Carnivore presence assessment in a protected area in the in the grassland biome based on camera trap surveys; Verlorenvallei Mpumalanga

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WRA

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Summary

This report on the project camera trapping exercise undertaken on Verlorenvallei nature Reserve. During 49 days of camera trapping we achieved an effort of 2066 camera trapping days which yielded 4045 independent animal pictures. We detected 23 mammal species of which 10 were carnivore species. Black backed jackal, serval, cape fox and side striped jackal were the most abundance and widely distributed carnivore species. We used a single season occupancy model to investigate serval presence on the study site. We found that serval preferred wetland areas and were positively associated with black backed jackal. Our results here concur with various other studies and we show that camera trapping in an occupancy framework can be used to rigorously asses multiple carnivore populations.

INTRODUCTION

Carnivores play important roles in both regulating and structuring ecosystems [1] which directly benefits the maintenance of biodiversity [2]. However Africa, and specifically in South Africa have seen large declines in the extent and density of large carnivores [3]. This has potentially resulted in a proliferation of small carnivore abundance and distribution due to meso-carnivore release [4]. As such a better understanding of small and mesocarnivore abundance, diversity and distribution are vital in understanding the impact of large carnivore removal carnivores. Furthermore, human activity and tolerance play equally important roles in carnivore density and distribution; equally inside and outside protected areas [5]. This is especially true for protected areas that are imbedded in a human dominated matrix.

To address issues surrounding small to medium carnivore conservation raised by conservation officials, we set up a camera trapping study at Verlorenvallei nature reserve, South Africa. We used a camera trapping survey to estimate the diversity and occupancy of small and medium carnivores. We used this approach to explicitly account for detection heterogeneity needed for robust estimates of occupancy and diversity. Furthermore, this approach is extendable to an annual monitoring plan that would yield robust trend estimates needed for conservation planning.

