Kongoni was found in Tarangire National Park and Simanjiro and one group observation in the Outside South area. The highest concentration of this species was observed in the central part of the Tarangire National Park (
Figure 18).

Kongoni trends from 1990 onwards are variable but tending toward declining (
Figure 17).

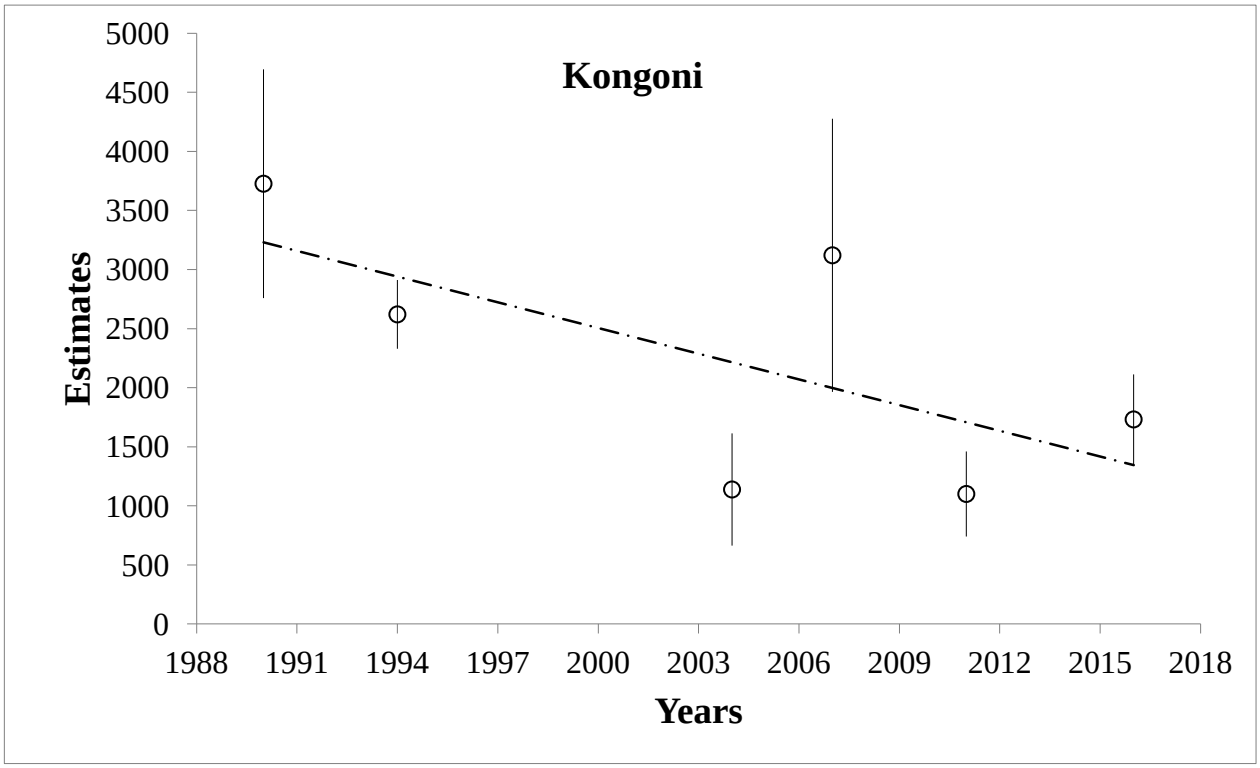

Figure 17: Kongoni population trend in Tarangire-Manyara Ecosystem, comparing SRF aerial counts from 1990 to 2016.

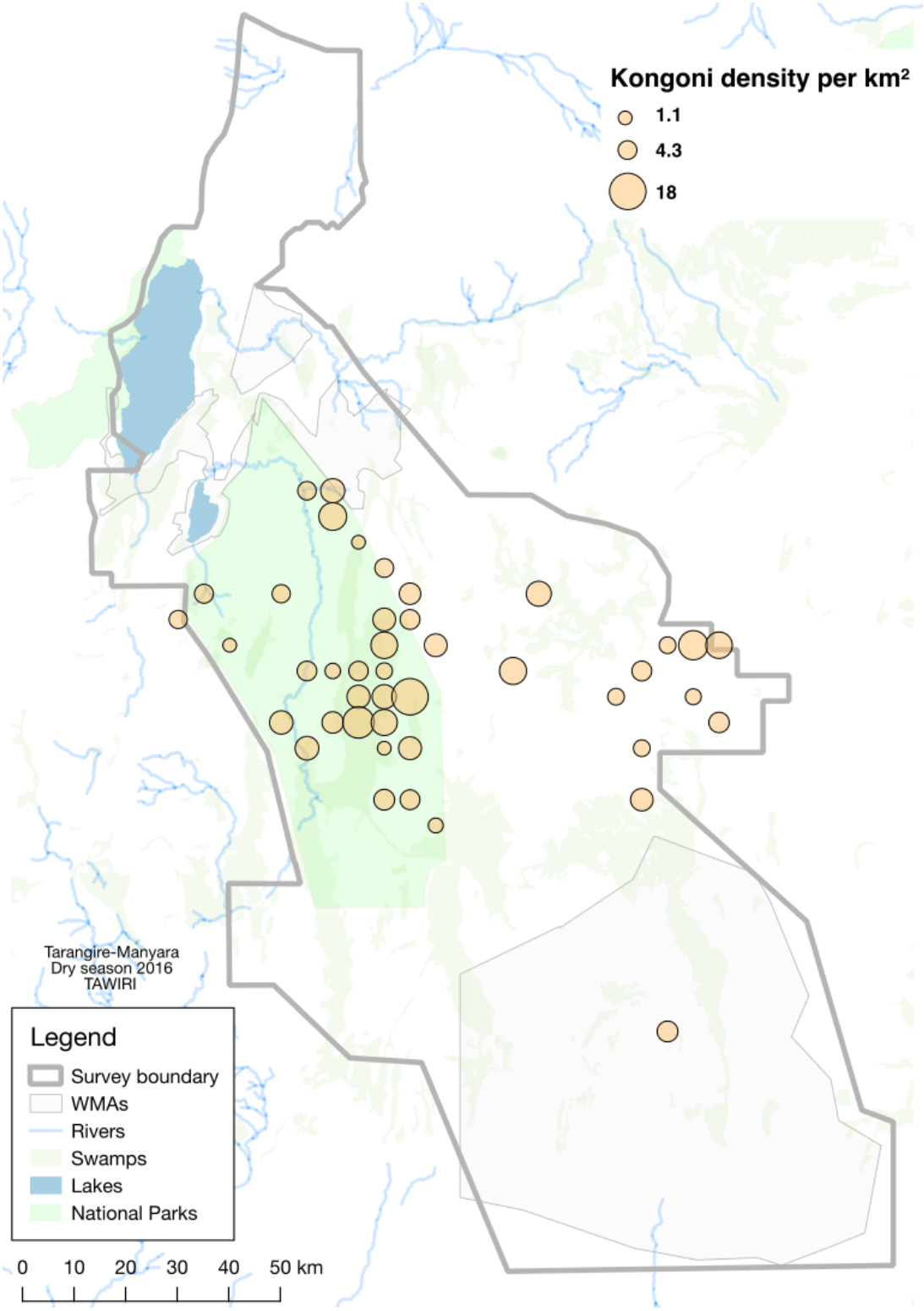

Figure 18: Kongoni distribution and density in the Tarangire-Manyara Ecosystem, dry season 2016

3.4.9 Eland distribution and density

Eland were observed in Tarangire National Park, Simanjiro and Outside South areas. The highest concentration of this species was observed in Tarangire National Park, and relatively low concentrations were observed in Simanjiro and Outside South areas (Figure 20).

Eland show a significant change from 2011, but have shown strong variability between surveys from 1990 onwards (Figure 19).

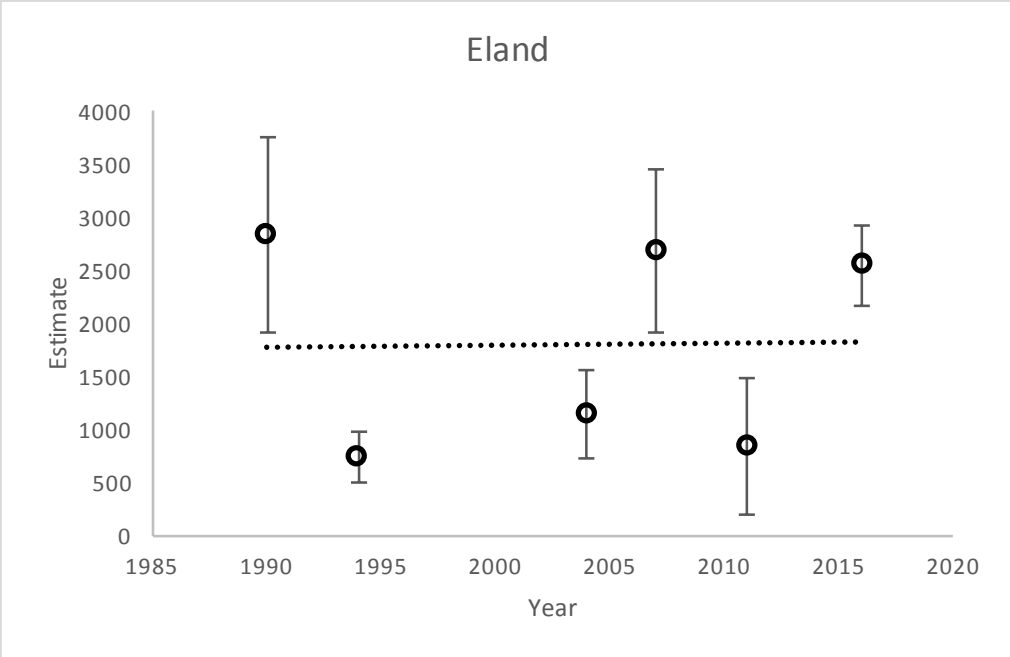

Figure 19: Eland population trend in Tarangire-Manyara Ecosystem, comparing SRF aerial counts from 1990 to 2016.

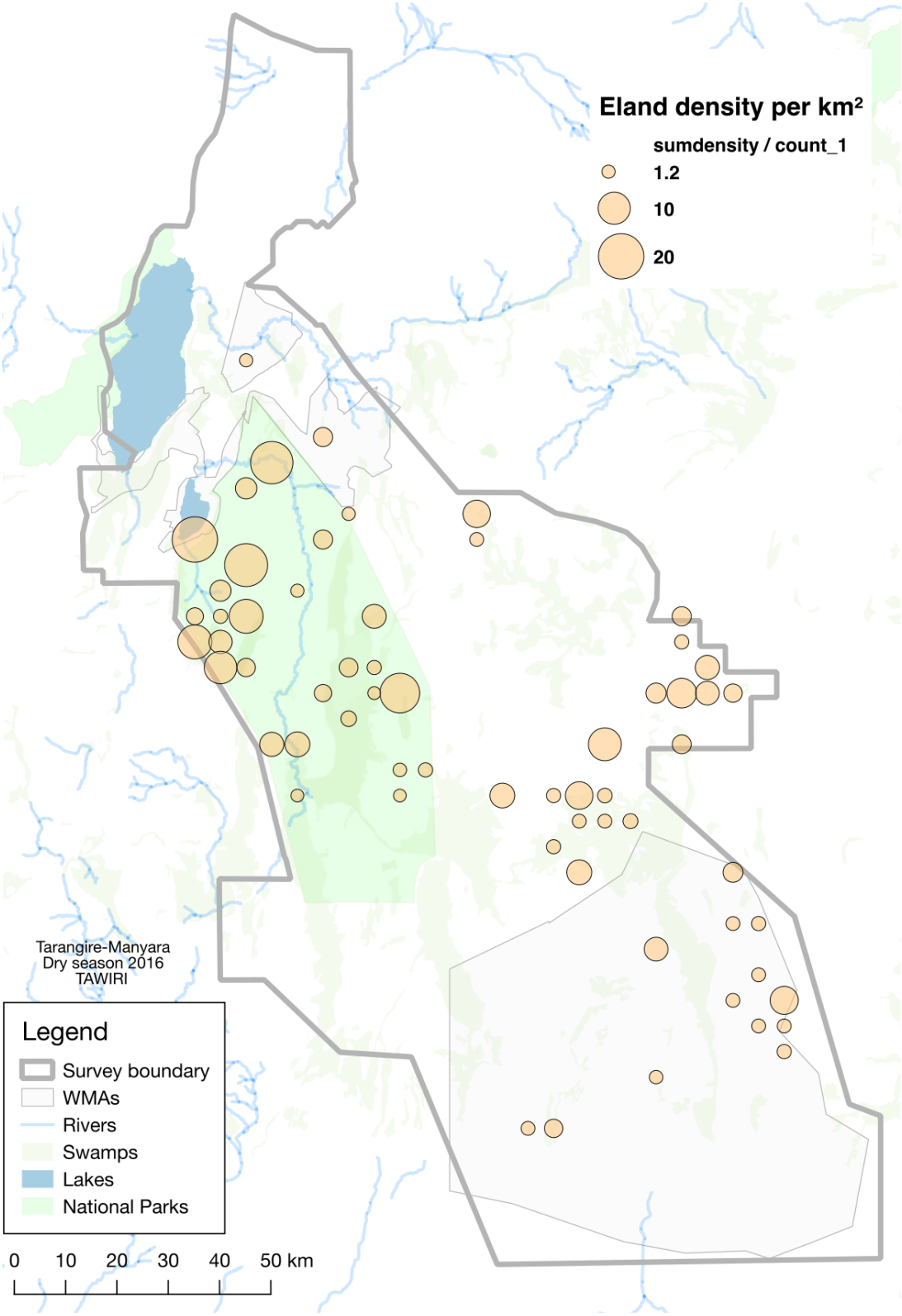

Figure 20: Eland distribution and density in the Tarangire - Manyara ecosystem, dry season 2016

3.4.10 Warthog distribution and density

This species was widely distributed all over the surveyed ecosystem with the exception of Mto wa Mbu and Kibaoni. The species highest concentration was observed in Tarangire National Park, Simanjiro and Lolkisale. Relatively low concentrations of the species were observed in Mkungunero and Outside South areas (
Figure 22).

