1. Introduction

Conducting aerial surveys is one of the core functions of the Ministry of Environment and Tourism. The surveys are essential management tools, allowing for informed decision making.

Aerial surveys have been conducted in Etosha National Park since 1968. Apart from a series of elephant surveys, these surveys were strictly speaking not comparable as they were undertaken at irregular intervals with different sampling intensities and area cover. The first comprehensive multi-species sample count was conducted in 1995, and repeated in 1998, 2000, 2002 and 2004.

The objectives of the 2005 aerial survey were:

1. To provide comparable estimates and trend data for some key species in support of species and park management,
2. To obtain a population estimate of elephants as required within the MIKE program and for CITES,
3. To update the population estimate of black rhino in support of the black rhino National Management Plan.

The survey was conducted from 23 August to 11 September 2005 using the Ministry's two aircraft, a Cessna 206 (V5-PRO) and a Cessna 182 (V5-ISE).

2. Survey Design and Methodology

The survey covered an area of 18551 km², excluding the Etosha pan. The survey area was stratified according to the expected distribution of wildlife, conforming largely to the sampling design used in 2004. The survey zone was stratified into seventeen blocks (Figure 1) according to the availability of permanent water. Areas within ten kilometers of perennial water points were counted at a planned sampling intensity of 40%, except blocks 8 (Narawandu) and 9 (Eindpaal), which were sampled at 20% intensity due to a lower observed density of animals in the surrounding areas. Since 2002, three additional water points were opened in south-eastern Etosha, which necessitated increasing the sampling intensity around these watering points to 40%.

Transects in each block were selected at the required transect spacing. At a strip width of 500m, transect intervals were 1.25 km for 40% intensity, 2.5km for 20% and 5 km for 10%. The transects were orientated in a north-south direction, except block 10 where the transects run east-west and block 14 where the transects were laid out in a NW-SE direction. The actual flight paths for the survey are presented in Figure 2. A summary of the block data is presented in Table 1.

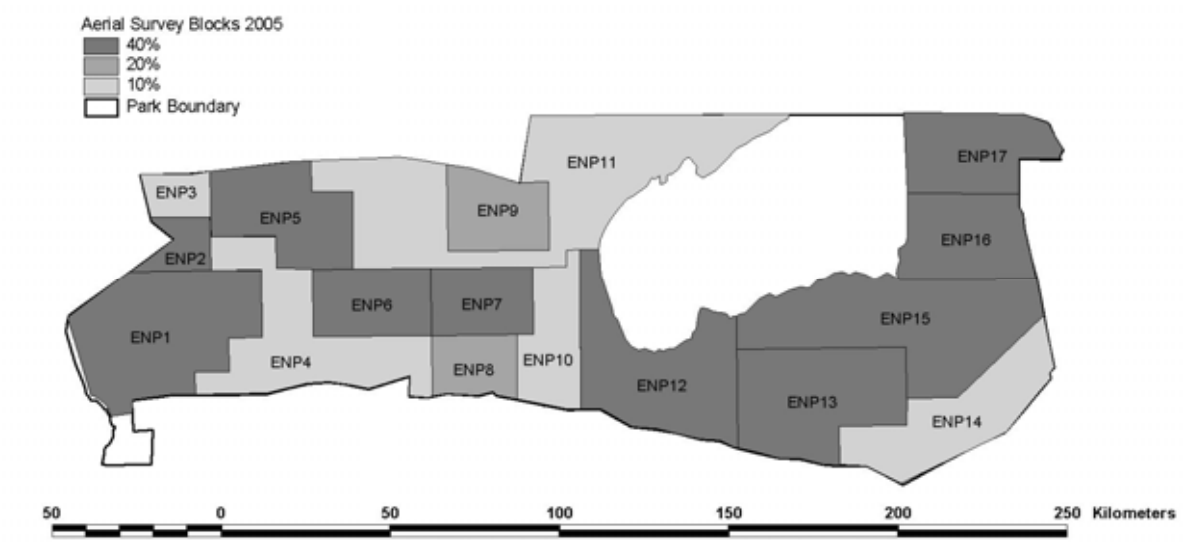

Figure 1: Layout of survey blocks and proposed intensity for the 2005 aerial survey.

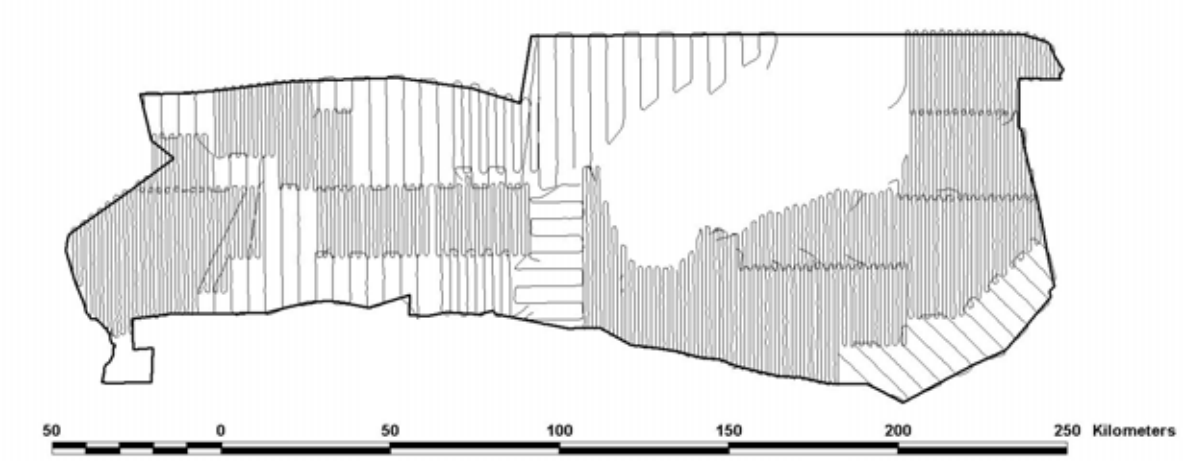

Figure 2: Actual flight paths for the 2005 aerial survey.

Table 1: Summary of data for the Etosha survey blocks.

Block	Transect Spacing (km)	Area (km²)	Total Transect Length (km)	Average Height (ft agl)	Strip Width (m)	Search Time (min)	Area Searched (km²)	Area of Block Searched (%)	Search Rate (km²/min)
ENP1	1.25	1728.1	1370.9	304	426	356	583.9	33.8%	1.6
ENP2	1.25	259.8	202.5	309	433	54	87.7	33.7%	1.6
ENP3410*	5.00	2396.1	467.6	316	443	123	207.1	8.6%	1.7
ENP5	1.25	1006.7	787.6	303	424	198	334.1	33.2%	1.7
ENP6	1.25	701.0	540.4	302	423	141	228.5	32.6%	1.6
ENP7	1.25	600.7	460.3	305	428	129	196.8	32.8%	1.5
ENP8	2.50	441.9	158.1	302	422	45	66.7	15.1%	1.5
ENP9	2.50	665.4	244.6	299	419	70	102.5	15.4%	1.5
ENP11	5.00	2811.9	541.9	304	426	140	230.8	8.2%	1.6
ENP12	1.25	1489.4	1193.3	300	420	330	501.2	33.6%	1.5
ENP13	1.25	1427.4	1141.9	299	418	318	477.4	33.4%	1.5
ENP14	5.00	1145.3	226.8	314	440	66	99.7	8.7%	1.5
ENP15	1.25	2038.2	1628.5	301	422	438	686.5	33.7%	1.6
ENP16	1.25	918.1	728.3	301	421	199	306.6	33.4%	1.5
ENP17	1.25	921.2	733.7	300	420	206	308.2	33.5%	1.5
		18551.1	**10426.5**			**2813**	**4417.7**	**23.8%**	**1.6**

* Blocks 3,4 and 10 were combined for analysis.

The survey was designed to calibrate the observers at a strip width of 250 metres on either side of the aircraft, following standard procedures. The boundaries of the strips on either side of the aircraft were delimited by a pair of streamers fixed to the lift struts of the wing. The calculated strip width (Norton-Griffifths 1978), for each observer is presented in Appendix 1.

The aircraft used in the survey were each equipped with two Garmin GPS 12 XL models. This ensured accurate navigation along the pre-determined transects, which had been downloaded as route files. Two observers called out the sightings of animals within the demarcated strips. The front seat recorder noted waypoints for each sighting, which included the species and number. The recorder also noted the height *above ground level* from the radar altimeter to allow for the calculation of the average height for each survey block, and additionally recorded the start and end times of each transect. The waypoint and flight data were downloaded to a personal computer using Ozi Explorer® software, after each flying session.

The localities of each sighting were plotted on maps using the Geographical Information System, ArcView® and ArcView Spatial Analyst® was used to generate density maps (Figure 3).

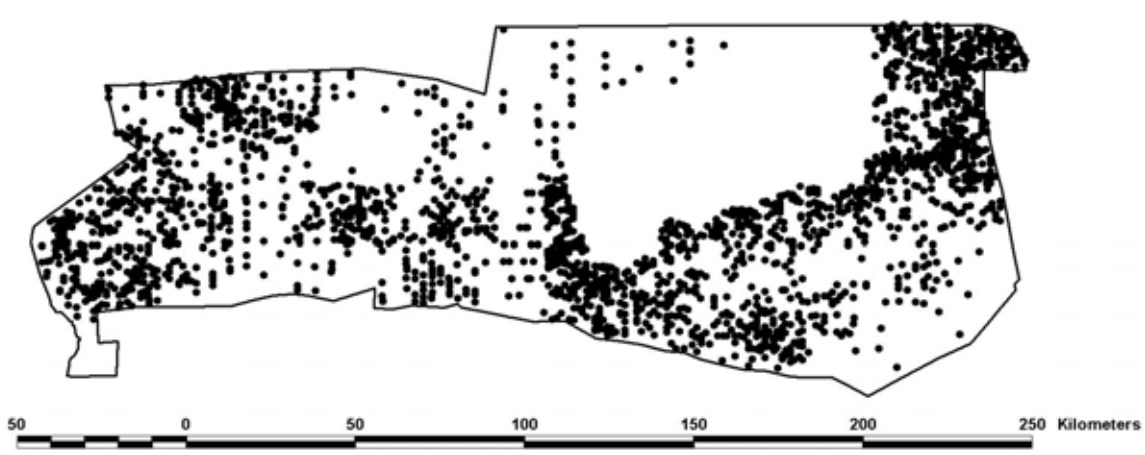

Figure 3: All sightings recorded during the 2005 aerial survey.