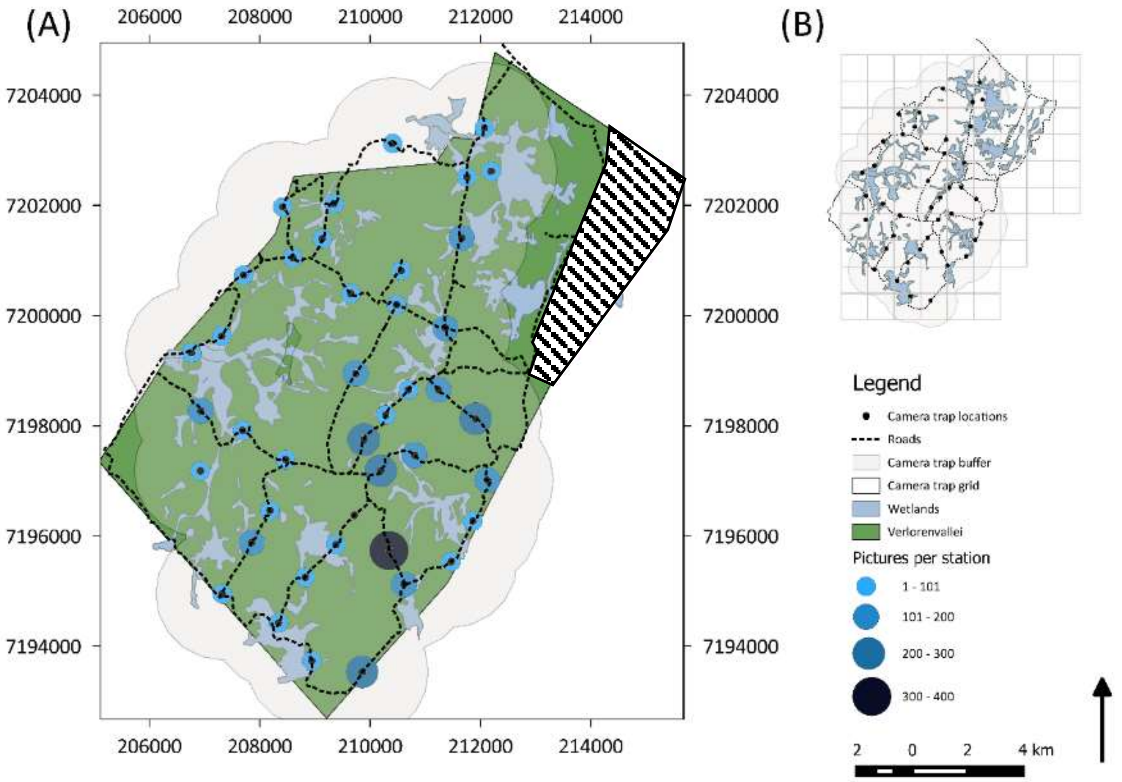

Fig. 1. Study area showing Verlorenvallei Nature Reserve with the number of animal pictures per camera trap (A) and camera trap grid (B); black bars indicates area not surveyed

Objectives

The aim of this study is to deploy and setup a camera trapping protocol that can be extended to an annual monitoring program; specific objectives include:

I. To estimate the species richness of small and medium carnivore species
II. To investigate the feasibility of using occupancy modelling framework as a monitoring approach to detect serval distribution trends
III. To estimate species diversity as detected by camera traps

METHODS

Study area

The study was conducted at Verlorenvallei Nature Reserve in Mpumalanga, South Africa (Fig. 1). The reserve had an area of 6061 ha of which 1120 ha (18%: Fig. 1) were classified as wetlands. The remained of the vegetation can be largely classified as Lydenburg Montane Grassland (Grassland Biome) [6]. Ecologically the wetlands of Verlorenvallei are in a near-pristine state of vegetation, and have excellent examples of the natural wetland characteristic of the Steenkampsberg Plateau biogeographical region [6]. Verlorenvallei mainly consists of three vegetation units; i) *Tristachya leucothrix* grassland, ii) *Coleochloa setifera* crest grassland, and iii) wetlands [7].

Carnivore species status

We used the 2004 Mammal Red List to extract a theoretical carnivore list for Verlorenvallei Nature reserve [8]. Verlorenvallei Nature reserve could potentially harbour 23 carnivore species (Table 1). Sixteen species are classified as 'least concern', five species as 'near threatened' and one species as 'data deficient' (Table 1).

Camera trapping

We followed camera trapping survey design guidelines for closed-population capture-recapture studies [9]. However we extended this survey design to an occupancy framework [10] since we were interested in carnivore occupancy, rather than density. Camera traps were set out in a grid pattern, where the size of each grid (1.2 km²) represented approximately half the home range recorded for serval at Secunda (2 km² - 5 km²; Matthews, *pers comm*). This resulted in an average spacing of 758 m between camera traps, which ensured that all the study sites were adequately surveyed and that all the serval within the survey grid had a non-zero capture probability. Due to a shortage of available cameras, we only deployed one camera in each grid (rather than a pair). However, this approach is adequate since occupancy models rely on detection non-detection data, and not individual identification.

We deployed the camera traps for a period of around 50 days. We considered a single 24-hour day as a sampling occasion [12]. We used a combination of infrared digital camera traps (Cuddeback Ambush Black Flash, Non Typical Inc., Park Falls, Wisconsin, USA) and white flash (Cuddeback Ambush & C1 White Flash models, Non Typical Inc., Park Falls, Wisconsin, USA). We programmed units to run for 24 hours, with a 1 minute delay between pictures. Camera traps were positioned on the side of vehicle roads at a height of 35 cm. Camera trapped images were catalogued using a photo database manager (Camera Base) [19]. We used the R package 'BiodiversityR' to produce species accumulation curves and rank abundance graphs [11].