Warthog show strong increases from previous censuses (
Figure 21). This may reflect better training of observers.

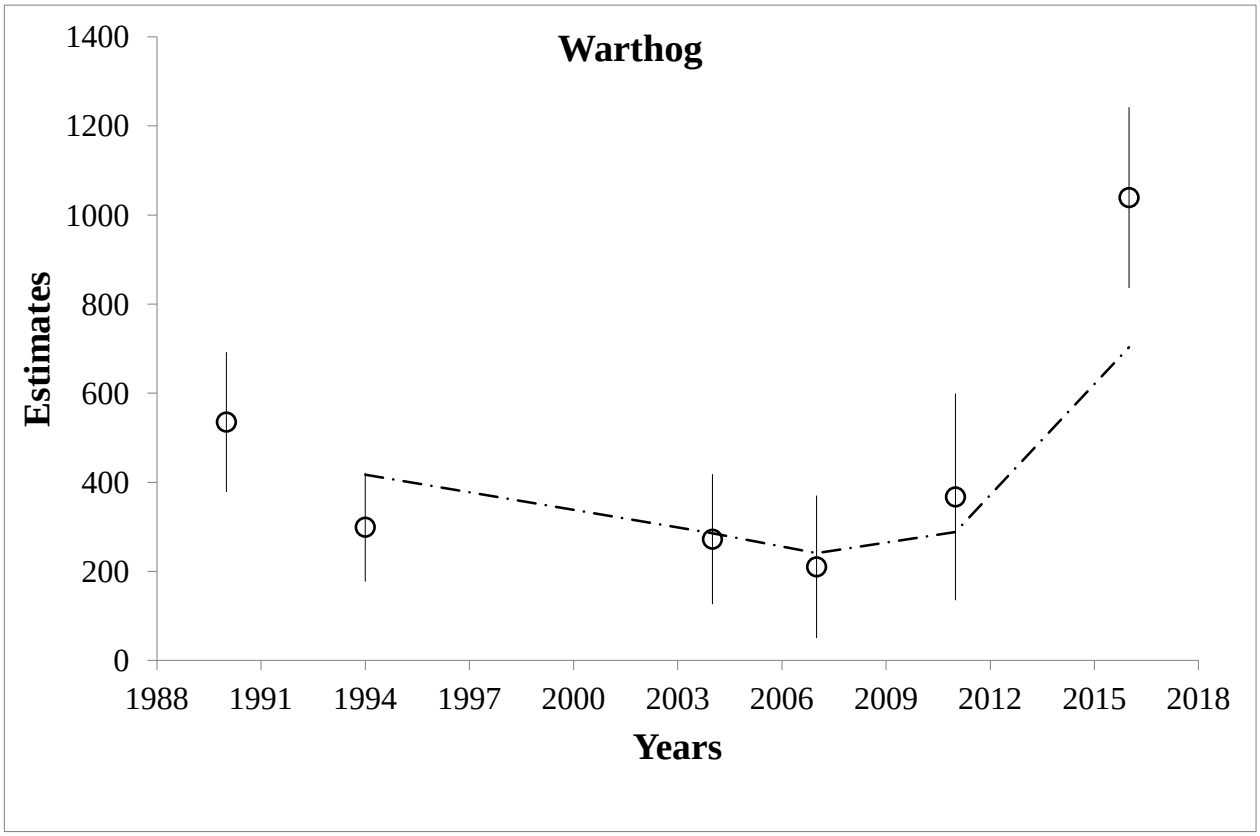

Figure 21: Warthog population trend in Tarangire-Manyara Ecosystem, comparing SRF aerial counts from 1990 to 2016.

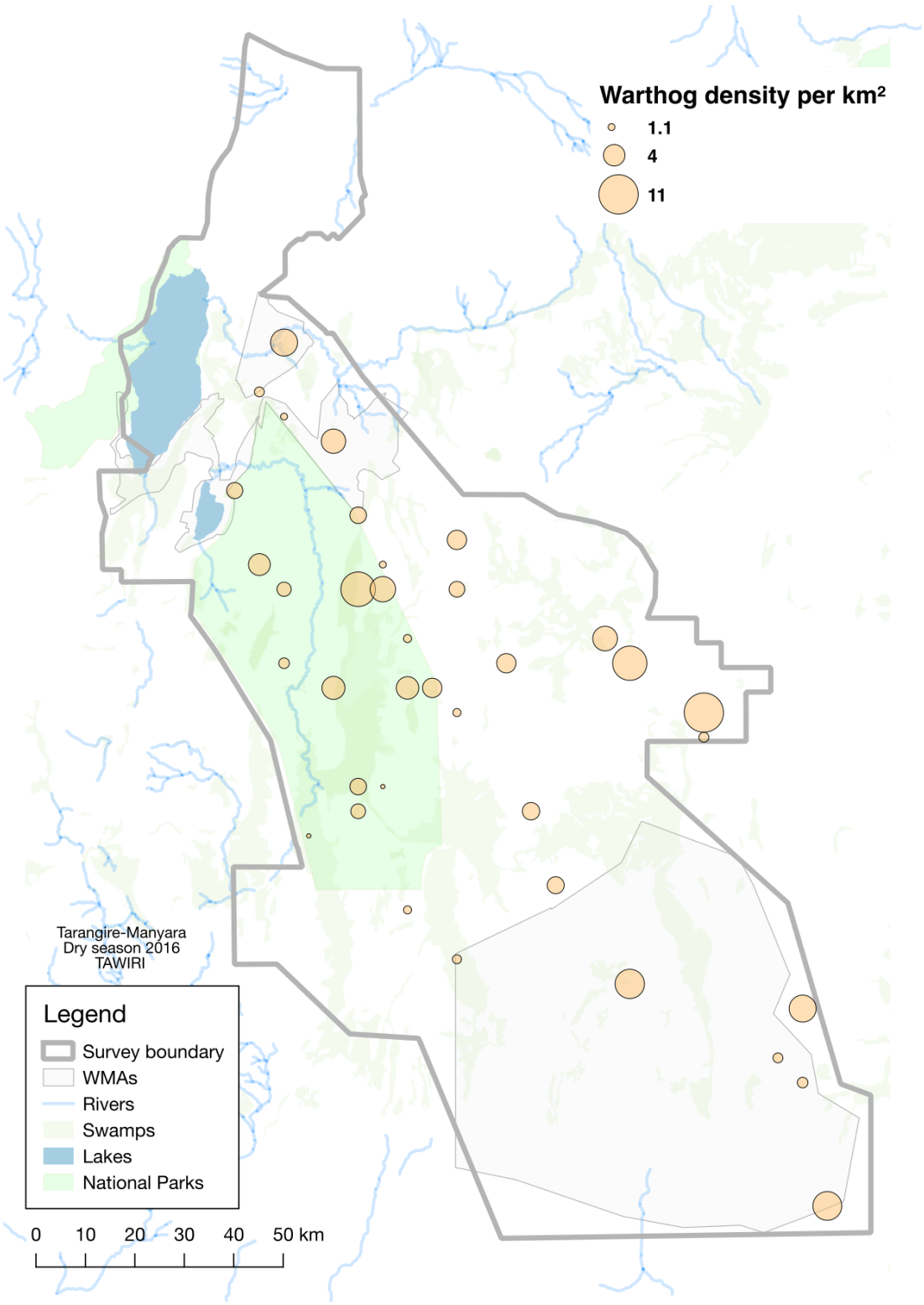

Figure 22: Warthog distribution and density in the Tarangire - Manyara ecosystem, dry season 2016

3.4.11 Greater and Lesser kudu density and distribution

In the 2016 dry season aerial census Greater kudu were observed in Tarangire National Park, Simanjiro, Mkungunero and Outside South areas. The highest concentration of Greater kudu was observed in Mkungunero, Simanjiro and Outside South areas (

Figure 24). The distribution pattern of Lesser kudu was restricted to Tarangire National Park and Simanjiro areas (

Figure 24).

Note that greater and lesser kudu species are often difficult to distinguish from the air, and aggregate estimates, maps and trends are shown for the ecosystem. These species are also difficult to spot from the air, and estimates often reflect better observer training and ground speed control.

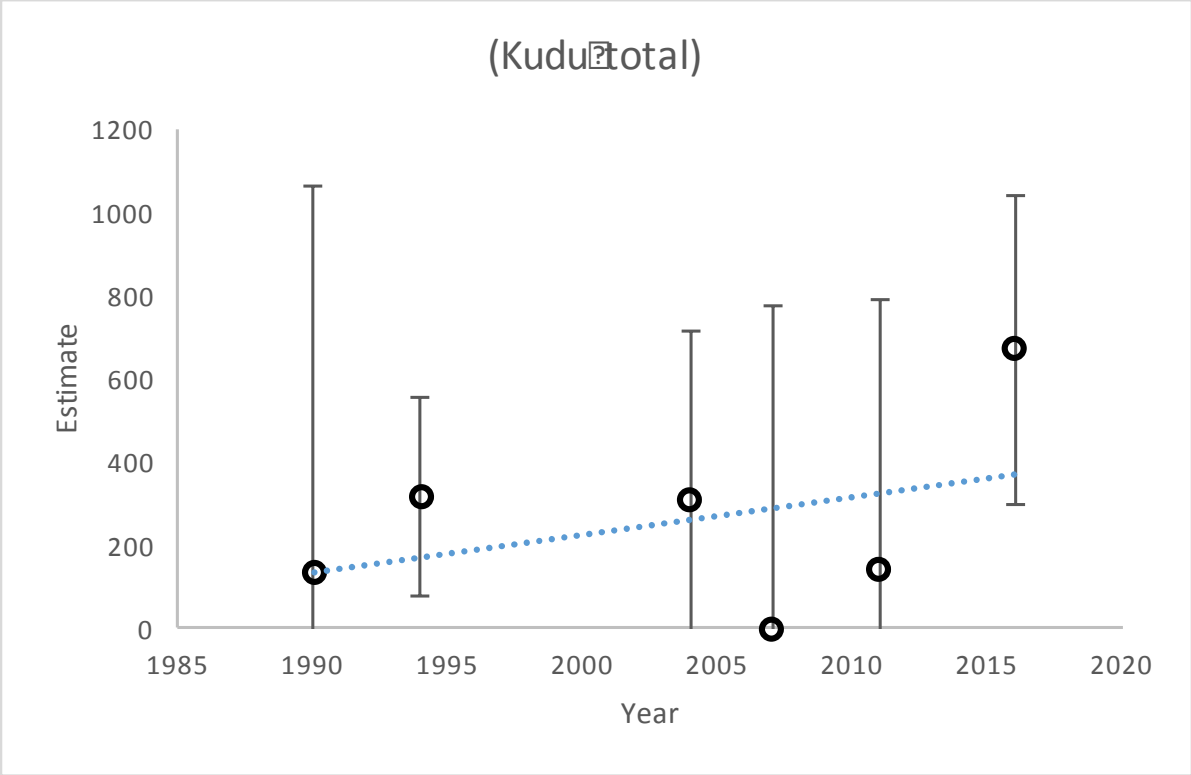

Figure 23: Kudu spp. (aggregate) population trends in Tarangire-Manyara Ecosystem, comparing SRF aerial counts from 1990 to 2016.