Jolly's method number 2 for unequal-sized sampling blocks was applied to the data. A spreadsheet model (Emslie 2002) was developed to calculate total population size, 95% confidence limits and the range for each species per stratum at 95% confidence limits. The equations as per Krebs (1999) were used. If the confidence limits were larger than 100%, the actual number of animals seen within the block was taken as the lower limit of the 95% range.

3. Results

Overall estimates of numbers of the most important species are summarised in Table 2. These species are those that can be counted through aerial survey sampling techniques with a reasonable degree of accuracy and precision. Table 2 includes population estimates, their 95% range, the actual number seen, and the densities for the whole of Etosha National Park.

Table 2: Summary of estimates and density of all species.

	Species	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
Ab	Red Hartebeest	375	1062	1527	1992	46986.2	465.0	30.4%	0.07
Am	Springbok	3631	13231	15550	17869	1169048.7	2319.2	14.9%	0.63
Ct	Blue Wildebeest	1308	3029	4244	5459	320909.0	1215.1	28.6%	0.22
Db	Black Rhino	256	683	807	931	3347.0	124.1	15.4%	0.04
Eb	Burchell's Zebra	3834	10937	12982	15027	908555.6	2044.6	15.7%	0.65
Gc	Giraffe	809	2722	3143	3564	38484.1	420.8	13.4%	0.15
La	Elephant	927	1941	2611	3282	97833.5	670.9	25.7%	0.13
Og	Oryx	1151	4955	5690	6425	117424.5	735.0	12.9%	0.23
Sc	Ostrich	722	2835	3345	3854	56397.7	509.4	15.2%	0.16
To	Eland	301	778	1103	1428	22944.8	324.9	29.5%	0.05

Table 3 to Table 12 summarise the estimates and summary data for selected species seen in each block. Figure 4 to Figure 14 present distribution and density maps, based on all sightings, for each species.

Table 3: Summary of estimates and density of red hartebeest.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	74	74	218	392	7394.7	174	79.74%	0.13
ENP2	16	17	47	78	221.0	31	64.89%	0.18
ENP3410	21	21	243	506	16579.4	263	108.39%	0.10
ENP5	62	62	187	344	5937.1	157	84.18%	0.19
ENP6	55	55	168	316	5197.3	148	88.30%	0.24
ENP7	3	3	9	25	58.0	16	173.45%	0.02
ENP8								0.00
ENP9	8	8	52	157	2225.9	105	203.39%	0.08
ENP11	3	3	36	103	1050.1	66	182.04%	0.01
ENP12	14	14	41	79	348.0	38	91.05%	0.03
ENP13	65	65	193	332	4700.3	139	71.62%	0.14
ENP14								0.00
ENP15	25	25	74	134	919.7	61	82.19%	0.04
ENP16	29	29	87	186	2354.5	99	114.11%	0.09
ENP17								0.00
Total	**375**	**1062**	**1527**	**1992**	**46986.2**	**465**	**30.44%**	**0.07**

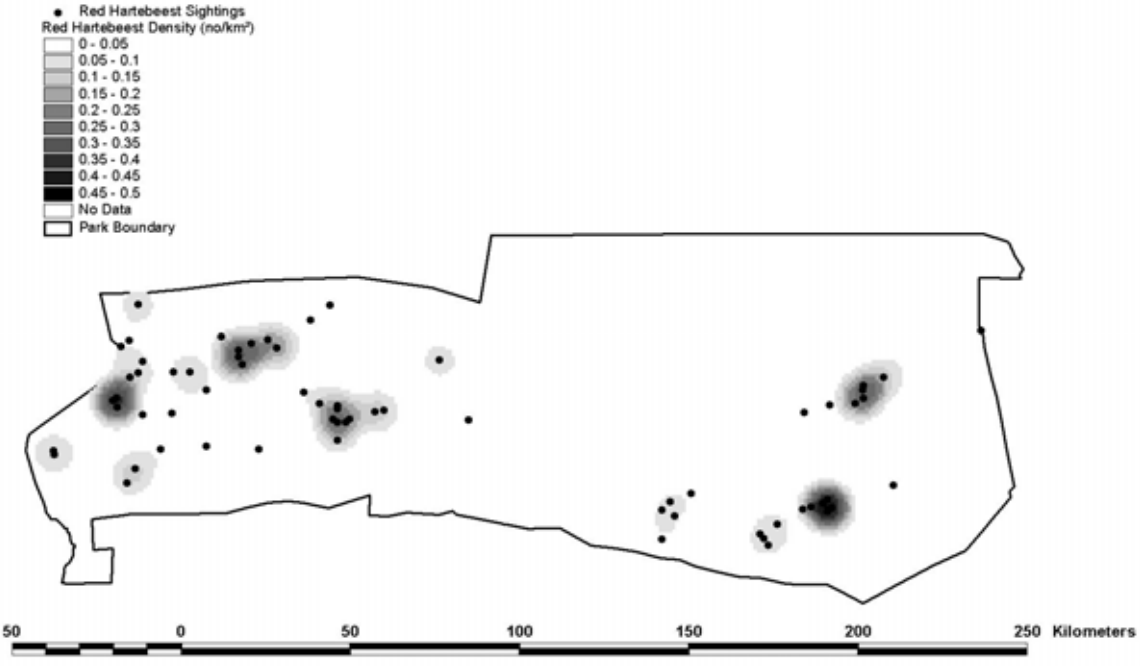

Figure 4: Distribution and density of red hartebeest.

Table 4: Summary of estimates and density of springbok.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	350	582	1031	1480	49353.6	449	43.55%	0.60
ENP2	179	179	530	1047	62443.1	517	97.50%	2.04
ENP3410	60	95	694	1293	85764.1	599	86.29%	0.29
ENP5	554	554	1670	2851	334670.6	1181	70.73%	1.66
ENP6	574	609	1752	2895	309044.8	1143	65.24%	2.50
ENP7	146	161	443	725	18462.7	282	63.60%	0.74
ENP8	56	56	369	741	26055.7	372	100.81%	0.84
ENP9								0.00
ENP11	3	3	36	87	613.9	51	139.19%	0.01
ENP12	701	1365	2073	2782	122974.2	709	34.18%	1.39
ENP13	46	46	137	254	3339.9	117	85.31%	0.10
ENP14								0.00
ENP15	398	661	1175	1689	66010.3	514	43.74%	0.58
ENP16	406	694	1216	1738	65343.2	522	42.94%	1.32
ENP17	158	158	472	792	24972.8	319	67.62%	0.51
Total	**3631**	**13231**	**15550**	**17869**	**1169048.7**	**2319**	**14.91%**	**0.63**

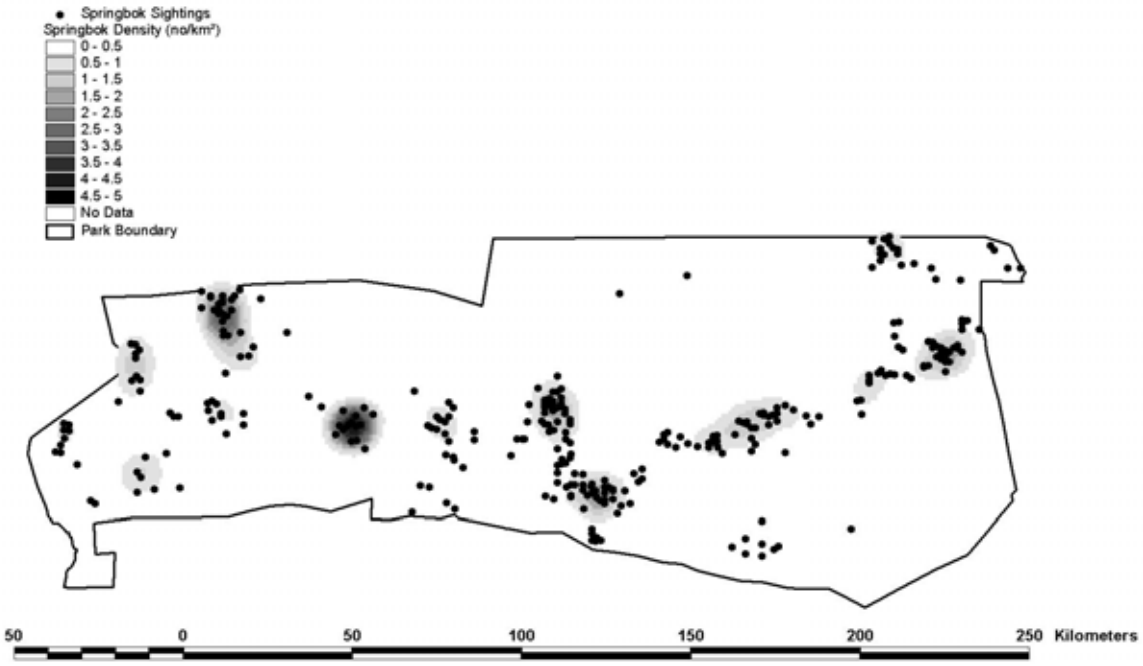

Figure 5: Distribution and density of springbok.