Serval occupancy models

Occupancy models are an effective method to account for heterogeneity in detection probabilities often associated with mammal surveys to produce unbiased estimates of species status [12]. We applied a single species occupancy model implemented in a maximum likelihood framework to investigate the factors affecting serval occupancy *(ψ)* and detection probability *(p)* [10]. We restricted the camera trapping period to 49 days to minimize the likelihood of changes in occupancy. We collapsed the 49 day sampling period into 7 sampling occasions of 7 days each to increase detection probabilities[13]. We used a two-step approach where we first modelled variation in *p* and then modelled *ψ.* Since wetland habitat association can affect serval distribution [14], we first tested the effect of distance to closed wetland on *p*, while keeping *ψ* constant (*p*[DistWet]*ψ*[.]). We also created a null model with *p* and *ψ* constant (p[.] ψ[.]). We then used the most parsimonious detection model and allowed *ψ* to vary by biological realistic hypothesis. Sympatric carnivores and wetland habitat can affect serval occupancy [14] and we account for these factors by fitting a models were ψ varied by distance to closest wetland (DistWet) and a jackal relative abundance index. We also created constant ψ model. We used a delta AIC ≤ 2 to identify the most parsimonious models [15] and applied model averaging to estimate *p, ψ* and covariate coefficients if we detected model uncertainty [15]. Finally we used the averaged site occupancy models to generate serval occupancy map by using inverse distance weighted interpolation (IDW) [16]. We used the following R packages for data analysis; 'unmarked' to fit occupancy models [17], AICcmodavg to apply model averaging [18] and 'Gstat' for IDW [19].

Table 1. Potential species list and conservation status of carnivore species at Verlorenvallei Nature reserve based on 2004 Red data book of the mammals of South Africa [8].

Species	Common	SA Red list status	2015 Survey	Frequency
Canis mesomelas	Black-backed Jackal	Least concern	✓	high
Vulpes chama	Cape Fox	Least concern	✓	meduim
Caracal caracal	Caracal	Least concern	✓	low
Felis silvestris	African Wild Cat	Least concern	✓	low
Atilax paludinosus	Marsh Mongoose	Least concern	✓	low
Cynictis penicillata	Yellow Mongoose	Least concern	✓	low
Civettictis civetta	African civet	Least concern	x	
Genetta genetta	Small spotted genet	Least concern	x	
Genetta maculata	Rusty spotted genet	Least concern	x	
Ictonyx striatus	Striped polecat	Least concern	x	
Galerella sanguinea	Slender Mongoose	Least concern	x	
Ichneumia albicauda	White-tailed Mongoose	Least concern	x	
Mungos mungo	Banded Mongoose	Least concern	x	
Proteles cristatus	Aardwolf	Least concern	x	
Aonyx capensis	Cape Clawless Otter	Least concern	x	
Panthera pardus	Leopard	Least concern	x	
Canis adustus	Side-striped Jackal	Near threatened	✓	meduim
Leptailurus serval	Serval	Near threatened	✓	high
Hyaena brunnea	Brown Hyaena	Near threatened	✓	low
Mellivora capensis	Honey Badger	Near threatened	✓	low
Lutra maculicollis	Spotted-necked Otter	Near threatened	x	
Poecilogale albinucha	African Weasel	Data deficient	x	

RESULTS

Camera trapping

We set up 43 camera stations achieving a coverage of 83% (Fig. 1) of the reserve, however we excluded reserve section west of the main road (around 600 ha; Fig. 1). During a camera trapping effort of 2066 camera trapping days we detected 23 mammal species (Table 2), two livestock species (Table 2) and 11 avian species (Table 2). Species accusation curves reached and asymptote for the carnivore species at around 25 camera trap stations (46% reserve coverage; Fig. 2a), while it seemed that for non-carnivorian species we were still adding new species even at 85% reserve coverage and 2066 camera trap days (Fig. 2b).