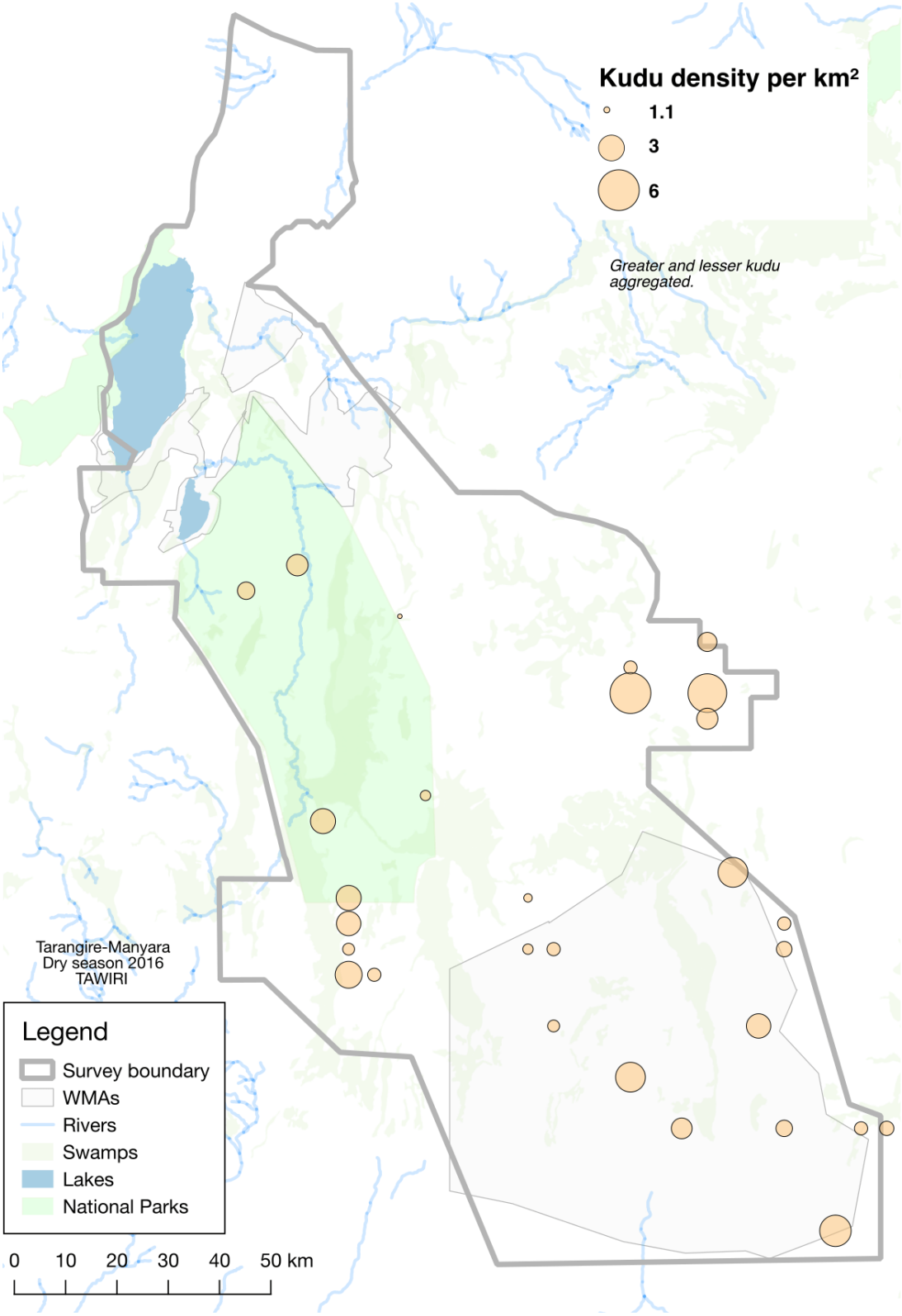

Figure 24: Greater and lesser kudu distribution and density in the Tarangire - Manyara ecosystem, dry season 2016

3.4.12 Oryx and Gerenuk

Oryx had a very restricted distribution in the survey and were only spotted in the Simanjiro. Gerenuk were observed in Tarangire National Park, Mkungunero and Simanjiro areas. Previous censuses confirmed that the distribution of both Oryx and Gerenuk are restricted to specific areas in the Tarangire-Manyara ecosystem (Tarangire-Manyara Aerial Survey, 2011) (
Figure 25).

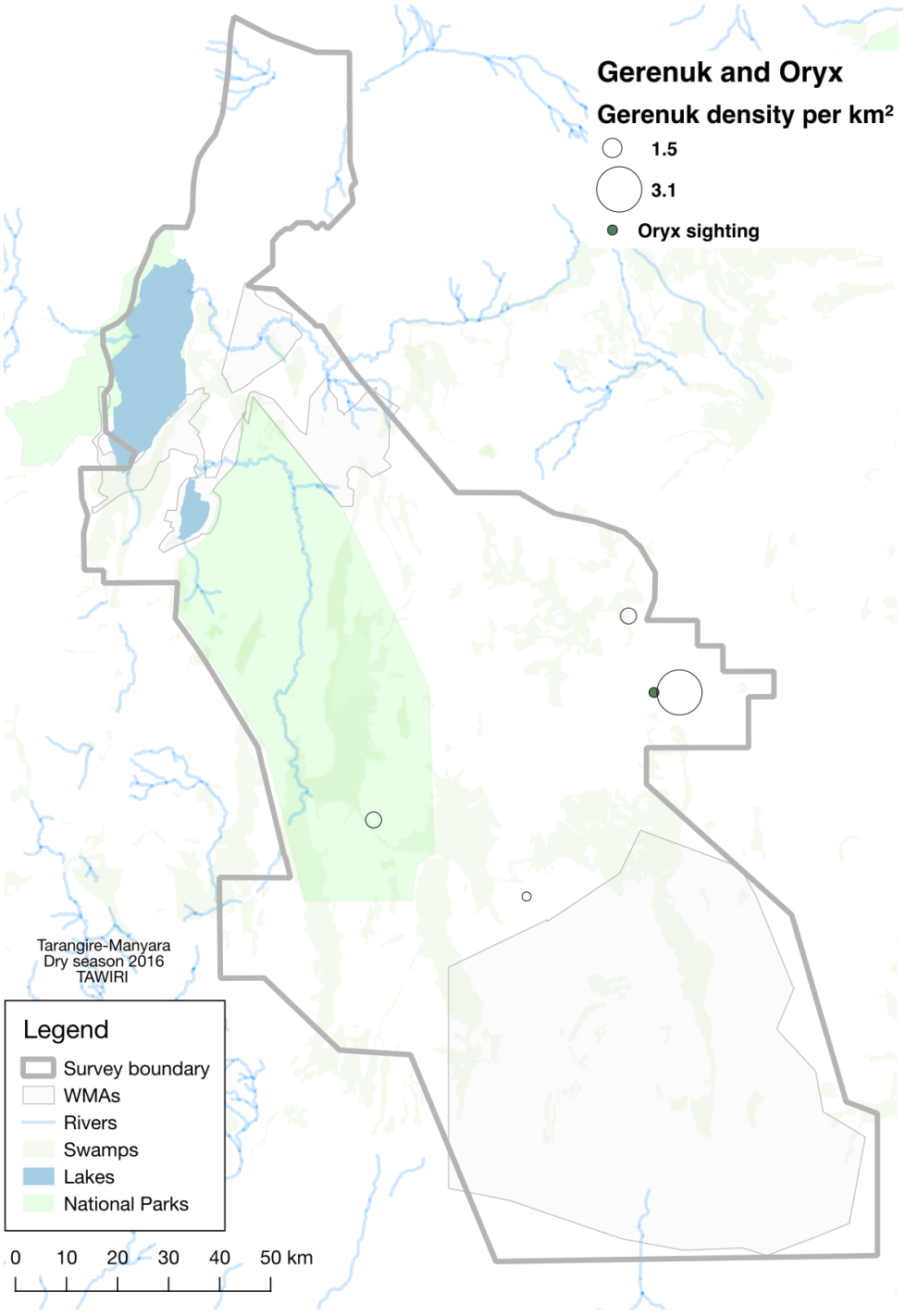

Figure 25: Oryx and Gerenuk distribution and density in the Tarangire-Manyara Ecosystem, dry season 2016

3.4.13 Common Waterbuck distribution and density

Waterbuck were found in limited numbers through the ecosystem. Highest concentrations were observed in northern Tarangire National Park and relatively low concentrations were observed in Mto wa Mbu, Kibaoni, Simanjiro and Mkungunero (Figure 26).

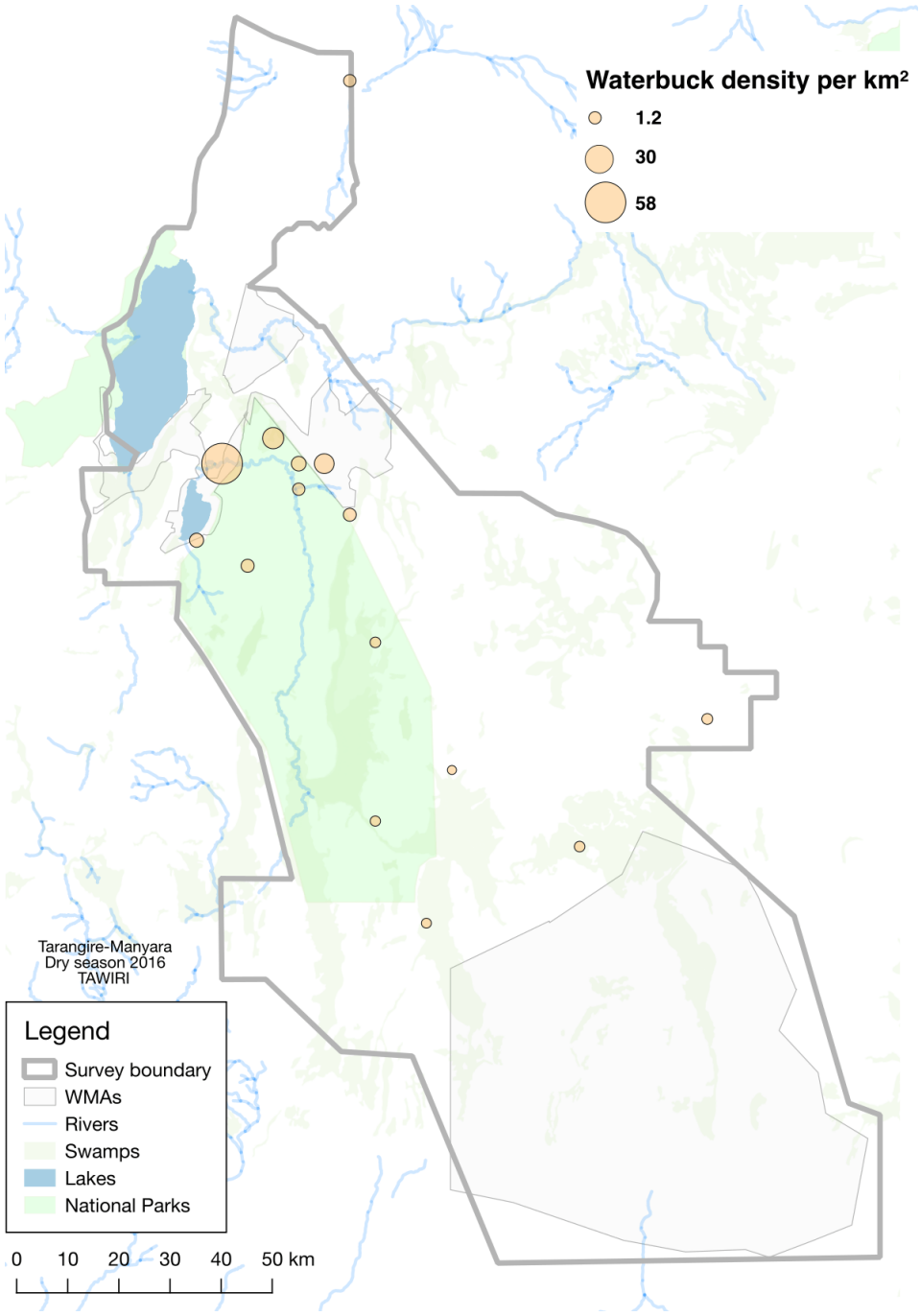

Figure 26: Common Waterbuck distribution and density in the Tarangire-Manyara Ecosystem, dry season 2016

3.4.14 Bohor reedbuck distribution and density

Bohor reedbuck were almost exclusively observed in Tarangire National Park, with one observation each in Simanjiro and Makame WMA (
Figure 27). Reedbuck are relatively difficult to spot from aircraft and the estimate here probably represents a strong undercount.