Table 5: Summary of estimates and density of blue wildebeest.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	132	132	389	689	22031.3	300	77.16%	0.22
ENP2								0.00
ENP3410	21	21	243	694	48758.8	452	185.88%	0.10
ENP5								0.00
ENP6	57	57	174	336	6215.0	162	93.17%	0.25
ENP7	58	58	176	384	10074.0	208	118.25%	0.29
ENP8	2	2	13	32	64.1	18	140.06%	0.03
ENP9								0.00
ENP11								0.00
ENP12	346	621	1023	1425	39583.9	402	39.29%	0.69
ENP13	16	16	48	126	1494.6	78	164.08%	0.03
ENP14								0.00
ENP15	215	215	635	1084	50398.4	449	70.75%	0.31
ENP16	376	475	1126	1776	101444.4	650	57.77%	1.23
ENP17	85	85	254	663	40844.4	408	160.75%	0.28
Total	**1308**	**3029**	**4244**	**5459**	**320909.0**	**1215**	**28.63%**	**0.22**

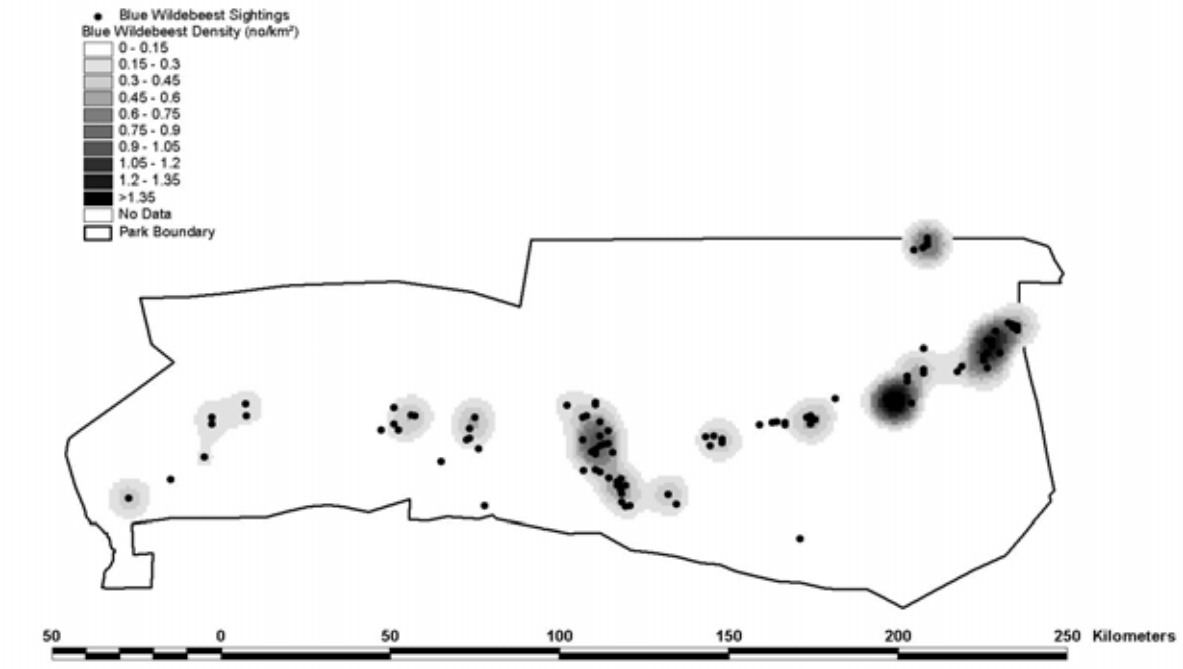

Figure 6: Distribution and density of blue wildebeest.

Table 6: Summary of estimates and density of black rhino.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	48	90	138	186	565.4	48	34.71%	0.08
ENP2	13	19	39	58	91.3	20	51.34%	0.15
ENP3410	3	3	12	33	112.6	22	187.56%	0.00
ENP5	19	19	30	55	144.2	25	81.33%	0.03
ENP6	1	1	3	8	6.4	5	170.10%	0.00
ENP7	3	3	9	21	31.0	12	126.91%	0.02
ENP8	3	3	20	40	80.4	21	104.54%	0.04
ENP9	3	3	19	47	155.8	28	143.50%	0.03
ENP11	2	2	24	55	225.2	31	126.45%	0.01
ENP12	43	59	118	177	856.2	59	49.98%	0.08
ENP13	29	30	65	101	305.3	35	53.93%	0.05
ENP14								0.00
ENP15	59	100	145	189	498.3	45	30.87%	0.07
ENP16	17	25	48	71	128.0	23	48.22%	0.05
ENP17	13	13	36	60	147.0	25	68.31%	0.04
Total	**256**	**683**	**807**	**931**	**3347.0**	**124**	**15.38%**	**0.04**

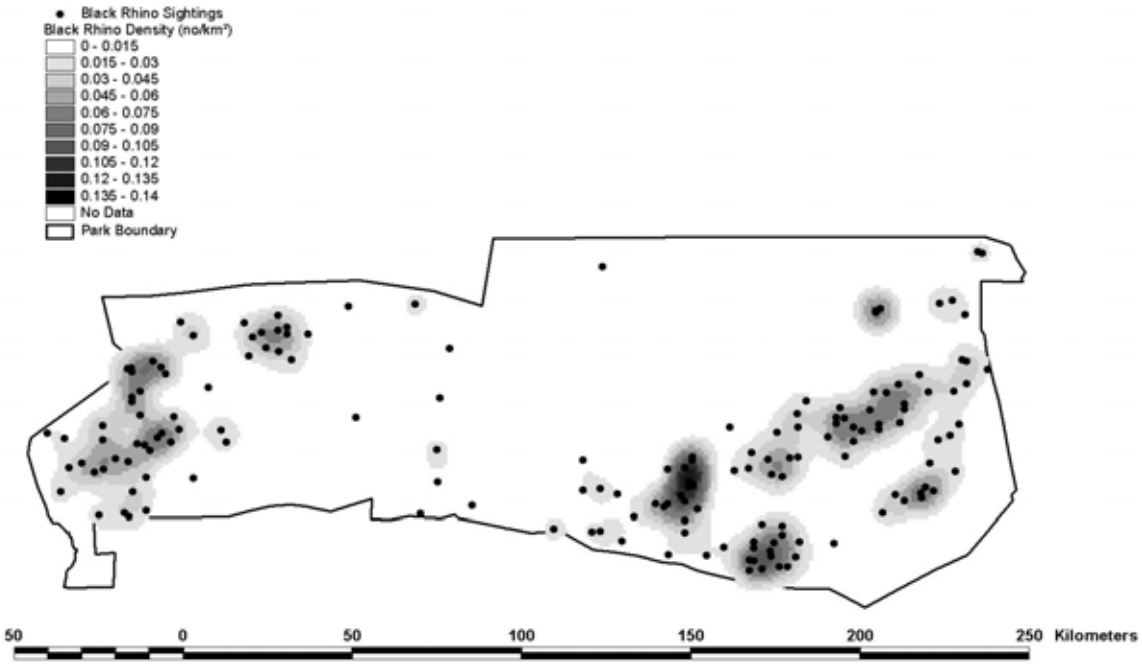

Figure 7: Distribution and density of black rhino.

Table 7: Summary of estimates and density of Burchell's zebra.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	519	1001	1529	2056	68122.6	527	34.51%	0.88
ENP2	52	64	154	244	1888.4	90	58.36%	0.59
ENP3410	57	57	659	1381	124568.5	722	109.46%	0.28
ENP5	145	203	437	672	13181.4	234	53.63%	0.43
ENP6	188	256	574	892	23935.4	318	55.44%	0.82
ENP7	159	302	483	663	7542.8	180	37.33%	0.80
ENP8	55	55	363	858	46090.0	495	136.52%	0.82
ENP9								0.00
ENP11	5	5	61	171	2915.5	111	181.99%	0.02
ENP12	785	1771	2322	2873	74366.4	551	23.74%	1.56
ENP13	256	525	762	999	13719.8	237	31.07%	0.53
ENP14								0.00
ENP15	829	1141	2447	3753	426223.2	1306	53.36%	1.20
ENP16	519	1026	1554	2082	66884.1	528	33.98%	1.69
ENP17	265	392	792	1192	39117.5	400	50.46%	0.86
Total	**3834**	**10937**	**12982**	**15027**	**908555.6**	**2045**	**15.75%**	**0.65**

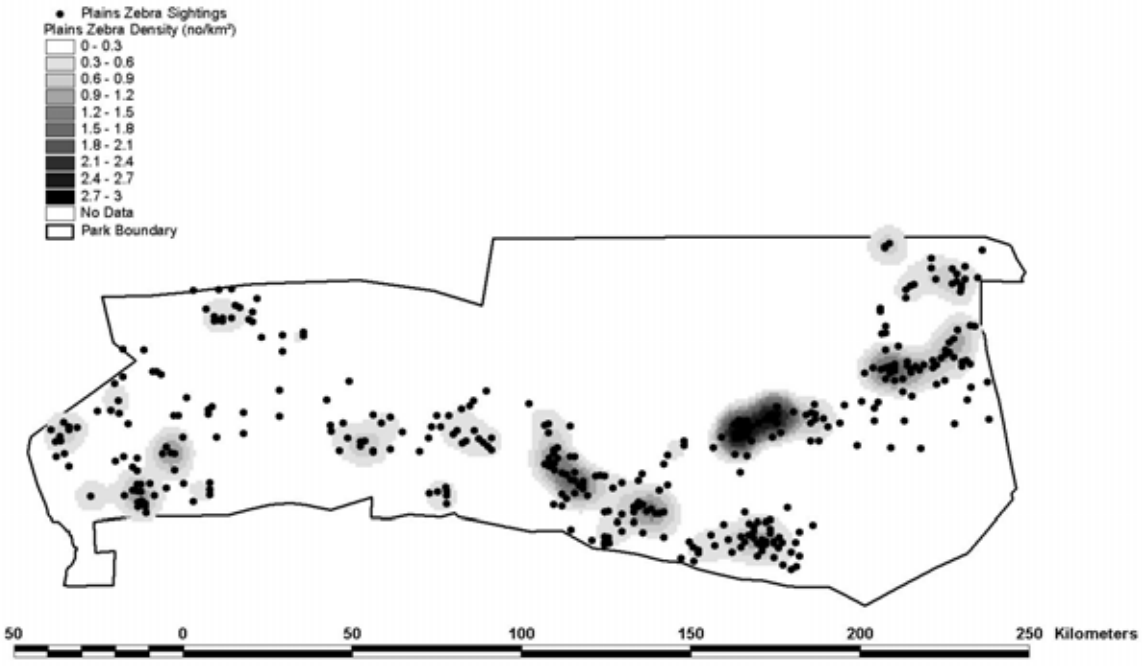

Figure 8: Distribution and density of Burchell's zebra.