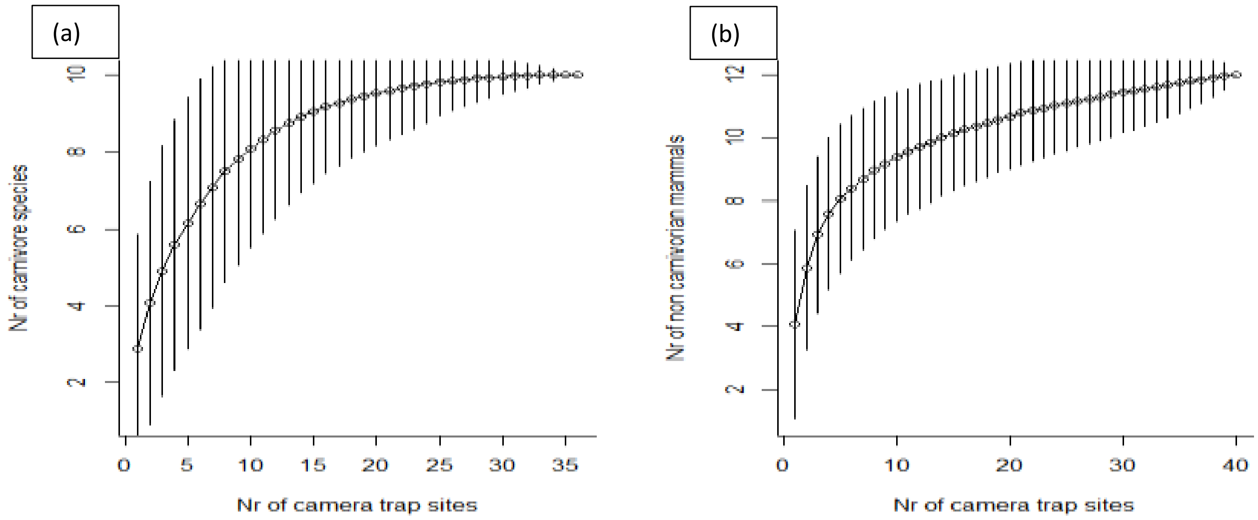

Fig. 2. Species accumulation curves for carnivores (a) and non-carnivorian mammals (b) at Verlorenvallei Nature reserve during a total camera trapping effort of 2066 camera trap days

Carnivores

While we detected 10 carnivore species, we failed to detect large carnivores at significant detections or distributions (>20kg; Table 2). Brown hyena accounted for the only large carnivore detected (>20kg), but only at five camera stations and at very low frequencies (Table 2). Verlorenvallei was dominated by back blacked jackal, which ranked high in relative abundance (Fig.3a) representing at least 60% of the carnivore photographed obtained (Fig. 4). Serval was the most common felid, detected at 25 sites (Naïve occupancy = 61%) and ranked to the second to black backed jackal (Fig. 4). Interestingly four out of the five top carnivore species detected (e.g. Naïve occupancy > 20%) were canids (Table 2). We only detected 10 out a potential 23 species (43%; Table 1&2). For these only Black backed jackal and Serval had high detection frequencies (Table 1). Side striped jackal and Cape fox were detected at medium rates while the others at low detection rates (Table 1).

Carnivore species detection and distribution varied spatially (Fig. 5) and the majority of carnivores were detected in the center of the reserve (Fig. 5). There were little spatial overlap in carnivore species, except for serval and black backed jackal who showed a large spatial overlap (Fig. 5).