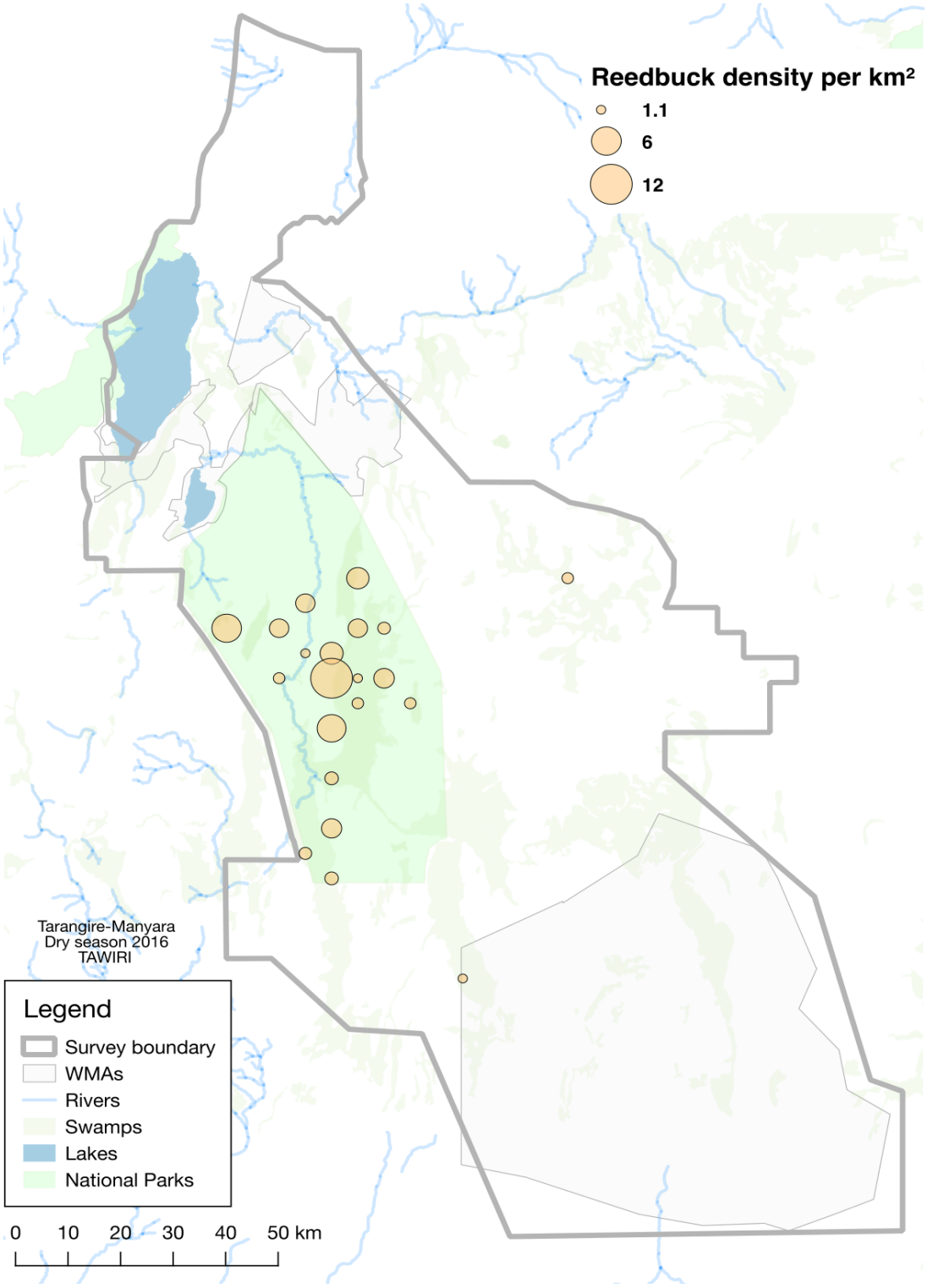

Figure 27: Reedbuck distribution and density in the Tarangire-Manyara Ecosystem, dry season 2016

3.4.15 Ostrich distribution and density

Ostrich were distributed over most of the surveyed areas with the exception of Outside South. The highest concentration of ostrich was observed in Tarangire National Park, Simanjiro and Kibaoni. Relatively low concentrations were observed at Kwakuchinja, Lolkisale and Mkungunero (
Figure 29).

Trends from 1995 are generally decreasing but stable from 2011 (
Figure 28).

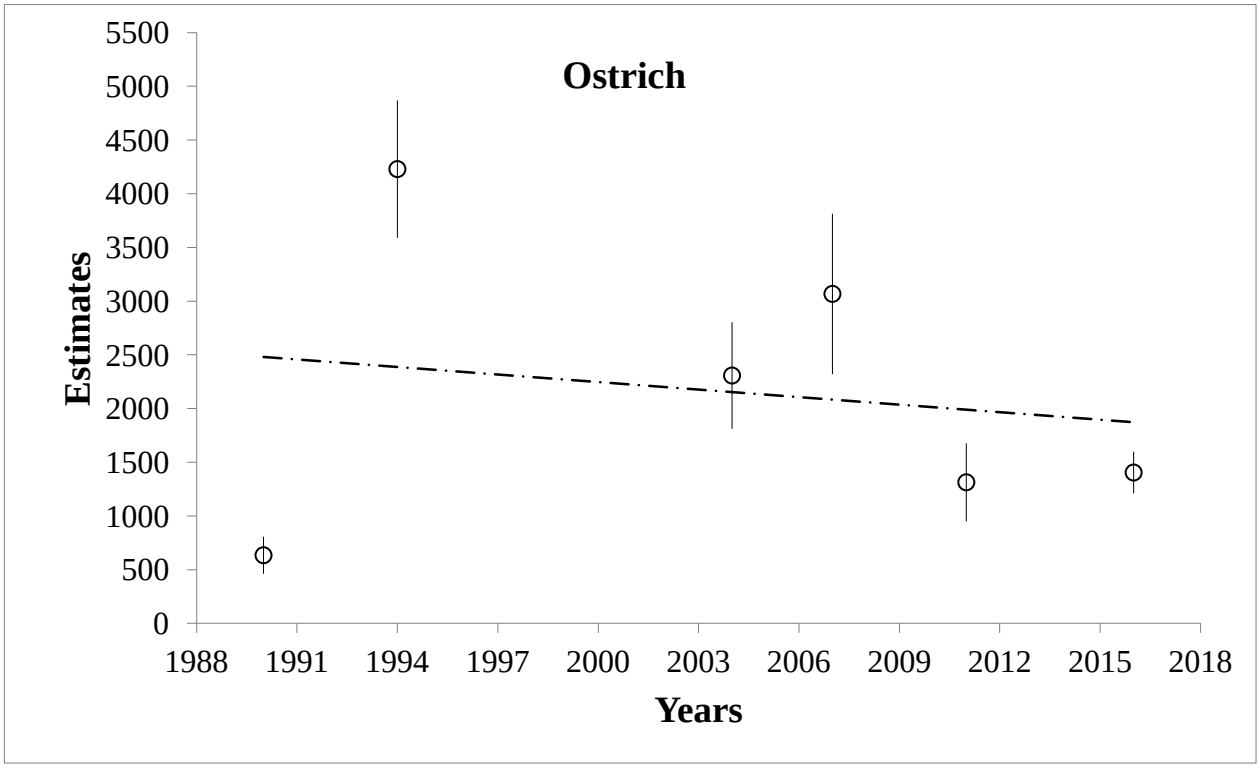

Figure 28: Ostrich population trend in Tarangire-Manyara Ecosystem, 1990 to 2016

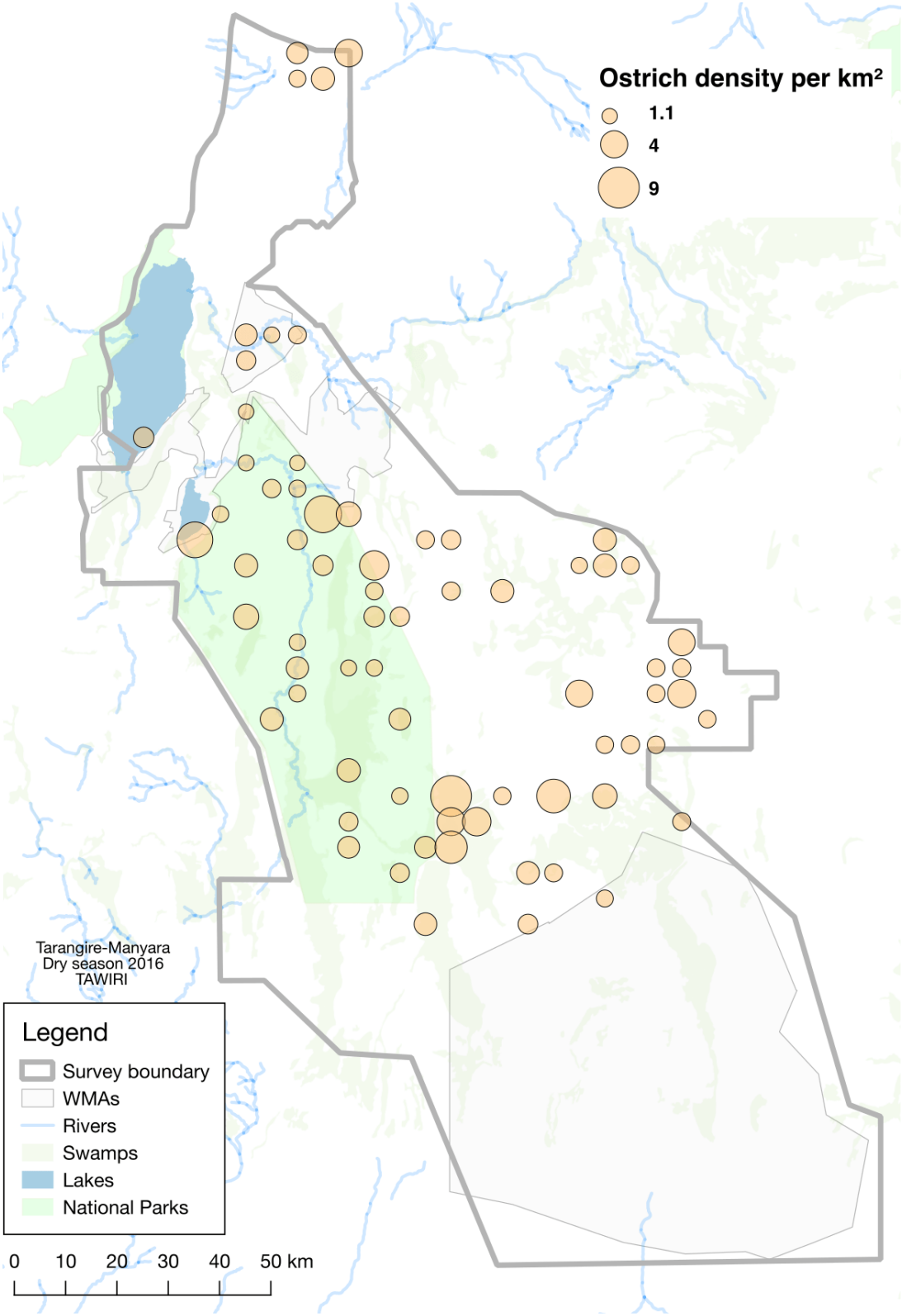

Figure 29: Ostrich distribution and density in the Tarangire - Manyara ecosystem, dry season 2016

3.4.16 Marabou stork, Pelicans and Ground Hornbill distribution

Large birds are occasionally seen in aerial surveys, but useful estimates are not normally produced. Marabou storks and Pelicans were seen in Kwakuchinja, Kibaoni and Tarangire National Park, with the highest concentration observed in Kibaoni. Ground hornbills were only spotted in the Simanjiro and Kibaoni.

3.5 Human Activities in Tarangire-Manyara Ecosystem

A total of thirteen human activities were recorded in the surveyed area, of which the estimates are presented in Table 7. The most abundant human activity recorded in Tarangire–Manyara ecosystem was cattle (331,336 ±25,503) followed by shoats (sheep and goats) (228,360 ±18,728). Other major human activities were settlements and cultivation (Table 7).

Table 7: Human activity estimates in the Tarangire -Manyara ecosystem

Human activities	No Obs	Counts	Estimate	SE
Cattle	153	32,677	**331,336**	25,503
Shoat (sheep and goats)	125	21,473	**228,360**	18,728
Boma: Occupied	105	918	**9,633**	3,144
Cultivation	126	811	**8,242**	2,072
Thatched House	82	585	**6,643**	1,046
House with mabati roof	71	398	**4,613**	742
Donkey	55	381	**4,393**	702
Boma: Abandoned	77	225	**2,979**	539
Boma: Unoccupied	88	221	**2,274**	219
Charcoal Kiln	18	63	**874**	249
Canoe	4	4		
Fish Camp	2	3		
Hut inside Boma-occupied	1	1		

3.5.1 Human activity estimates by administrative areas

Livestock husbandry was the most abundant human activity in the surveyed area. The highest number of cattle was observed in the Simanjiro (119,505 ±13,900), Makame WMA (54,955 ±13,664) and Lolkisale (32,653 ±8,521). The second most abundant human activity was sheep and goat husbandry in the Simanjiro (75,813 ±10,590), Makame WMA (35,489 ±8494) and Mto wa Mbu (34,656 ±7,892) (Table 8).