Table 8: Summary of estimates and density of giraffe.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	113	229	333	437	2637.5	104	31.19%	0.19
ENP2	29	44	86	128	410.7	42	48.81%	0.33
ENP3410	27	100	312	525	10778.8	212	67.98%	0.13
ENP5	5	5	15	30	51.2	15	96.95%	0.01
ENP6	13	14	40	65	150.6	25	63.58%	0.06
ENP7	25	25	52	86	272.3	34	66.34%	0.09
ENP8	10	10	66	177	2332.8	111	168.93%	0.15
ENP9	2	2	13	39	139.1	26	203.39%	0.02
ENP11	4	4	49	119	1173.0	70	144.29%	0.02
ENP12	122	231	361	490	4100.6	129	35.87%	0.24
ENP13	50	71	149	227	1484.8	78	52.33%	0.10
ENP14	6	6	69	181	2694.8	112	162.83%	0.06
ENP15	96	198	283	369	1813.3	85	30.05%	0.14
ENP16	146	310	437	565	3892.0	127	29.14%	0.48
ENP17	161	318	481	645	6552.6	164	33.99%	0.52
Total	**809**	**2722**	**3143**	**3564**	**38484.1**	**421**	**13.39%**	**0.15**

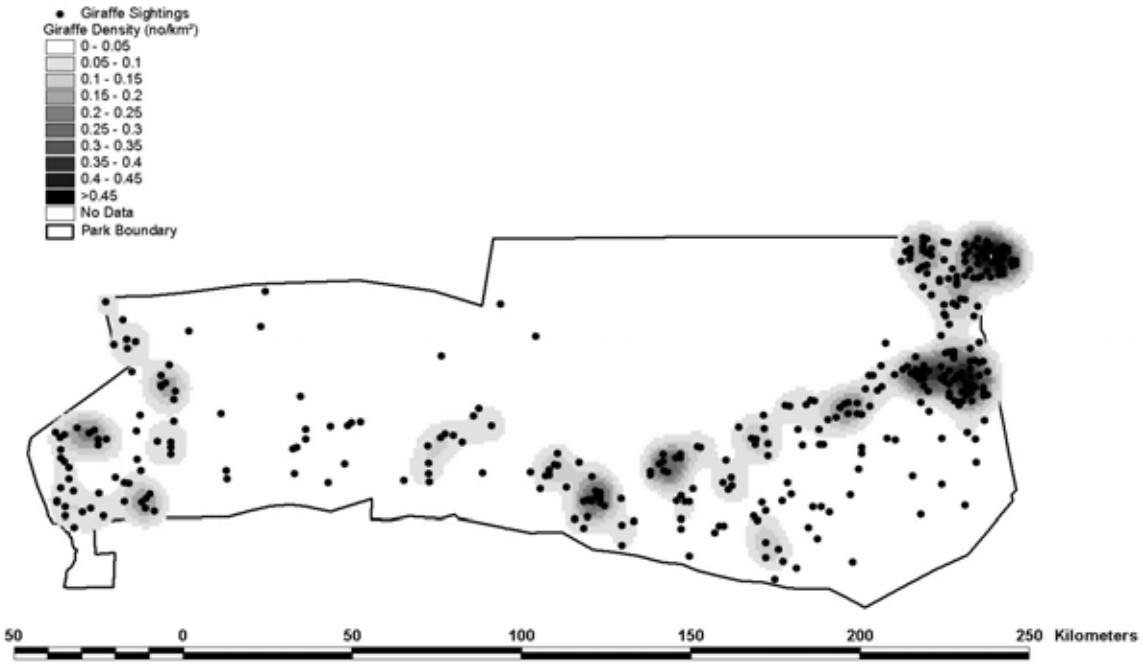

Figure 9: Distribution and density of giraffe.

Table 9: Summary of estimates and density of elephant.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	108	119	312	506	9172.8	194	62.00%	0.18
ENP2								0.00
ENP3410								0.00
ENP5	59	59	54	109	712.5	55	100.45%	0.05
ENP6	70	70	211	396	8161.7	186	88.20%	0.30
ENP7	43	43	33	78	456.2	44	132.69%	0.06
ENP8	19							0.00
ENP9	29	29	181	510	21829.5	329	181.98%	0.27
ENP11	1	1	12	35	129.4	23	191.73%	0.00
ENP12	91	91	269	484	11337.3	215	79.95%	0.18
ENP13	65	65	193	331	4605.5	137	70.90%	0.14
ENP14	1	1	11	37	143.9	26	225.74%	0.01
ENP15	154	154	390	650	16895.0	260	66.72%	0.19
ENP16	35	35	96	173	1430.2	77	80.60%	0.10
ENP17	252	268	574	880	22959.4	306	53.36%	0.62
Total	**927**	**1941**	**2611**	**3282**	**97833.5**	**671**	**25.69%**	**0.13**

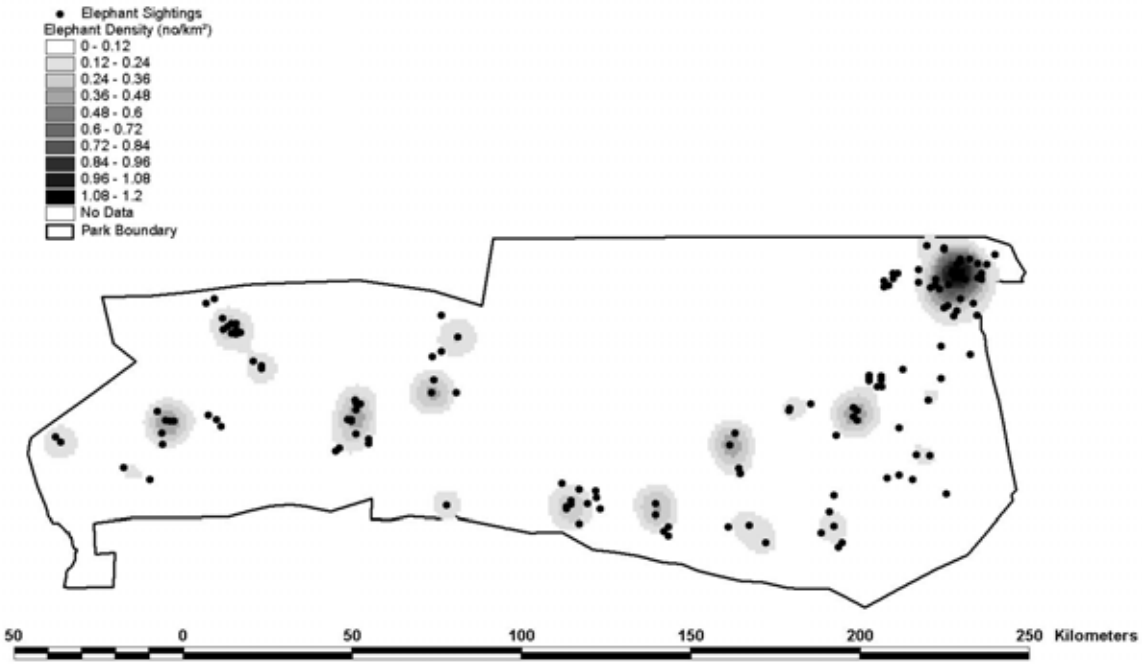

Figure 10: Distribution and density of elephant.

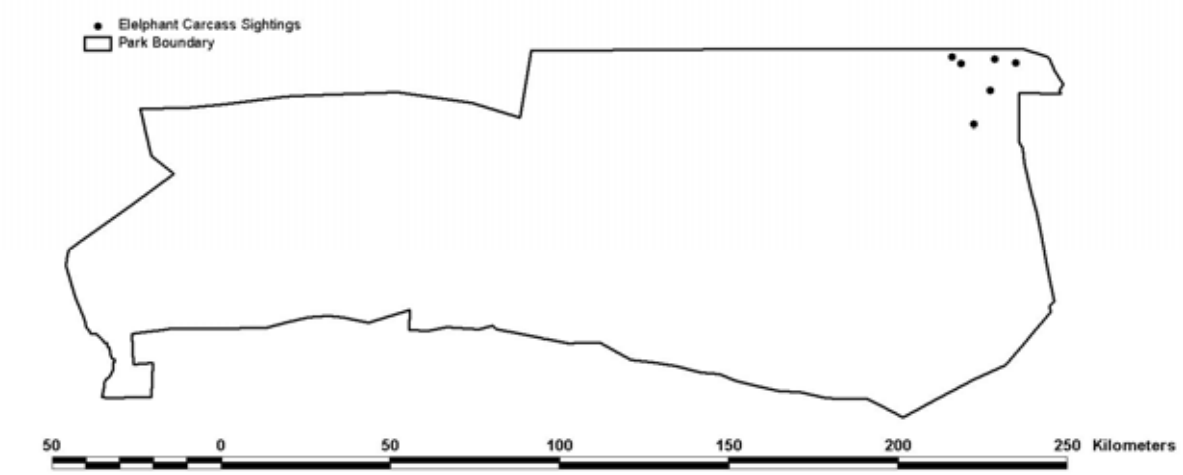

Figure 11: Distribution of elephant carcasses.

Table 10: Summary of estimates and density of oryx.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	219	365	645	925	19184.4	280	43.40%	0.37
ENP2	36	53	107	161	682.6	54	50.68%	0.41
ENP3410	48	255	555	855	21532.8	300	54.04%	0.23
ENP5	64	81	193	305	2988.6	112	57.86%	0.19
ENP6	50	57	153	248	2154.6	95	62.54%	0.22
ENP7	46	60	140	219	1468.3	79	56.92%	0.23
ENP8	81	111	534	957	33684.8	423	79.25%	1.21
ENP9	10	10	65	158	1754.5	93	144.45%	0.10
ENP11	11	11	134	265	4099.8	131	98.09%	0.05
ENP12	150	241	444	646	10036.3	202	45.64%	0.30
ENP13	48	78	143	208	1044.4	65	45.72%	0.10
ENP14	6	6	69	176	2458.1	107	155.52%	0.06
ENP15	61	113	180	248	1140.3	68	37.51%	0.09
ENP16	148	278	443	608	6531.3	165	37.24%	0.48
ENP17	173	329	517	705	8663.8	188	36.38%	0.56
Total	**1151**	**4955**	**5690**	**6425**	**117424.5**	**735**	**12.92%**	**0.23**