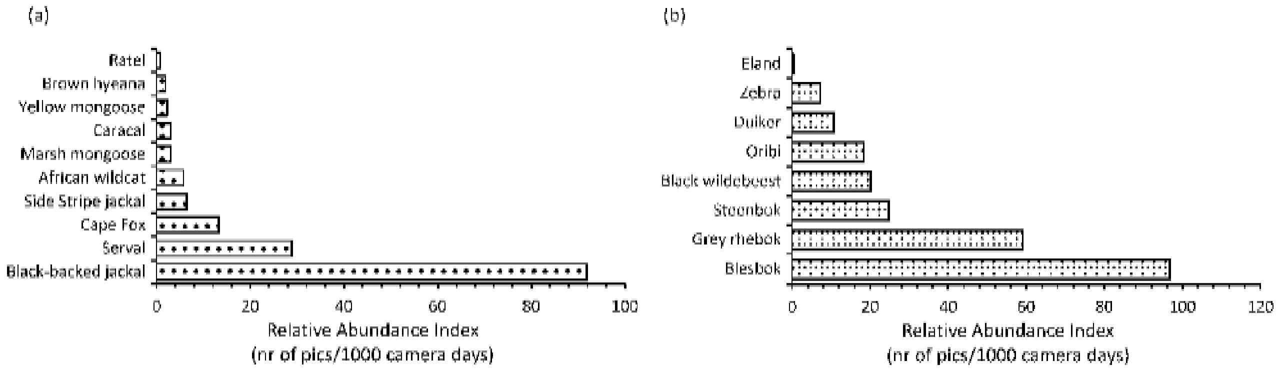

Fig. 3. Relative Abundance Index (RAI) of carnivorian (a) and ungulates (b) detected at Verlorenvallei Nature reserve

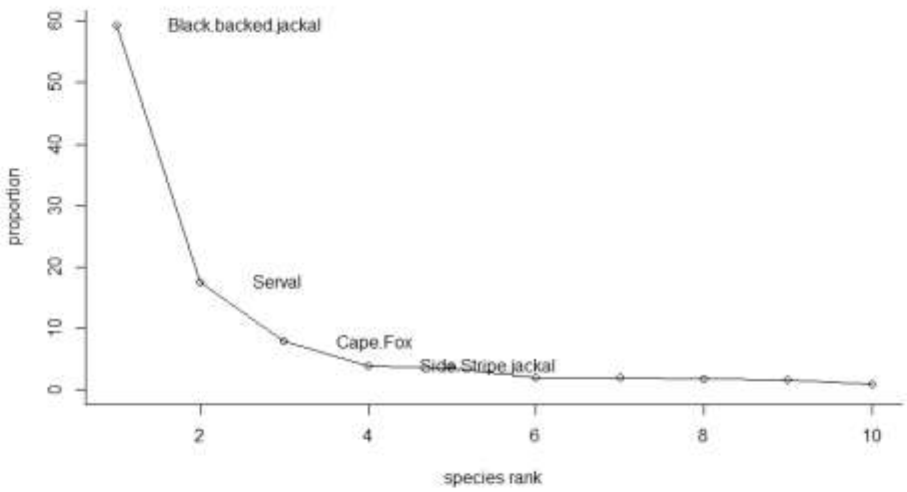

Fig.4. Rank abundance of the number of independent carnivore pictures obtained during a camera trapping effort of 2066 camera trapping days

Table 2: Camera trapping results for Verlorenvallei Nature reserve; *Events = nr of pictures, Frequency = nr of pictures/1000 camera trap days, Naïve Occupancy is proportion of grid cells occupied*