Table 8: Human activities by administrative area

	Burunge WMA				Kibaoni				Kwa Kuchinja				Lake Manyara NP				Loiborsoit				Makame WMA			
Type	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE
Beehive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boma - occupied	11	523	4,510	2,866	4	10	87	41	15	21	189	29	1	1	8	8	12	109	931	481	13	50	541	144
Boma - unoccupied	5	8	69	28	3	4	35	21	7	13	105	37	1	1	8	8	10	27	289	63	8	11	216	66
Boma - abandoned	0	0	0	0	1	1	9	9	0	0	0	0	0	0	0	0	13	20	177	39	14	76	1,370	510
Canoe	3	3	26	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cattle	14	3,308	28,526	6,727	6	981	8,575	3,366	20	3,537	28,481	3,928	1	1,048	8,236	8,559	18	3,682	32,653	8,521	15	3,049	54,955	13,664
Cattle dip	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Charcoal kiln	1	1	9	8	0	0	0	0	0	0	0	0	0	0	0	0	2	8	71	48	4	13	216	111
Cultivation	15	40	345	42	9	23	152	62	10	15	121	40	0	0	0	0	11	79	701	434	13	43	775	178
Donkey	4	48	414	177	1	2	17	15	6	43	346	161	0	0	0	0	5	26	231	101	6	46	829	416
Fish camp	0	0	0	0	0	0	0	0	1	2	16	16	1	1	8	8	0	0	0	0	0	0	0	0
Hut - metal roof	11	69	595	115	4	12	105	59	9	43	346	231	0	0	0	0	8	40	355	115	5	32	577	462
Shoats (sheep and goats)	14	1,571	13,565	2,175	6	289	2,526	754	14	2,408	19,390	5,686	1	316	2,483	2,581	14	2,439	21,630	5,072	13	1,969	35,489	8,404
Hut - thatched	8	27	233	60	3	12	105	46	8	31	258	75	1	5	39	41	7	41	364	128	11	123	2,217	894
Treefelling	2	2	17	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Mkungunero				Mto wa Mbu				Out west				Outside South				Simanjiro				Tarangire NP			
Type	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE	N. obs	Count	Est	SE
Beehive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boma - occupied	8	48	775	570	9	100	1,851	1,037	5	7	61	24	3	3	50	21	24	70	605	119	0	0	0	0
Boma - unoccupied	11	23	354	69	4	8	151	71	5	5	44	16	2	1	30	19	29	106	917	146	3	11	87	67
Boma - abandoned	12	39	608	124	0	0	0	0	4	8	70	36	4	1	100	56	28	71	614	90	1	4	32	30
Canoe	1	1	16	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cattle	13	1,323	20,819	4,708	9	955	16,165	4,351	1	101	1,400	718	4	550	9,136	2,484	44	13,018	119,505	13,000	3	324	2,553	2,210
Cattle dip	0	0	0	0	1	1	19	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Charcoal kiln	1	4	66	35	0	0	0	0	1	1	16	15	4	21	381	105	1	12	104	56	0	0	0	0
Cultivation	13	81	1,281	305	3	5	95	48	12	21	184	32	5	25	415	80	29	458	3,981	2,002	8	21	165	70
Donkey	9	67	1,099	147	4	14	265	136	0	0	0	0	1	4	66	45	18	122	1,055	266	1	9	71	67
Fish camp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hut - metal roof	7	60	976	156	8	41	754	252	2	4	35	25	0	0	0	0	17	90	890	208	0	0	0	0
Shoats (sheep and goats)	11	764	13,413	2,157	6	1,011	16,656	7,892	2	42	368	240	2	320	5,315	1,299	36	8,766	75,813	10,560	4	725	5,713	1,918
Hut - thatched	10	42	681	104	1	2	38	35	5	9	79	36	2	14	233	137	23	274	2,370	471	3	9	71	39
Treefelling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

n.b. Allocation of estimates to administrative areas is limited by the inherent inaccuracy of subunits (± 1.25km accuracy) and available GIS data. While some incursions of livestock and habitation or cultivation were estimated inside protected areas during flights, estimates inside protected areas are generally from areas close to boundaries (see maps) and should be checked on the ground.

3.5.2 Human Activity Trends

Human activity trends were generated by comparing the estimates of the previous aerial survey (dry season 2011) with the current census estimates. Thirteen human activities were observed in the Tarangire-Manyara ecosystem in 2016 aerial census, among these only seven human activities qualified for *d*-test. Four human activities showed an increasing trend (the *d*-value is greater than 1.96), these are cattle (*d*=5.15), shoats (*d*=4.27), thatched roof houses (*d*=2.73) and donkeys (*d*=2.58). Three human activity showed a stable trend (the *d*-value is less than 1.96), these are bati roof houses (*d*=1.24), occupied bomas (*d*=1.66) and farm plots (d=1.7), Table 9.

Table 9: Human activity trend in Tarangire-Manyara ecosystem, dry season 2016

	1990		1994		2004		2007		2011		2016		2007/04	2011/07	2016/11
Species Name	**Estimate**	SE	**Estimate**	SE	**Estimate**	SE	**Estimate**	SE	**Estimate**	SE	**Estimate**	SE	d-test	d-test	d-test
Cattle	**52,290**	13,389	**134,268**	19,699	**137,249**	19,018	**196,950**	26,463	**164,878**	19,857	**331,013**	25,503	-0.41	1.50	**5.14**
Shoats	**38602**	1991	**82477**	6794	**107748**	18926	**121740**	22693	**113671**	19213	**228,360**	18,728	-0.41	1.50	**4.27**
Boma occupied	**903**	213	**2936**	466	**4150**	563	**16411**	1606	**3455**	514	**9,633**	3,144	-1.51	0.54	1.94
Farm plots	**8,456**	2754	**40,299**	6905	**4,086**	855	**49,152**	7345	**4,477**	772	**8,242**	2,072	1.76	-1.82	1.70
Thatched roof	**2,925**	638	**17,426**	2945	**689**	297	**9,228**	1447	**3,316**	623	**6,643**	1,046	-0.28	-0.27	**2.73**
Mabati roof	**50**	36	**1641**	67	**769**	370	**12268**	3180	**3392**	644	**4,613**	742	**-2.19**	1.91	1.24
Donkey	**150**	93	**4,909**	196	**2,340**	868	**1,284**	450	**2,124**	527	**4,393**	702	-1.02	1.07	**2.58**

**d-tests (right three columns) compare succeeding surveys: 2004 and 2007, 2007 and 2011, 2011 and 2016. Significant values are shown in dark bold.*

3.5.3 Cattle distribution and density

Cattle were widely distributed over the entire surveyed area (

Figure 31). Highest concentrations were observed in the Simanjiro, Kibaoni, Kwakuchinja, Mto wa Mbu, Mkungunero, and the swamps of Makame WMA. Relatively low cattle density was observed in the Outside South area.

Cattle show a strong increase from 1990 onwards, with the population almost doubling from 2007 and 2011 (

Figure 30). It is unknown how much of this represents a local increase or how much could represent an influx of animals from other parts of the country or even internationally, but reflects patterns seen in other survey areas.

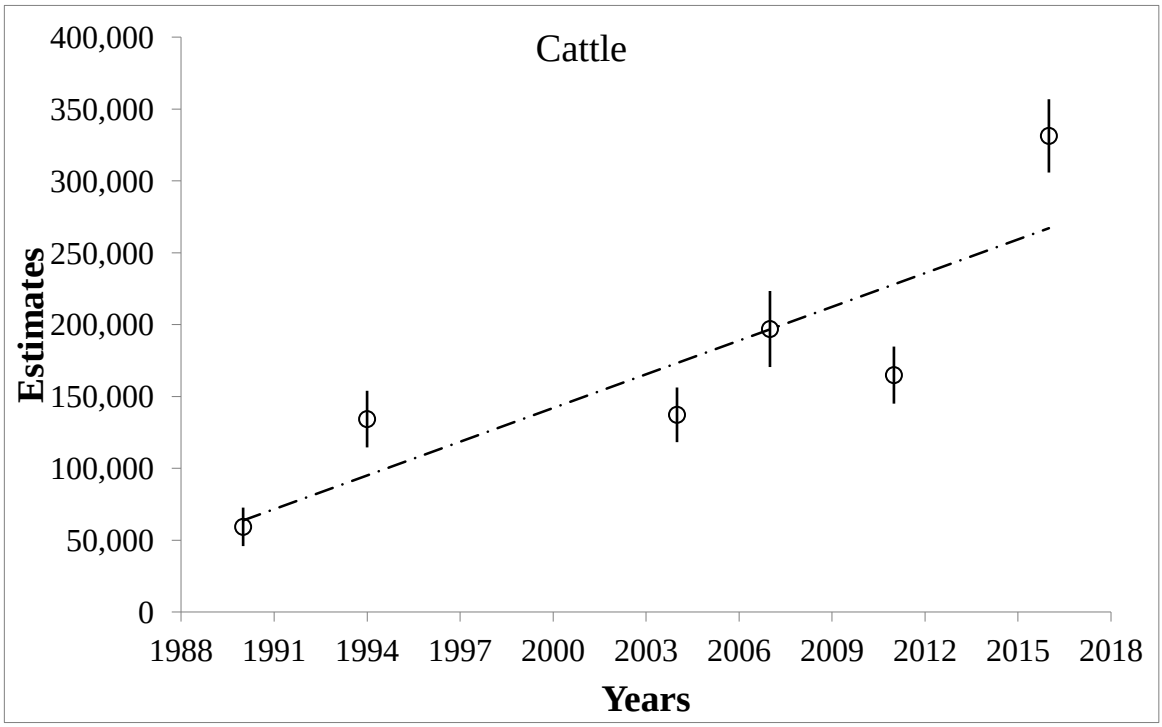

Figure 30: Cattle population trend in Tarangire-Manyara ecosystem, dry season 2016

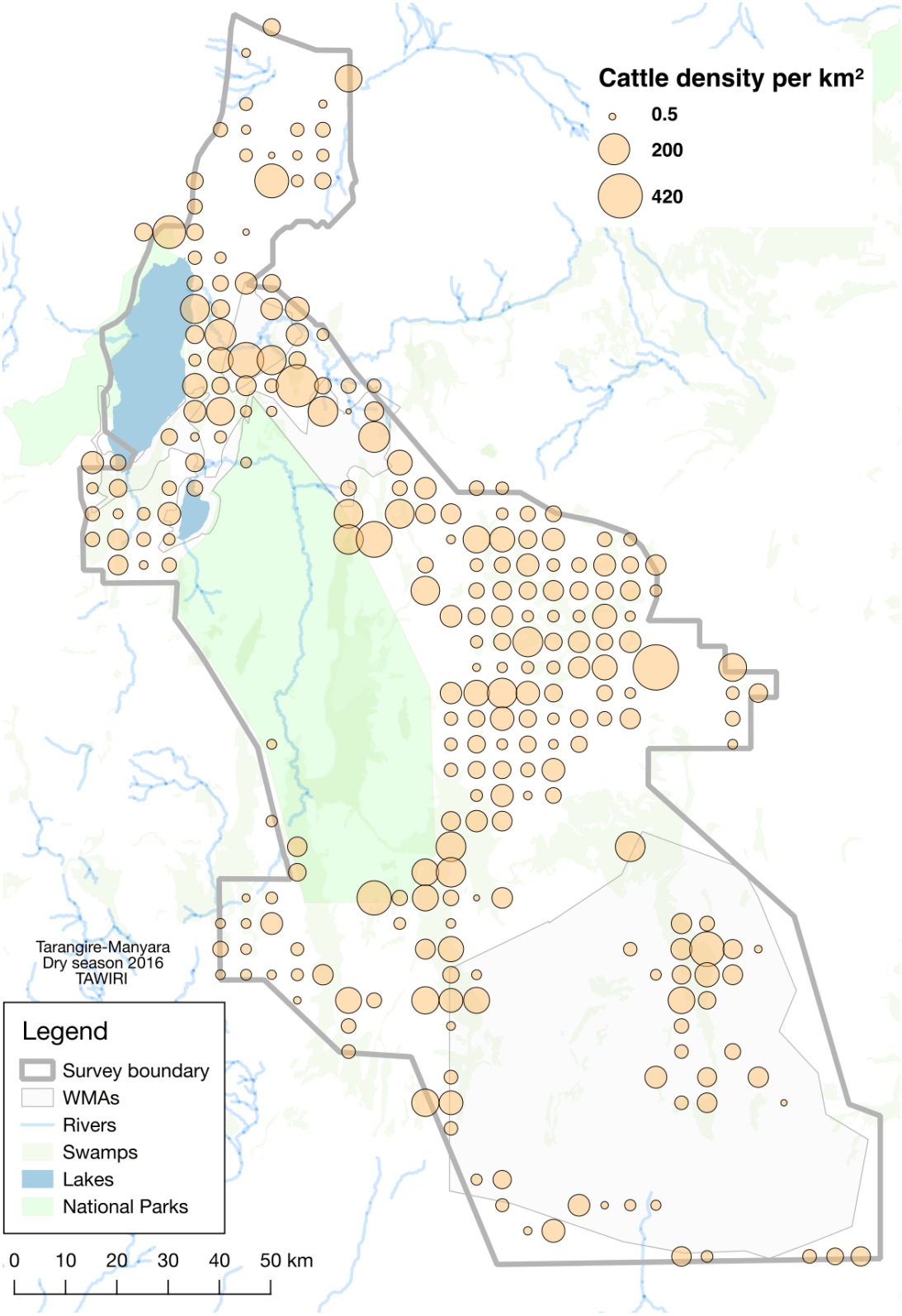

Figure 31: Cattle distribution and density in the Tarangire-Manyara Ecosystem, dry season 2016

3.5.4 Shoat distribution and density

Similar to cattle, shoats (sheep and goats) were widely distributed over entire surveyed area with few individuals along the Southern boundary of Tarangire National Park. The highest concentrations of shoats were observed in Simanjiro, Kibaoni, Kwakuchinja, Lolkisale, Mto wa Mbu and Mkungunero. Relatively low density was observed in the Outside South area (
Figure 33).

As with cattle, shoats show increases from 1990 up to 2016, more than doubling from 2007 and 2011 to 2016 (
Figure 32).