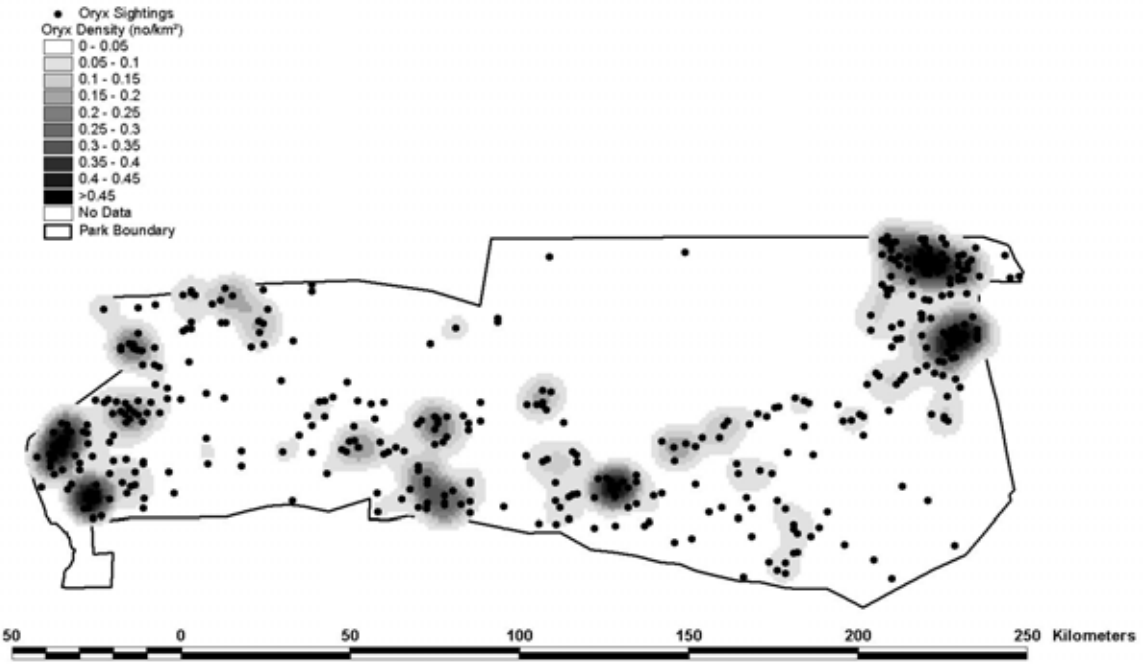

Figure 12: Distribution and density of oryx.

Table 11: Summary of estimates and density of ostrich.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	93	178	274	370	2241.5	96	34.93%	0.16
ENP2	8	14	24	34	24.2	10	42.93%	0.09
ENP3410	46	241	532	824	20332.0	292	54.80%	0.22
ENP5	101	194	304	415	2937.6	111	36.35%	0.30
ENP6	95	95	290	507	11154.8	217	74.89%	0.41
ENP7	82	85	240	395	5587.9	155	64.66%	0.40
ENP8	25	95	165	234	911.1	70	42.23%	0.37
ENP9	7	11	45	79	233.9	34	75.34%	0.07
ENP11	32	201	389	577	8448.4	188	48.41%	0.14
ENP12	94	173	278	383	2689.0	105	37.69%	0.19
ENP13	37	76	110	145	290.2	34	31.26%	0.08
ENP14	3	3	34	76	368.7	41	120.47%	0.03
ENP15	43	77	127	177	632.5	50	39.63%	0.06
ENP16	19	31	57	83	161.1	26	45.55%	0.06
ENP17	37	71	111	150	384.9	40	35.85%	0.12
Total	**722**	**2835**	**3345**	**3854**	**56397.7**	**509**	**15.23%**	**0.16**

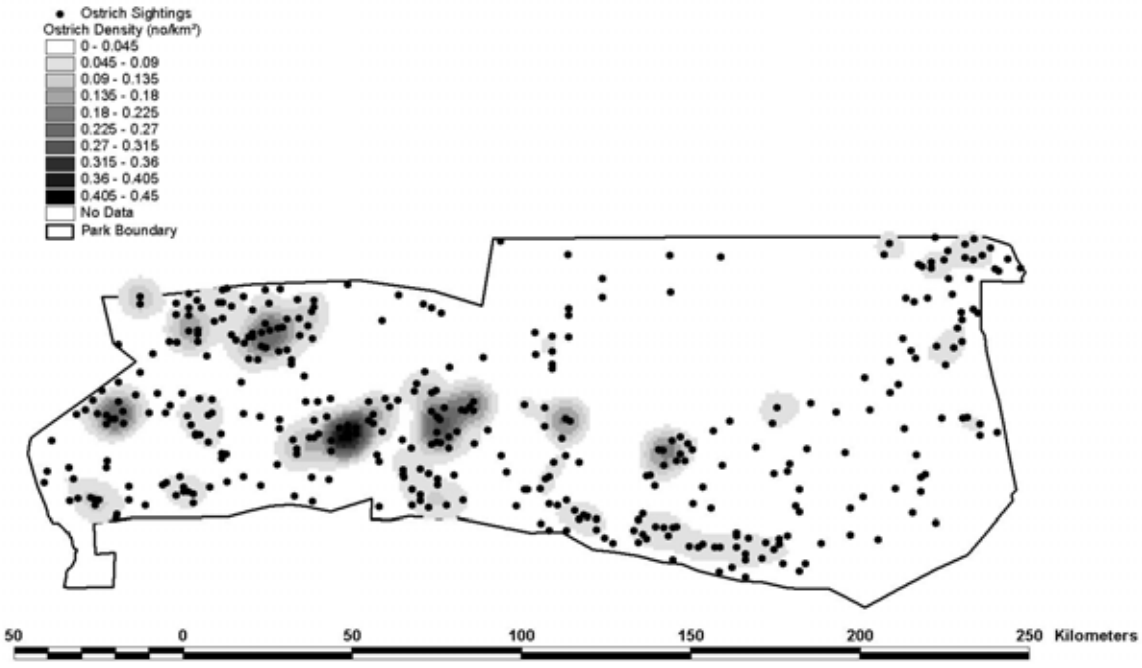

Figure 13: Distribution and density of ostrich.

Table 12: Summary of estimates and density of eland.

Block	No seen	Lower	Estimate	Upper	Variance	95% Confidence Interval	CI as % of Population Estimate	Density (no/km²)
ENP1	57	57	168	280	3073.5	112	66.74%	0.10
ENP2								0.00
ENP3410	3	3	35	77	435.9	43	123.03%	0.01
ENP5	70	103	211	319	2810.0	108	51.30%	0.21
ENP6	31	31	95	208	3015.3	113	119.32%	0.13
ENP7								0.00
ENP8								0.00
ENP9								0.00
ENP11								0.00
ENP12	3	3	9	23	52.0	15	164.26%	0.01
ENP13	10	10	30	70	394.6	40	134.89%	0.02
ENP14								0.00
ENP15	2	2	6	16	23.4	10	163.85%	0.00
ENP16	8	8	24	50	166.9	26	110.13%	0.03
ENP17	117	120	350	580	12973.2	230	65.82%	0.38
Total	**301**	**778**	**1103**	**1428**	**22944.8**	**325**	**29.46%**	**0.05**

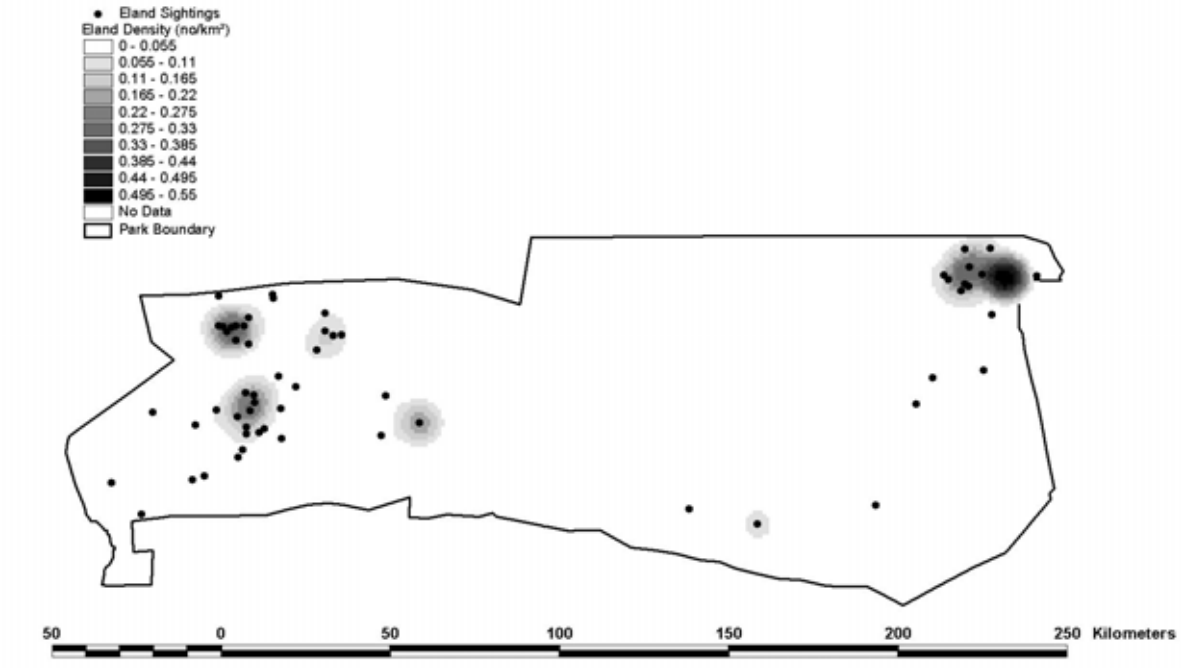

Figure 14: Distribution and density of eland.

Figure 15 to Figure 24 present comparative population estimates and the 95% range for each species for aerial sample counts conducted during the dry periods of 1995, 1998, 2000, 2002, 2004 and 2005. The sampling intensities of the 1998 survey were the lowest of the surveys, and the population estimates reflect those.