Common name	Species	Events	Frequency	Nr of Cameras	Naïve Occupancy
Ungulates	**8**				
Blesbok	*Damaliscus pygargus phillipsi*	254	96.84	25	0.61
Grey rhebok	*Palea capreolus*	155	59.09	36	0.88
Steenbok	*Raphicerus campestris*	65	24.78	20	0.49
Black wildebeest	*Connochaetes gnou*	53	20.21	8	0.20
Oribi	*Ourebia ourebi*	48	18.3	22	0.54
Duiker	*Sylvicapra grimmia*	28	10.67	17	0.41
Zebra	*Equus quagga*	19	7.24	4	0.10
Eland	*Taurotragus oryx*	1	0.38	1	0.02
Carnivores	***10***				
Black-backed jackal	*Canis mesomelas*	241	91.88	35	0.85
Serval	*Leptailurus serval*	76	28.97	25	0.61
Cape Fox	*Vulpes chama*	35	13.34	8	0.20
Side Stripe jackal	*Canis adustus*	17	6.48	10	0.24
African wildcat	*Felis silvestris lybica*	15	5.72	4	0.10
Marsh mongoose	*Atilax paludinosus*	8	3.05	5	0.12
Caracal	*Caracal caracal*	8	3.05	4	0.10
Yellow mongoose	*Cynictis penicillata*	6	2.29	2	0.05
Brown hyeana	*Hyaena brunnea*	5	1.91	5	0.12
Ratel	*Mellivora capensis*	2	0.76	2	0.05
Other mammals	***5***				
Cape porcupine	*Hystrix africaeaustralis*	60	22.87	22	0.54
springhare	*Pedetes capensis*	14	5.34	1	0.02
Scrub hare	*Lepus saxatilis*	11	4.19	6	0.15
Red rock rabbit	*Pronolagus spp.*	5	1.91	3	0.07
Bushpig	*Potamochoerus larvatus*	2	0.76	2	0.05
Birds	***11***				
Crow	*Corvus capensis*	15	5.72	8	0.20
Bustard	*Neotis denhami*	7	2.67	4	0.10
Guineafowl	*Numida meleagris*	6	2.29	4	0.10
Secretary bird	*Sagittarius serpentarius*	5	1.91	4	0.10
Francolin	*Francolinus*	5	1.91	3	0.07
Longtailed widow	*Euplectes progne*	2	0.76	2	0.05
Red-wattled lapwing	*Vanellus indicus*	4	1.52	1	0.02
Grey heron	*Ardea cinerea*	1	0.38	1	0.02
Spotted thick-knee	*Burhinus capensis*	1	0.38	1	0.02
Grass owl	*Tyto capensis*	1	0.38	1	0.02
Orangethroated longclaw	*Macronyx capensis*	1	0.38	1	0.02
Livestock					
Cattle	*Bos sp.*	5	1.91	1	0.02
Donkey	*Equus africanus*	1	0.38	1	0.02
Other					
UN	UN	48	18.3	23	0.56
Humans	Homo sapies	459	174.99	34	0.83