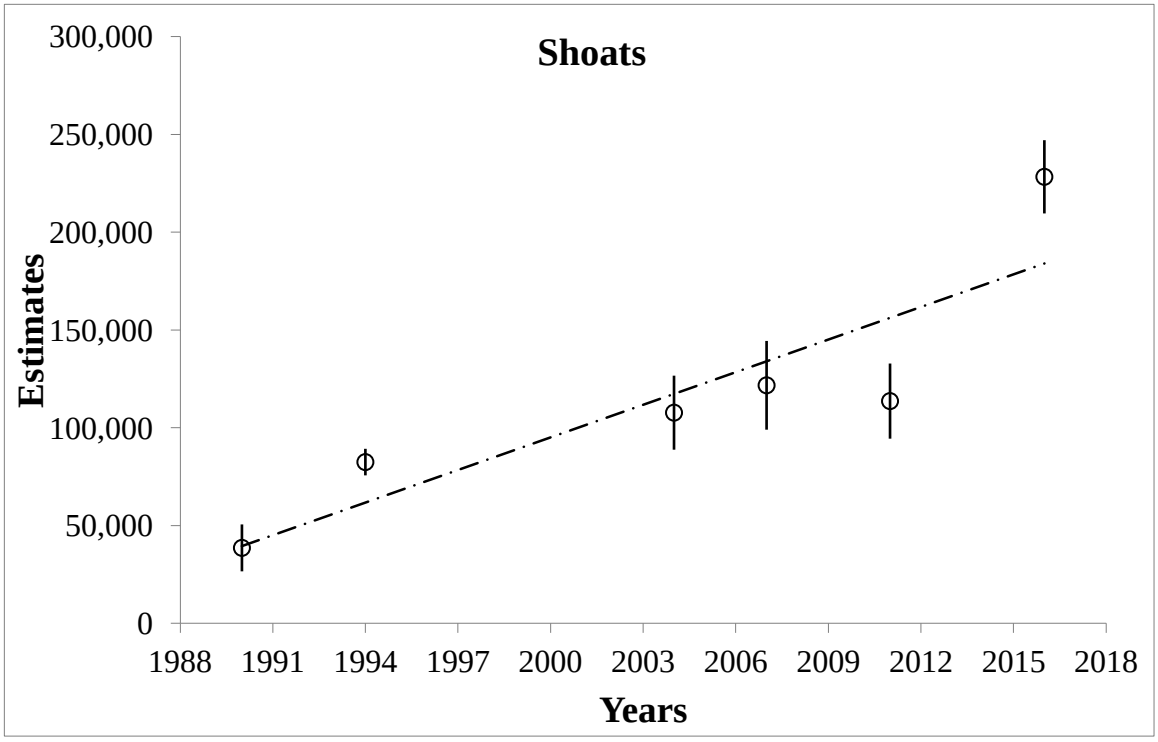

Figure 32: Shoats population trend in Tarangire-Manyara ecosystem, dry season 2016

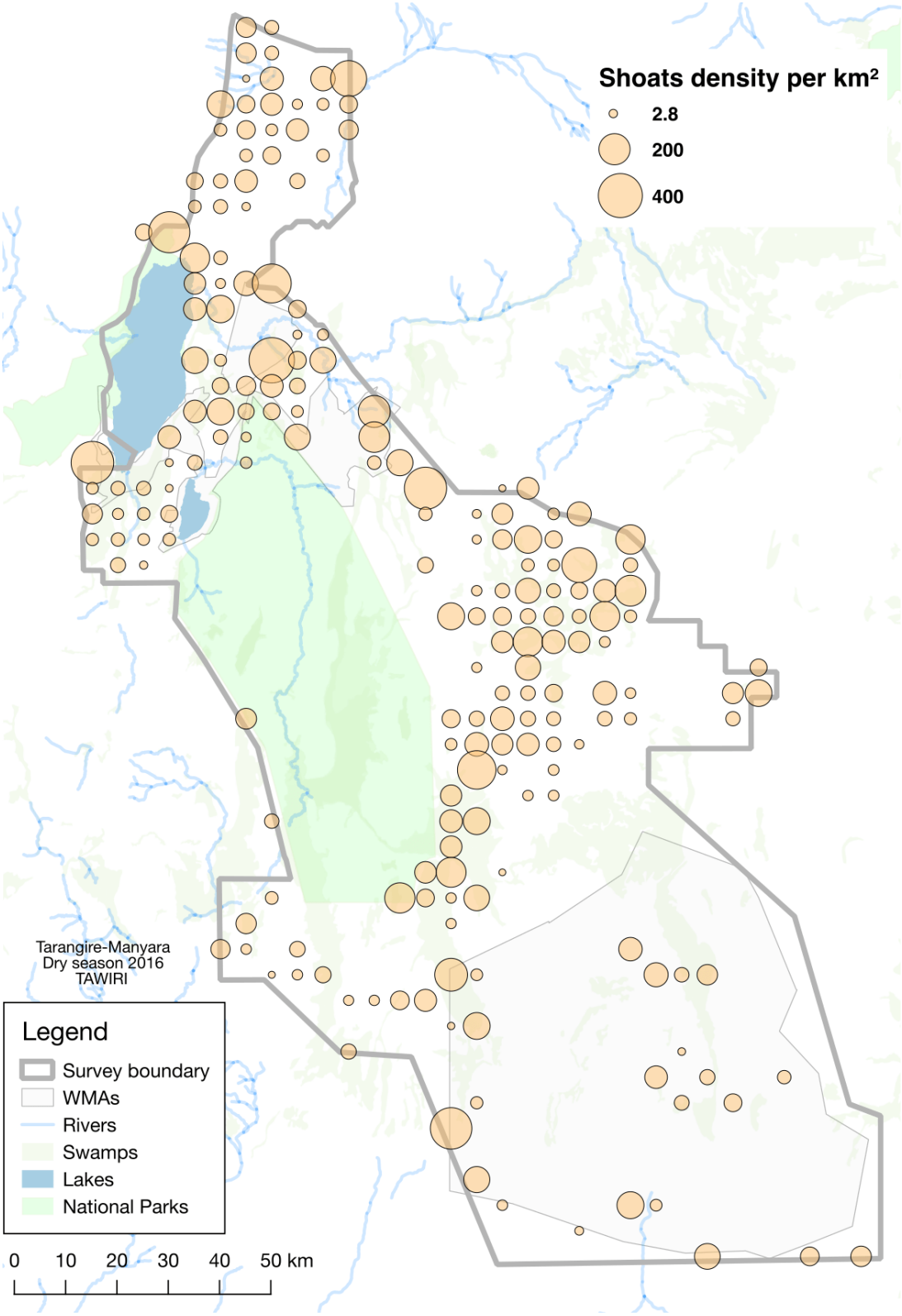

Figure 33: Shoat distribution and density in the Tarangire - Manyara ecosystem, dry season 2016

3.5.5 Agriculture

The 2016 aerial census over the Tarangire-Manyara ecosystem shows that agriculture is practiced in all administrative areas. The highest intensity of cultivation was observed in Simanjiro, Kibaoni, Mkungunero and Kwakuchinja. Relatively low intensity cultivation was observed in Outside South and Mto wa Mbu (
Figure 35).

Note: SRF is not suited to detecting land use and its trends, as demonstrated in

Figure 34 *below. It is difficult to determine what counts as a 'farm plot' from the air, and small changes in seasonality can dramatically change how the land is planted. Similar problems are experienced with houses and clusters of houses.*

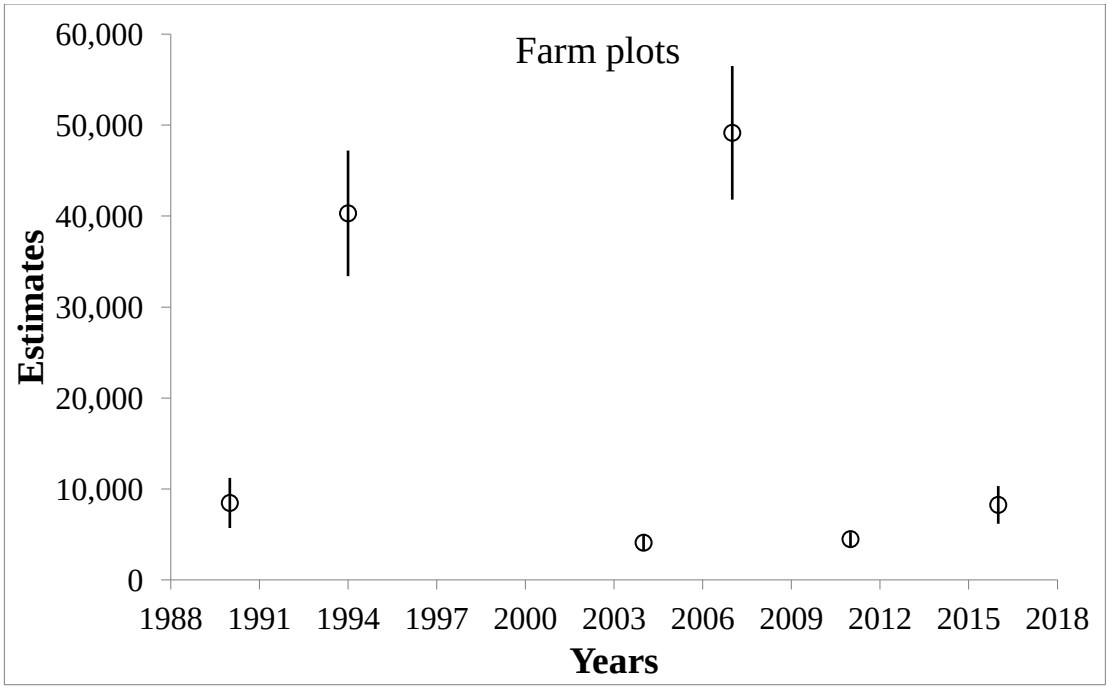

Figure 34: Farm plots trend in Tarangire-Manyara ecosystem, dry season 2016.

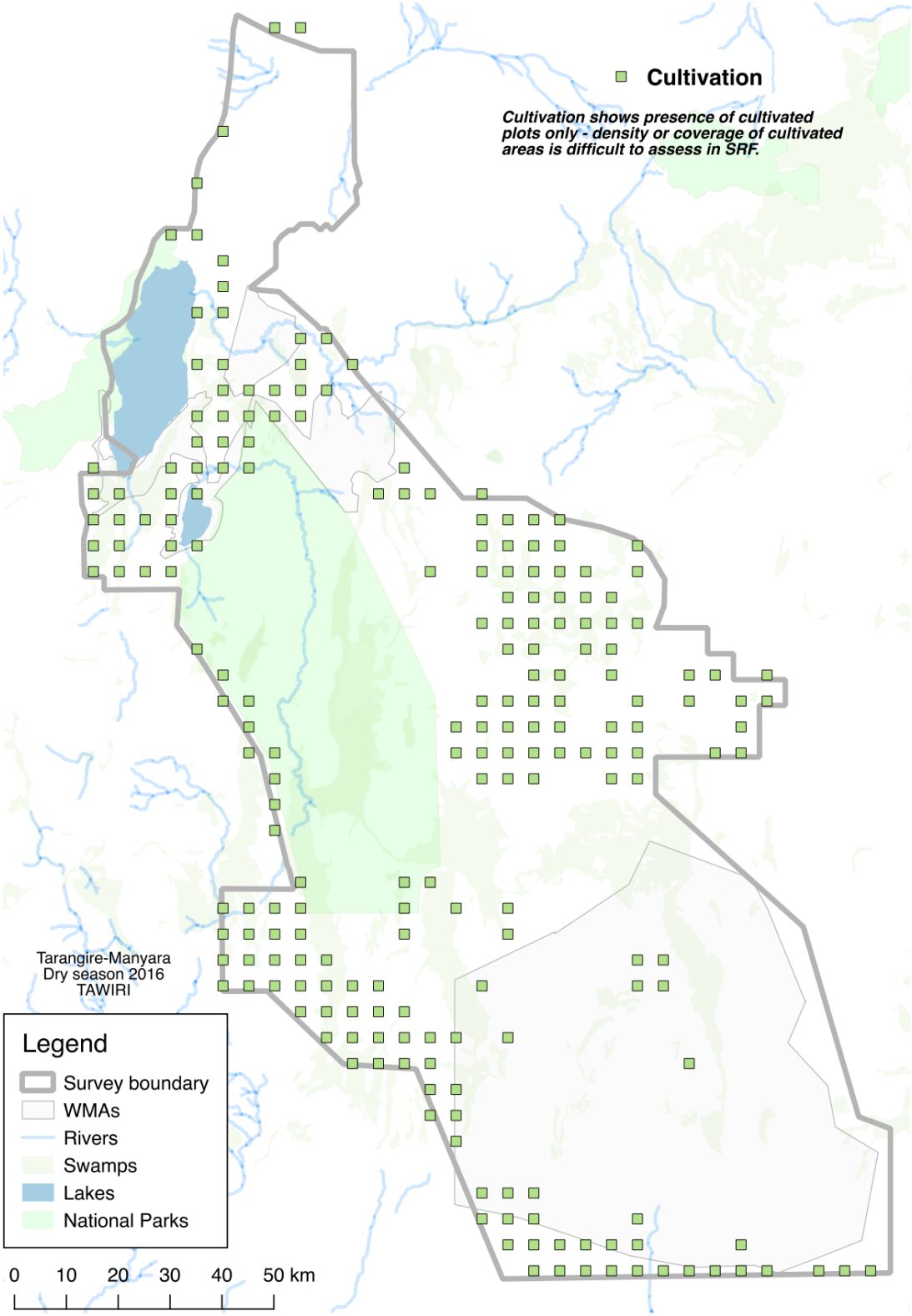

Figure 35: Cultivation distribution in the Tarangire-Manyara Ecosystem, dry season 2016

3.5.6 Human Settlements

Recorded types of human settlements are *bati* roofs (corrugated iron sheet), thatched roofs, occupied bomas, unoccupied bomas and abandoned bomas. Human settlements were widely distributed over the survey area, with fewer settlements close to the southwestern part of the Tarangire National Park. The distribution pattern of human settlements is very similar to that of agriculture and livestock (see Figure 39 and Figure 40).