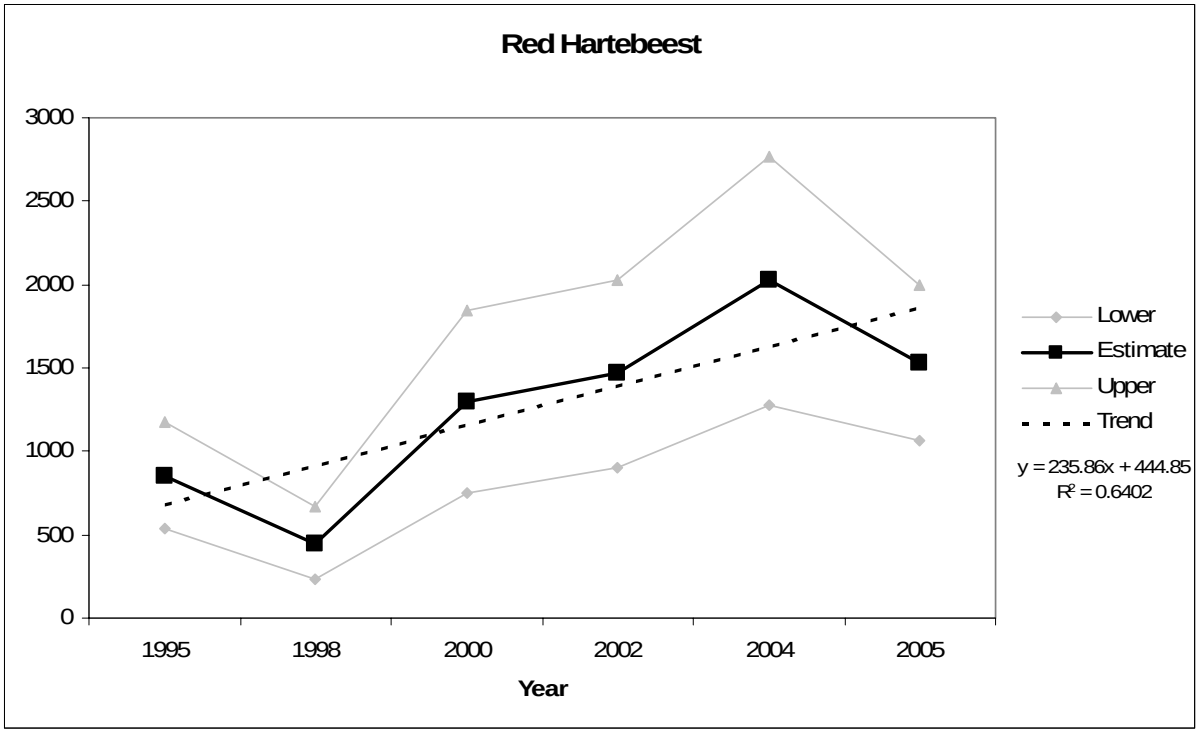

Figure 15: Population trends for red hartebeest.

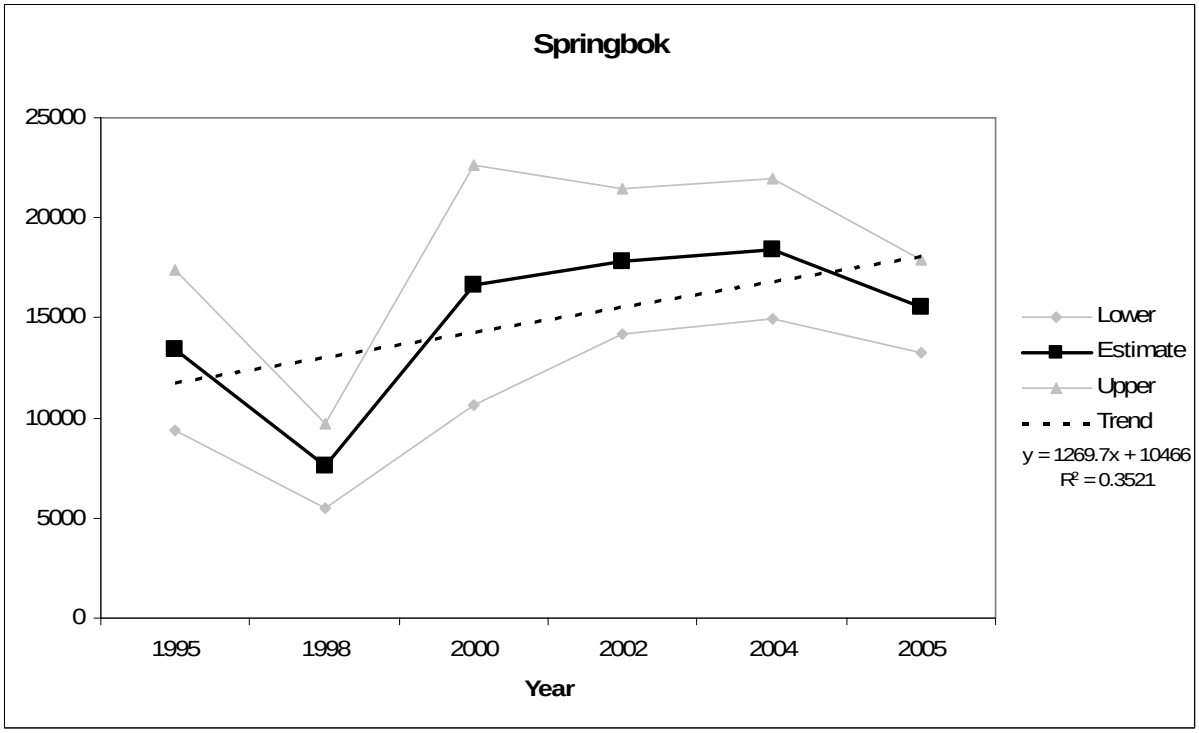

Figure 16: Population trends for springbok.

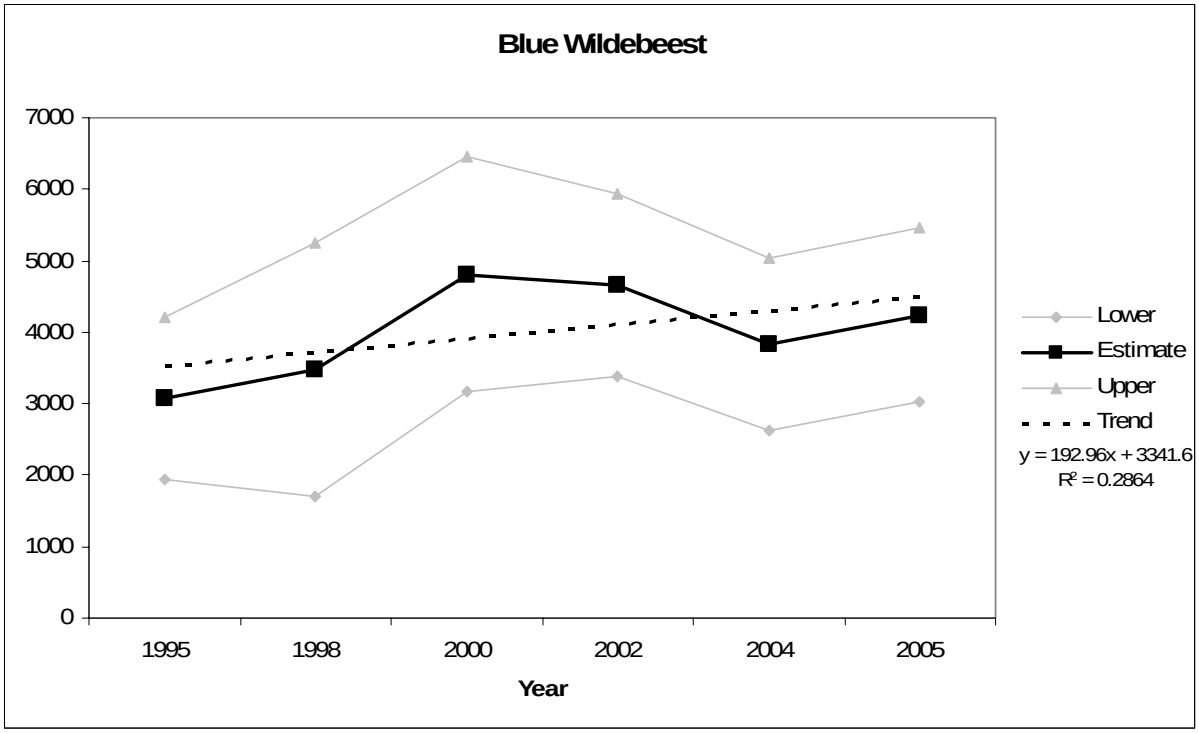

Figure 17: Population trends for blue wildebeest.

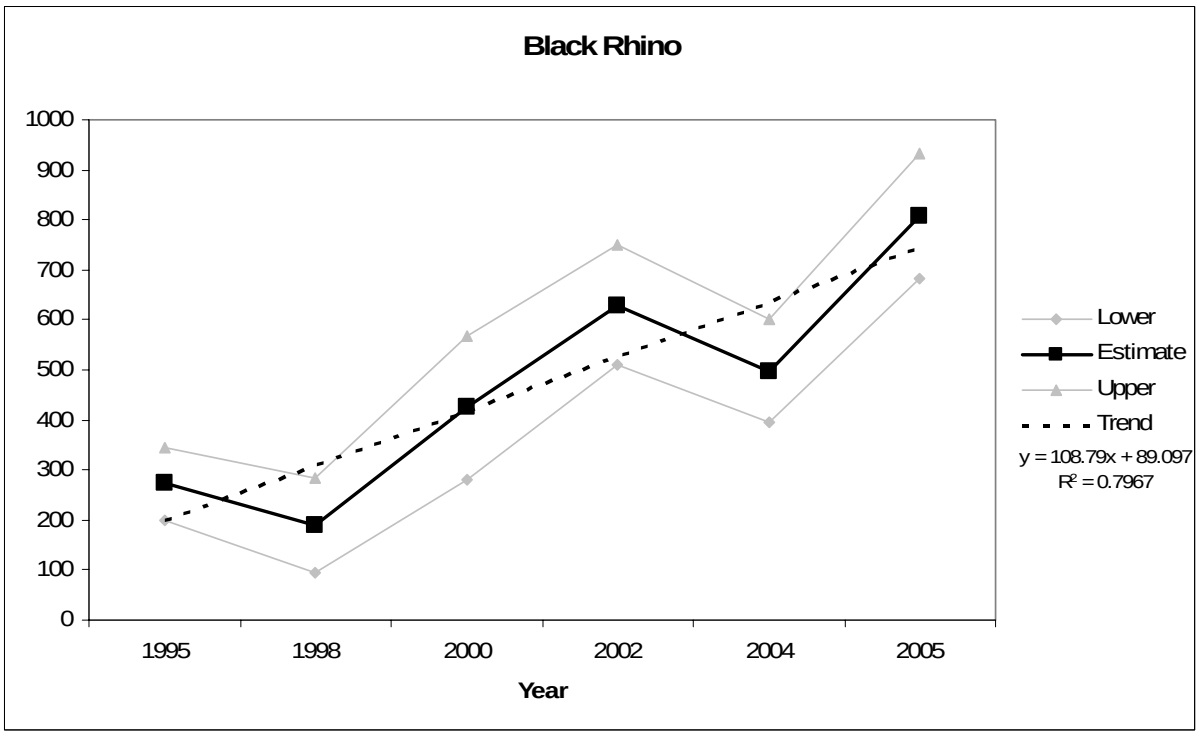

Figure 18: Population trends for black rhino.

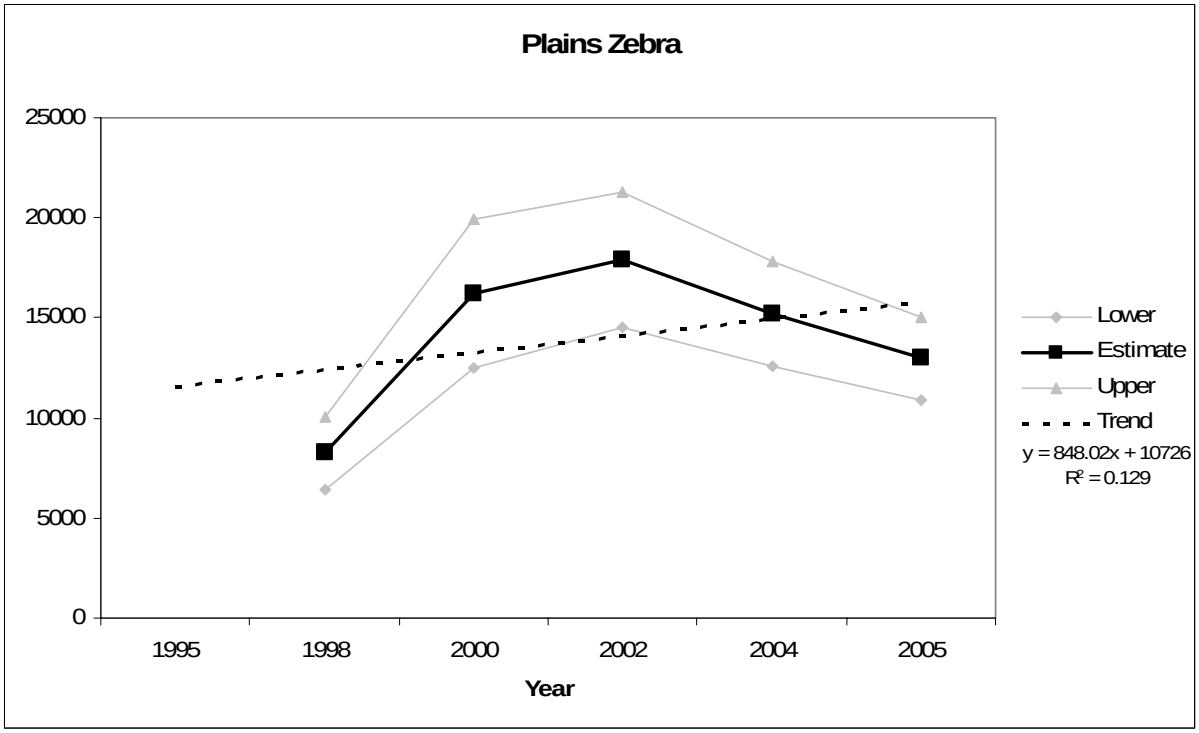

Figure 19: Population trends for Burchell's zebra.

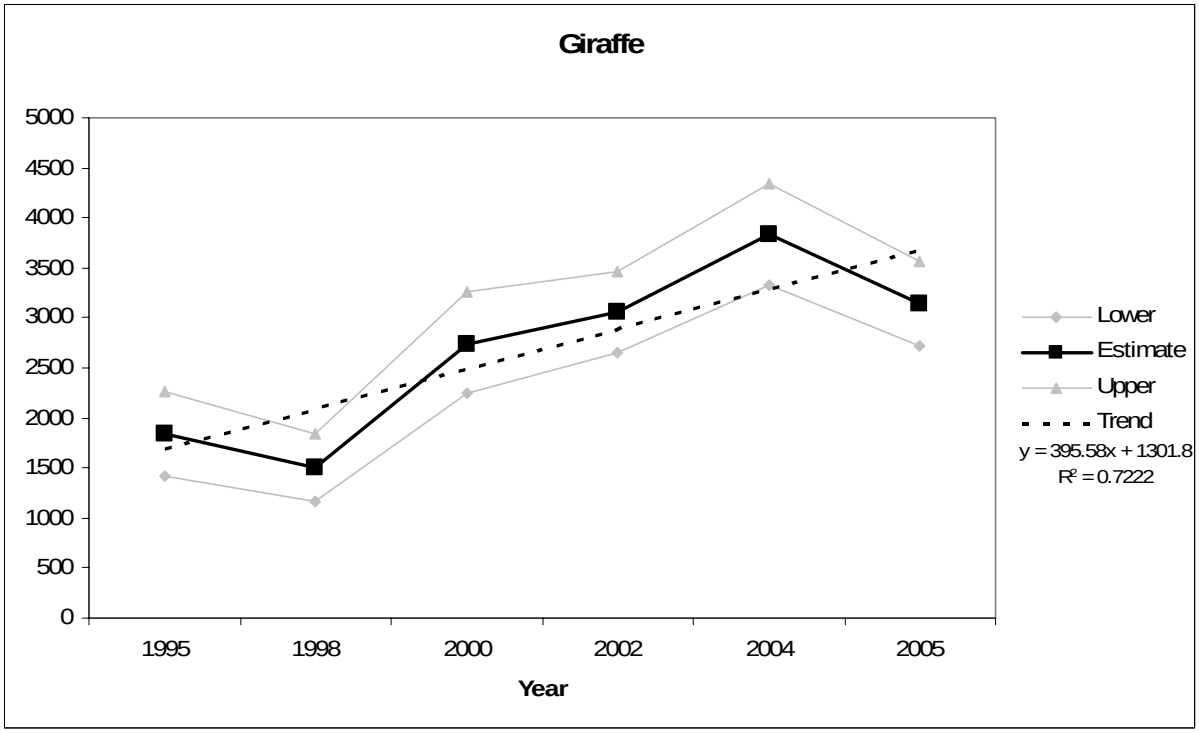

Figure 20: Population trends for giraffe.

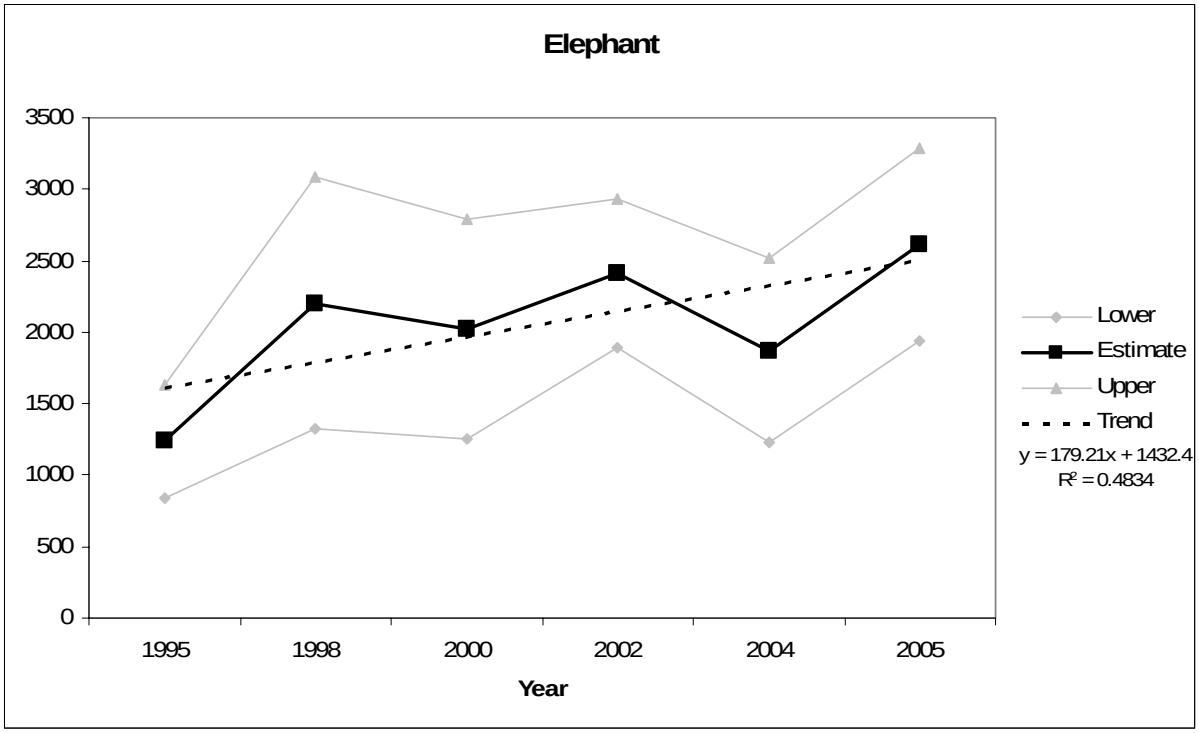

Figure 21: Population trends for elephant.

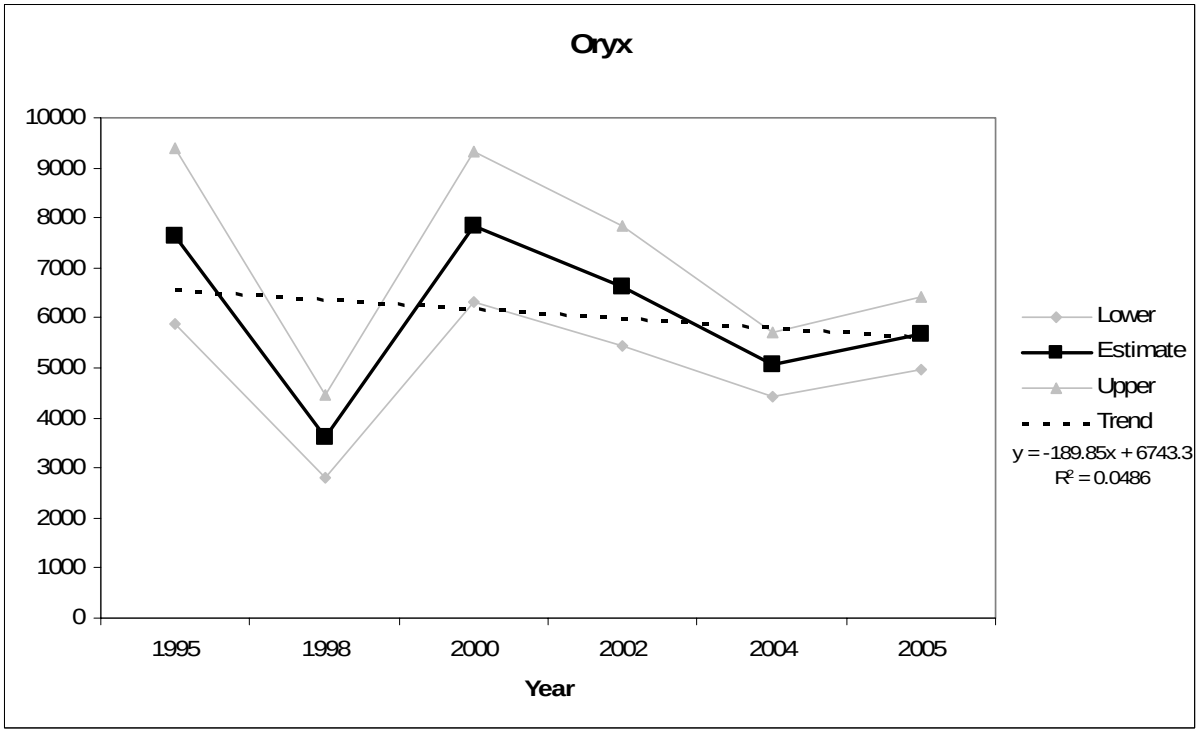

Figure 22: Population trends for oryx.