Note: the geographic accuracy from aircraft observations and the generalisations from mapping methods lead to uncertainty about locations; while results presented here may suggest "illegal" settlements inside protected areas, these must be verified on the ground as they may only represent structures found close to the boundaries.

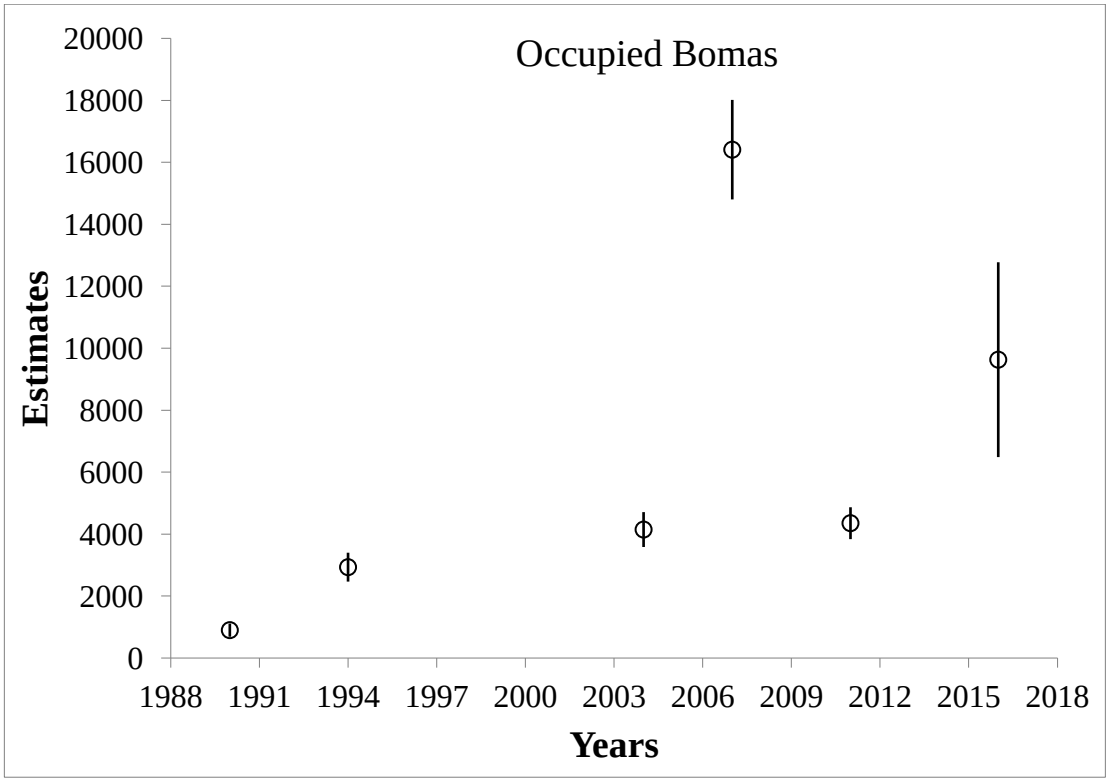

Figure 36: Occupied bomas trend in Tarangire-Manyara ecosystem, dry season 2016

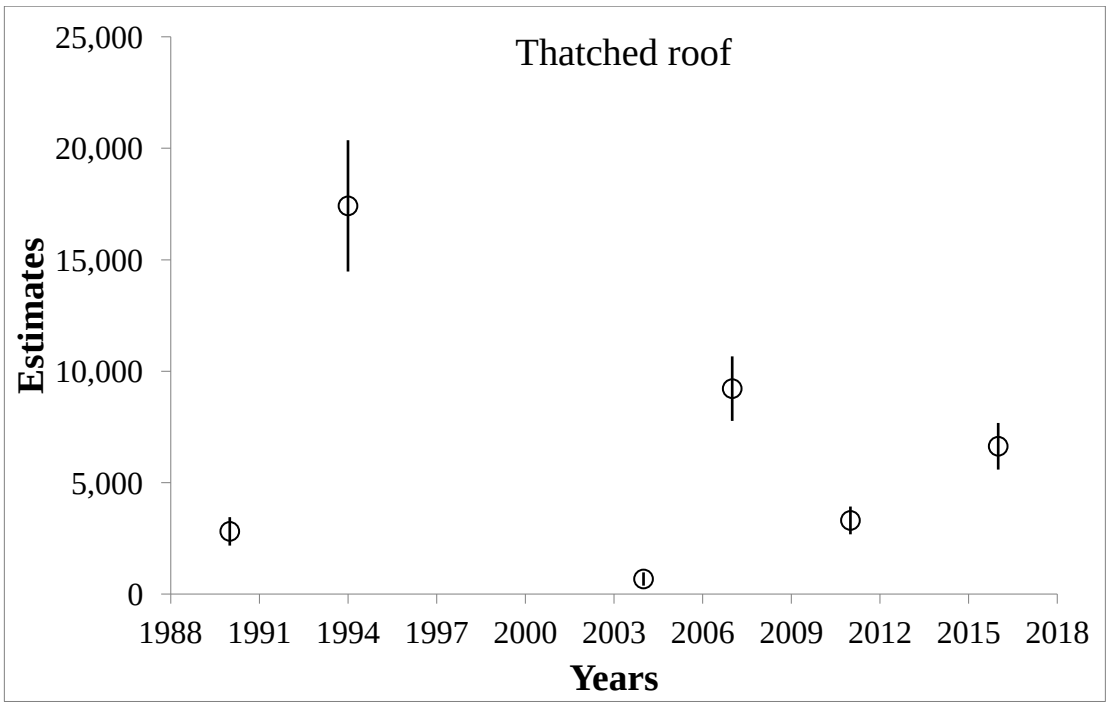

Figure 37: Thatched roof trend in Tarangire-Manyara ecosystem, dry season 2016

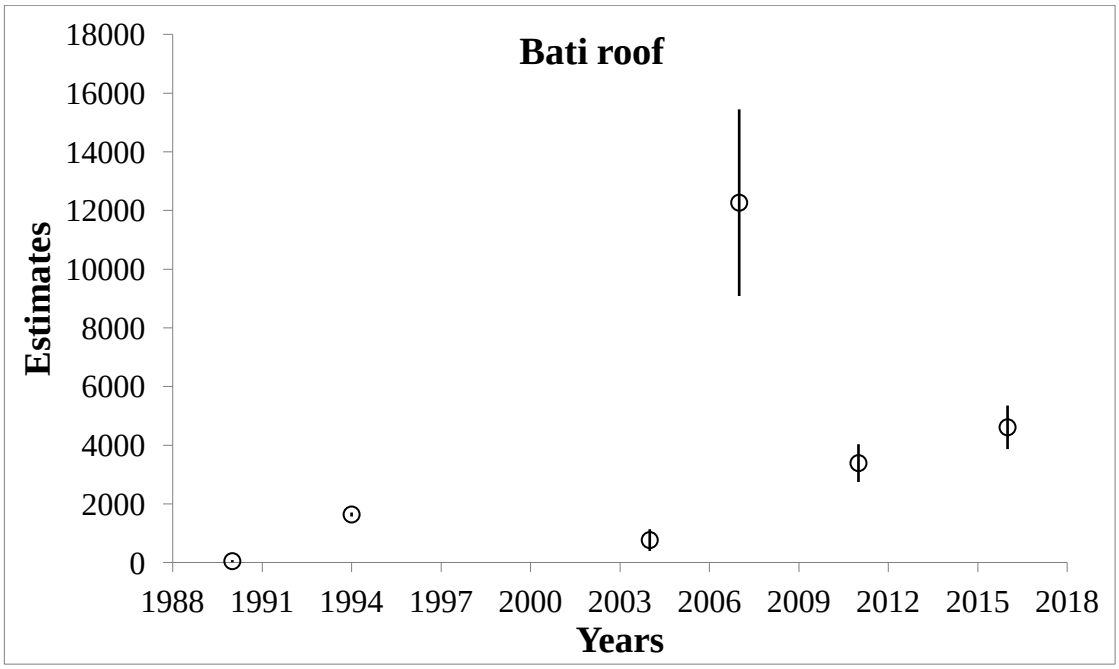

Figure 38: Bati roof trend in Tarangire-Manyara ecosystem, dry season 2016

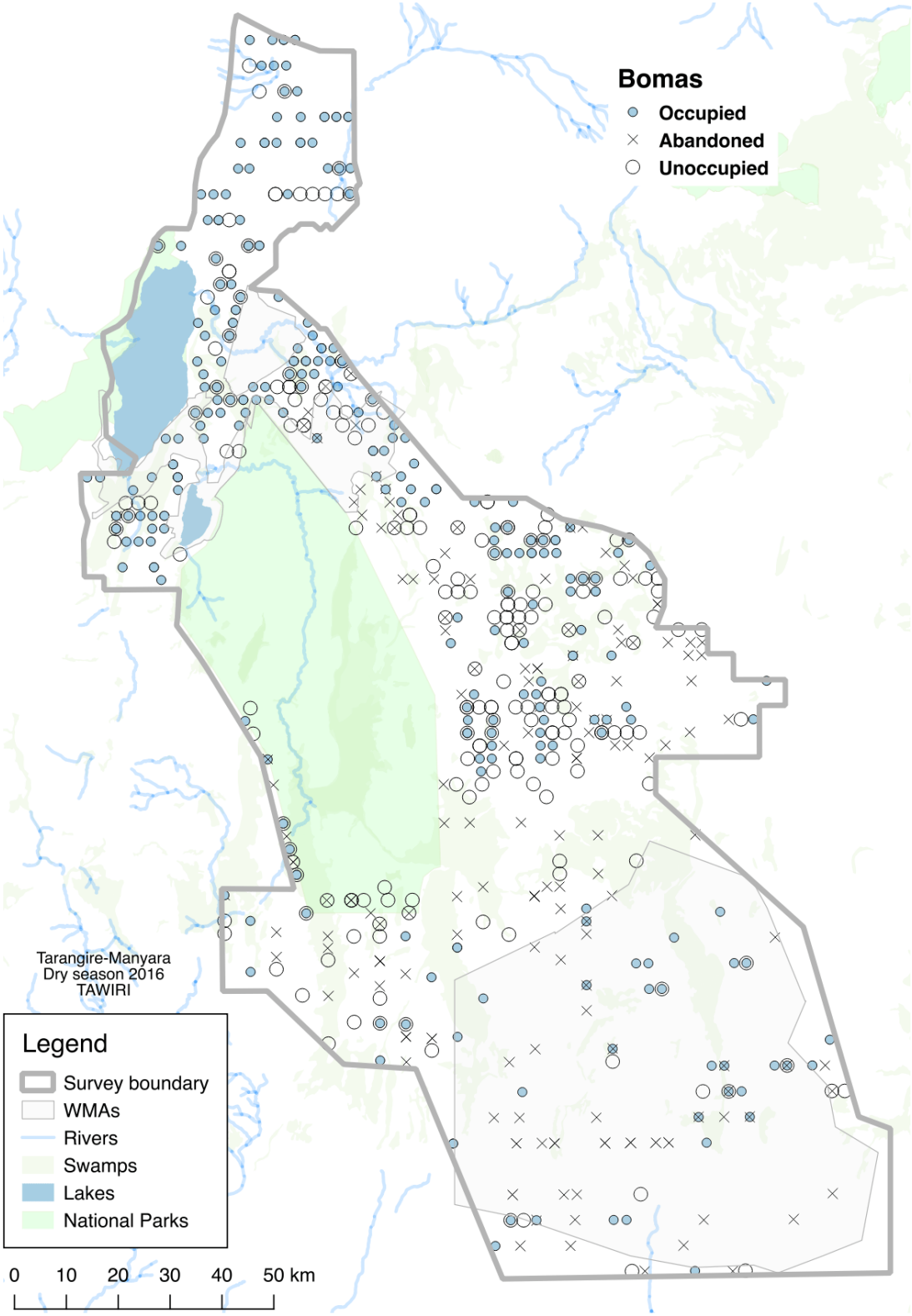

Figure 39: Boma distribution in the Tarangire-Manyara Ecosystem, dry season 2016

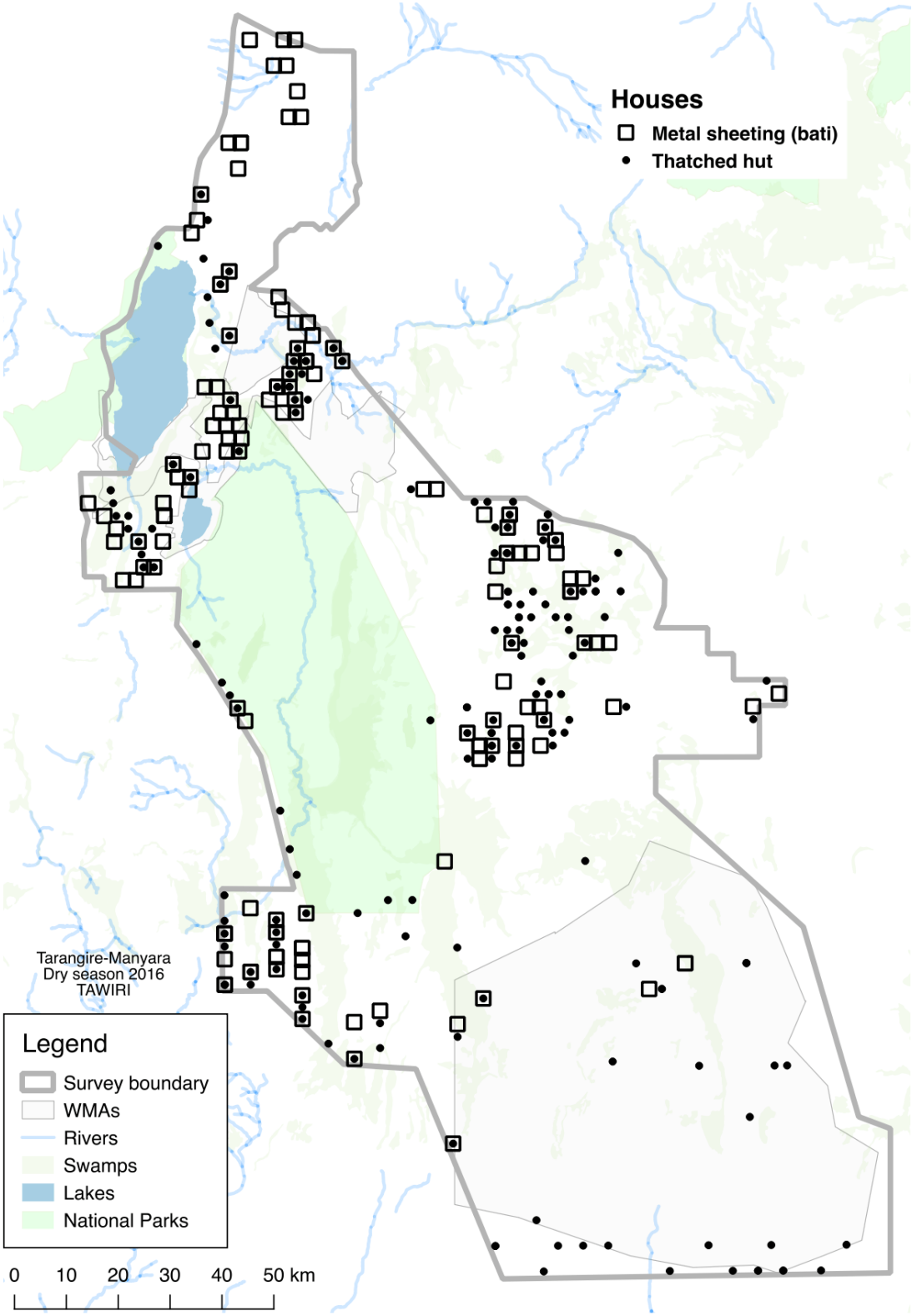

Figure 40: Bati and thatched roof distribution and density in the Tarangire-Manyara Ecosystem, dry season 2016

3.5.7 Tree felling and charcoal kiln density and distribution

Charcoal kilns were found in a few areas, namely Simanjiro, Outside South, and a few on the boundary of Tarangire National Park. Two sites of tree felling were spotted in Kibaoni and widely distributed in the southern part of Makame WMA (Figure 41).

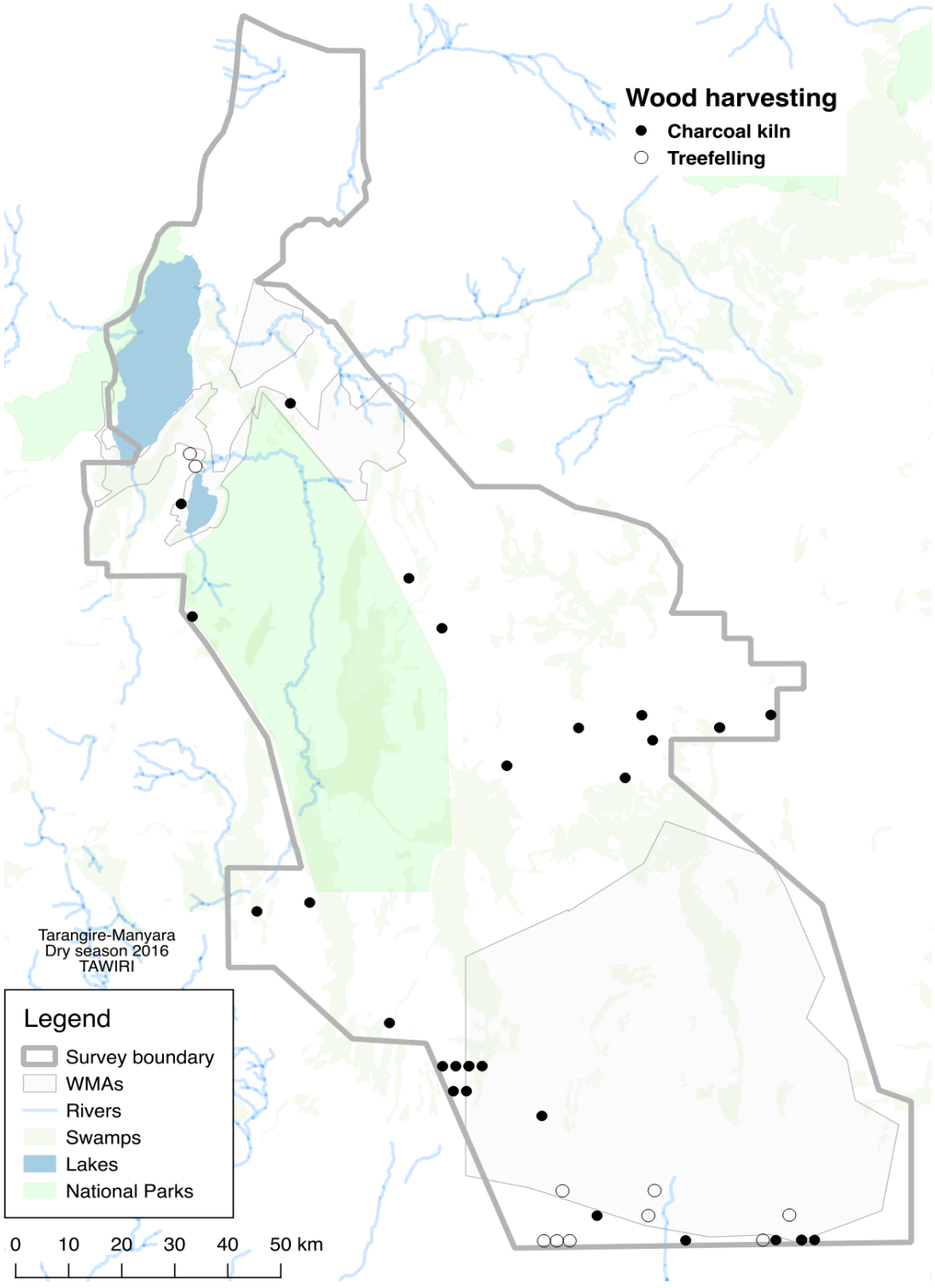

Figure 41: Tree felling and Charcoal kiln locations in the Tarangire-Manyara Ecosystem, dry season 2016

4 Acknowledgements

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6 Appendices

6.1 Appendix i: List of Census Crew for the 2016 Dry Season Aerial Census Over the Tarangire-Manyara Ecosystem.

Aircraft	5H-TPM (TANAPA)	5H-TPK (TANAPA)
Pilot	B. Kessy (TANAPA)	D. Mwano (TANAPA)
FSO	M. Mwita (TAWIRI)	W. Marealle (TAWIRI)
Left RSO	Azori Mosi Migezo (WD)	S. Mwambola (TAWIRI)
Right RSO	Gabriel Nyaki (TANAPA)	Peter Chacha (NCAA)
Aircraft	5H-TPM (TANAPA)	
Pilot	W. Minja (WD)	
FSO	W. Marealle (TAWIRI)	
Left RSO	S. Mwambola (TAWIRI)	
Right RSO	Peter Chacha (NCAA)	

6.2 Appendix ii. List of Ground Crew Participation for The 2016 Dry Season Aerial Census of the Tarangire-Manyara Ecosystem

Scientific Supervision	Dr. Simon Mduma (TAWIRI)
Field Supervision	Dr. Edward Kohi (TAWIRI)
Logistics and Coordination	H. Maliti (TAWIRI); Enyasi Lejora (TANAPA) and Alex Choya (WD)
Survey Technical Advisor	H. Frederick (Consultant)
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6.3 Appendix iii: Species List

The following is a list of all species recorded in the 2016 aerial census in the Tarangire-Manyara Ecosystem. Nomenclature follows Foley *et al* 2014.

Mammals		**Birds**	
Olive baboon	*Papio cynocephalus*	Ground hornbill	*Bucorvus leadbeateri*
Fringed-eared oryx	*Oryx gazella*	Ostrich	*Struthio camelus*
Buffalo	*Syncerus caffer*	Pelican	*Pelecanus onocrotalus*
Bushbuck	*Tragelaphus scriptus*	Marabou stork	*Leptoptilos crumenifer*
Bohor reedbuck	*Redunca redunca*		
Bush pig	*Potamochoerus porcus*		
Duiker, common	*Sylvicapra grimmia*		
Eland	*Taurotragus oryx*		
Elephant	*Loxodonta africana*		
Giraffe	*Giraffa camelopardalis*		
Grant's gazelle	*Gazella granti*		
Greater kudu	*Tragelaphus strepsiceros*		
Kongoni	*Alcelaphus buselaphus*		
Impala	*Aepyceros melampus*		
Bohor reedbuck	*Redunca redunca*		
Vervet monkey	*Cercopithecus aethiops*		
Warthog	*Phacochoerus aethiopicus*		
Waterbuck	*Kobus ellipsiprymnus*		
Wildebeest	*Connochaetes taurinus*		
Zebra	*Equus burchelli*		
Dik-dik	*Madoqua kirkii*		
Steenbok	*Raphicerus campestris*		
Thomson's gazelle	*Eudorcas thomsonii*		

7 Glossary of Important Census Terminology

7.1 Survey Area (Z)

The survey area (also referred to as census zone) is defined as the whole area in which the number of animals is to be estimated. In some censuses the survey area is divided into sub-zones (strata) for various reasons. For example, divisions could be based on political and/or management boundaries, or ecological zones.

7.2 Sample

The sample zone is that portion of the survey area that is actually searched and counted. To count every single animal in a protected area would be prohibitively expensive and time-consuming (sizes of protected area range from about 200 to 80,000 km^2). For this reason, only parts of the survey area are searched, and the method assumes that what is seen in those parts (samples) are about the same as what we would see if we searched over the other parts. In an SRF survey the sample zone is made up of transects and each transect is a sample unit.

7.3 Population Estimate (Y)

All animals and human activities within the counting strips are recorded during an SRF. The assumption is made that animals are evenly distributed over the survey area so that if 10% of the area is searched, it will contain about 10% of the animals. This allows us to estimate the number of animals in the survey area. The *standard error* is used to gauge the reliability of our population estimate.

7.4 Standard Error (Se)

Because animals are never distributed evenly over the census zone, each transect (sample) will vary in the density of animals that it contains. Any single population estimate may therefore be higher or lower than the true population total. The potential magnitude of this sampling error can be determined by examining the variation between the numbers of animals counted in each of the sample units. The *standard error* is a measure of this variation.

If the standard error is small, then we can estimate the population to within a narrow range of numbers (we say the estimate is precise). If the standard error is high, the true population estimate lies within a wide range of possible numbers. **Caution must be taken when interpreting estimates with wide standard errors** (above 20% of the estimate) as a wider SE, indicates a less reliable estimate. Critical management decisions should not be based on a single SRF estimate and, more specifically, one with *wide standard errors.*

7.5 Confidence Limits (Cl)

The population sizes presented in our reports are estimates (see "Population estimate", above), and therefore, it is helpful to know the lowest and highest probable population size. Confidence limits are a way of describing these upper and lower bounds on our estimate. By default, the confidence limits presented in our reports are “95% confidence limits", that is, there is a 95% probability that the true population size falls within these limits. The formula for calculating the 95% confidence limits is:

95% CL = $Y \pm$ (SE x t value).

Where: Y = Population estimate

SE = the standard error of the estimate Y.

"t critical value" depends on sample size (number of transects).

7.6 SIGNIFICANT DIFFERENCE (*d*-Test Between Population Estimates)

It is often useful to compare two or more population estimates for a given species, to see whether the species is increasing or decreasing in numbers. If estimates from two different surveys are different, it might be due to:

1. Chance. Estimates always vary from one survey to another because of how the animals are distributed, and due to which transects (of all the possible transects) we flew.
2. The number of animals in the protected area have increased or decreased.

d-value is used to test the difference between two independent estimates. The statistical test takes into account the *standard error* of a population estimate to determine whether the variation between estimates is more likely to be due to sample variation or a true change in population size. A *significant difference* between population estimates strongly suggests that the population has increased or decreased between surveys. If the difference is *not significant*, then we do not have any statistical evidence for population change; in effect, we must assume the population has stayed the same. Two estimates are significantly different from each other at the 5% level if the *d*-value is greater than 1.96.