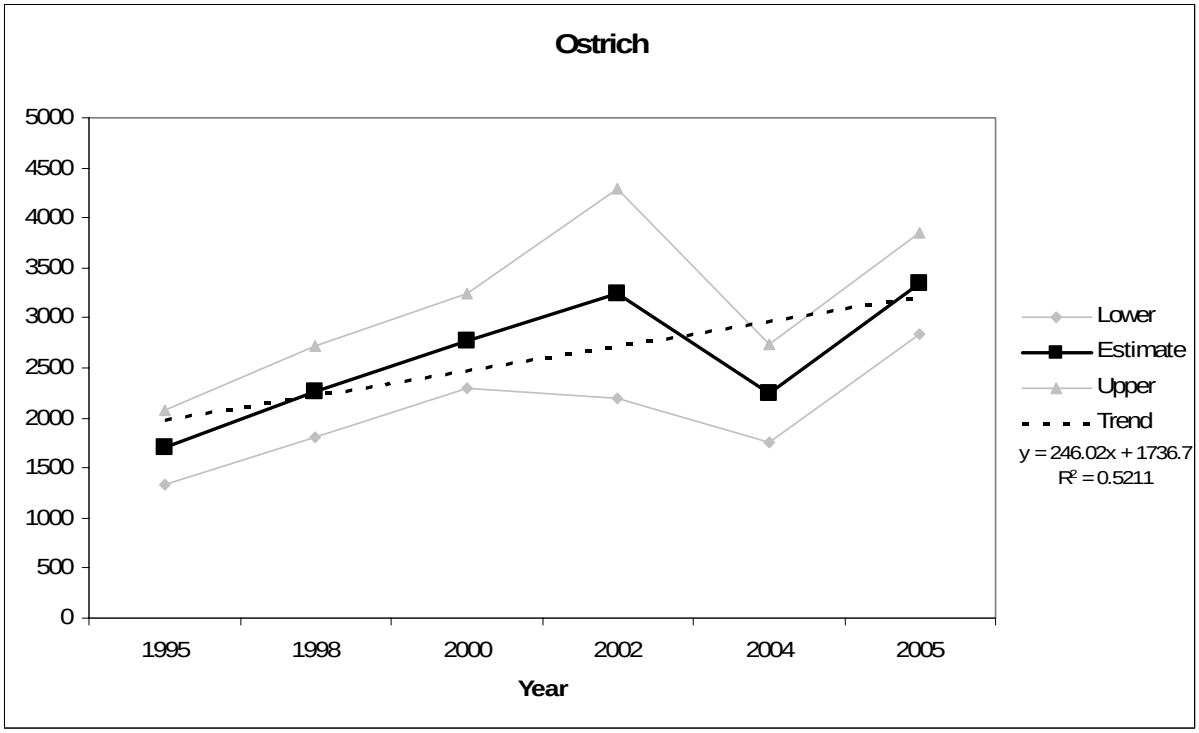

Figure 23: Population trends for ostrich.

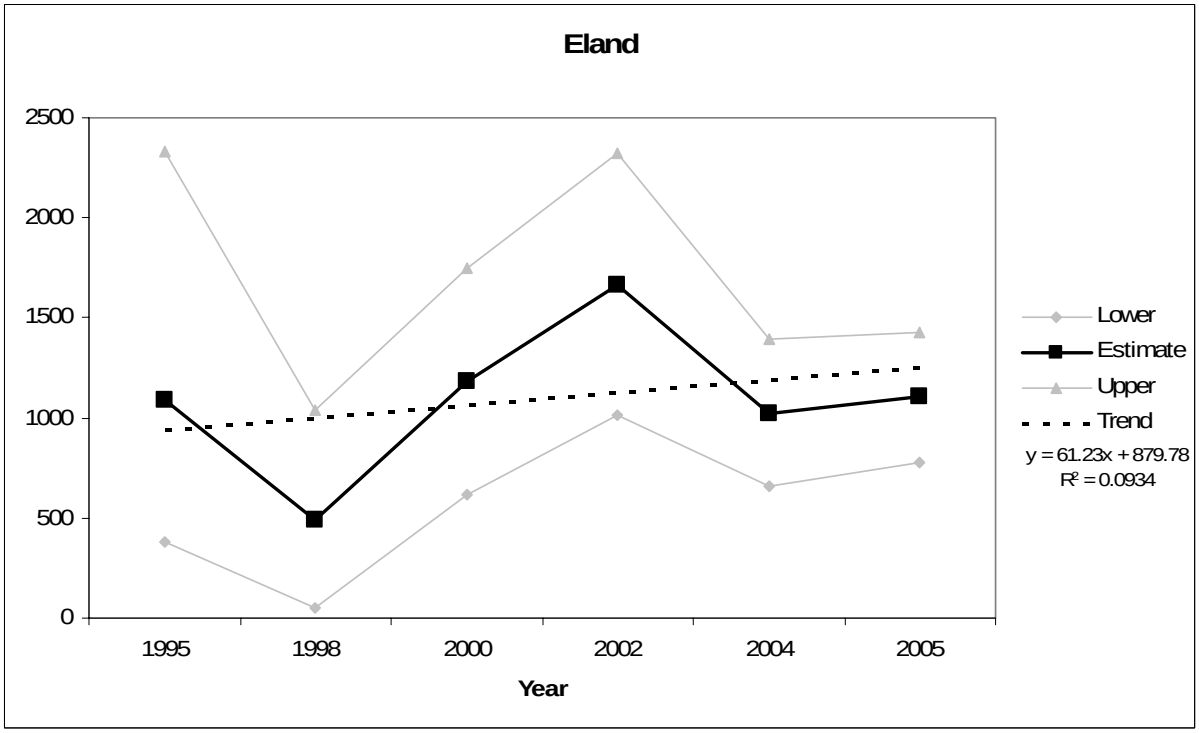

Figure 24: Population trends for eland.

4. Discussion

The entire survey was flown using the same two observers. This effectively cancelled any observer bias and is reflected in the confidence intervals obtained for many species.

One worrying aspect is the apparent decline in oryx numbers over the past ten years. This matter should be investigated.

Appendix I: Observer Calibration

Crew ISE

Gabriel Shatumbu

	Height	In	Out	Width	O-I + 1
	300	8	23	15	16
	300	7	28	21	22
	300	6	30	24	25
	310	10	30	20	21
	300	7	30	23	24
	300	8	30	22	23
	300	8	30	22	23
	350	8	29	21	22
	400	7	32	25	26
	250	7	23	16	17
	300	8	30	22	23
	290	6	29	23	24
	290	7	30	23	24
	250	7	29	22	23
	320	6	28	22	23
	300	6	30	24	25
	270	7	29	22	23
	300	6	30	24	25
	280	7	29	22	23
	280	8	29	21	22
Average	**299.5**				**22.7**
	Calibrated strip width (m)				**227**

Johannes Kapner

	300	10	27	17	18
	300	12	30	18	19
	300	12	29	17	18
	310	9	29	20	21
	300	9	29	20	21
	300	9	30	21	22
	300	7	28	21	22
	350	12	32	20	21
	400	14	32	18	19
	250	8	22	14	15
	300	8	25	17	18
	290	10	30	20	21
	290	8	28	20	21
	250	7	25	18	19
	320	9	28	19	20
	300	11	28	17	18
	270	10	27	17	18
	300	10	29	19	20
	280	9	28	19	20
	280	7	25	18	19
Average	**299.5**				**19.5**
	Calibrated strip width (m)				**195**
	Total strip width for ISE crew				**422**

Crew PRO

Gabriel Shatumbu

	Height	In	Out	Width	O-I + 1
	290	4	27	23	24
	300	5	29	24	25
	300	4	28	24	25
	300	4	30	26	27
	300	4	24	20	21
	300	4	26	22	23
	300	4	28	24	25
	300	4	29	25	26
	310	4	26	22	23
	300	4	26	22	23
	300	4	27	23	24
	310	4	29	25	26
	300	4	26	22	23
	290	5	27	22	23
	290	4	25	21	22
	300	4	29	25	26
Average	**299.375**				**24.13**
	Calibrated strip width (m)				**242**

Johannes Kapner

	300	5	22	17	18
	300	5	21	16	17
	300	5	23	18	19
	300	5	23	18	19
	300	5	21	16	17
	300	6	22	16	17
	310	4	20	16	17
	300	5	22	17	18
	300	4	22	18	19
	310	5	20	15	16
	300	5	23	18	19
	290	5	22	17	18
	290	6	23	17	18
	300	4	20	16	17
Average	**300**				**17.78571**
	Calibrated strip width(m)				**178**
	Total strip width for PRO crew				**420**

Appendix II: Survey Cost

The table below gives an analysis of the survey cost.

Item	Cost N$
S&T	
Overtime	
Vehicles[1]	
Plane[2]	
Other	
Total	

[1] Only the cost of fuel and emergency repairs.
[2] Only the cost of avgas and landing fees.

Appendix III: Survey Participants

Pilots: Martin du Plessis, Dr Nad Brain
Recorders: Werner Kilian, Wayne Handley
Observers: Gabriel Shatumbu, Johannes Kapner
Data Management and ground support: Holger Kolberg, Fillemon Iifo