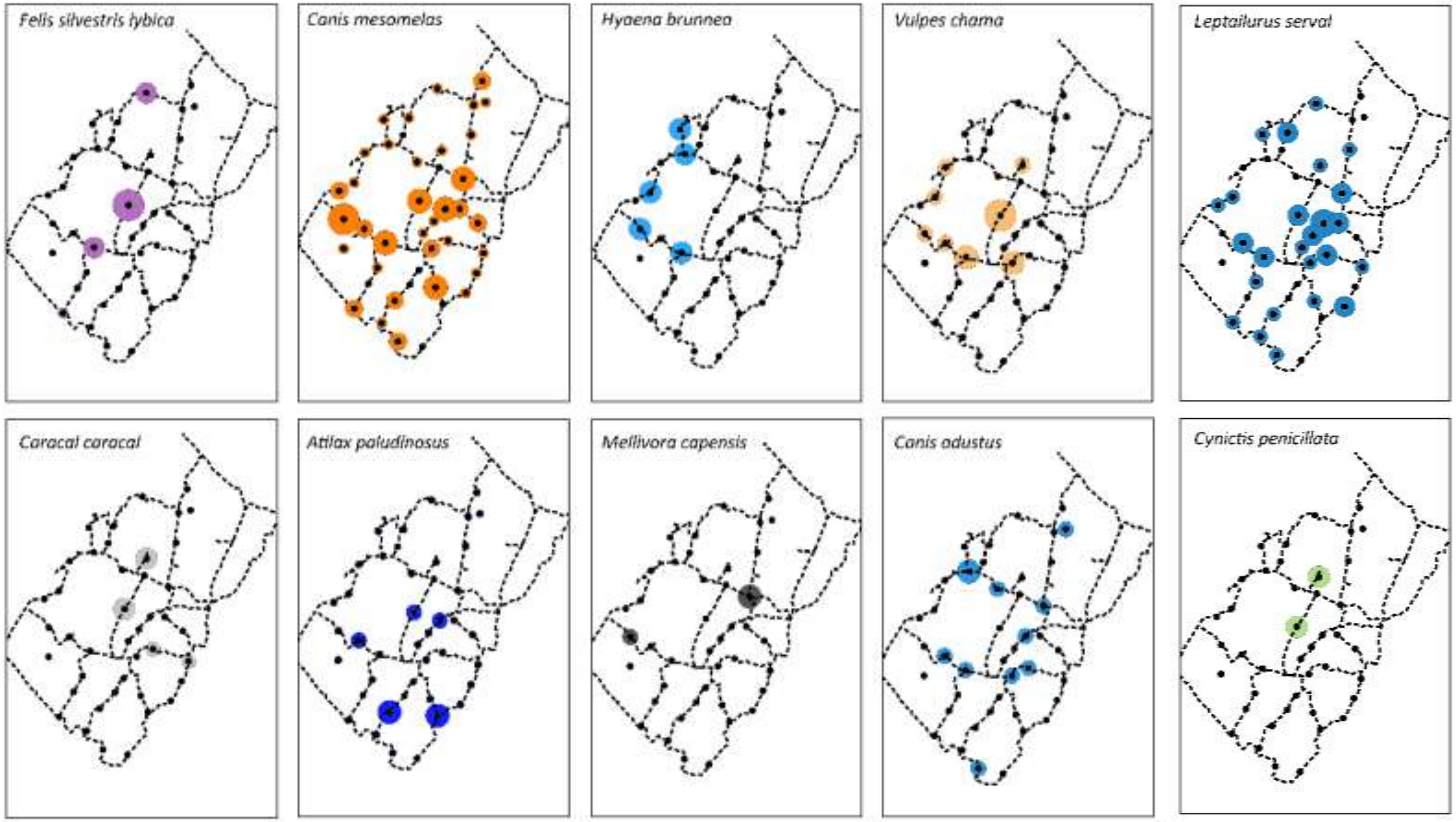

Fig. 2. Distribution and RAI of carnivores at Verlorenvallei Nature reserve as determined by camera trapping, circle size graphically indicates the number of pictures taken (e.g. ↑ circle ↑ nr of pictures)

Serval occupancy

Serval detection probability were significantly affected by distance to nearest wetland (AIC = 258.19) compared to a constant model (AIC = 263.16). There were a negative relationship between *p* and distance to nearest wetland (*β* -0.59, SE= 0.23) which suggest that serval detection probability declines as the distance from wetland increases (Fig. 6). We thus retained DistWet effecting *p* when fitting occupancy models.

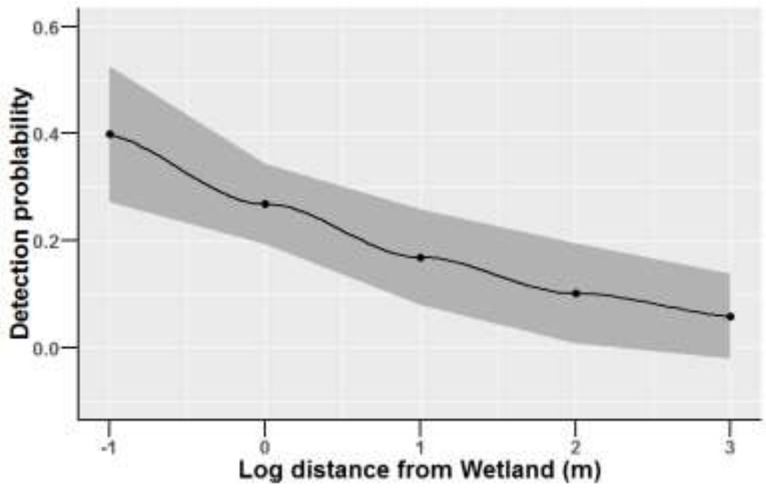

Fig. 6. Effect of scaled distance to closest wetland on the detection probability of serval at Verlorenvallei Nature reserve – Shaded grey areas = 95% Confidence Interval

Only one candidate model had delta AICc ≤ 2 (Table 3) suggesting that only black back jackal RAI were the best variable explaining serval *ψ*. (Table 3). Serval occupancy probabilities increased with increased detection of black back jackal (Fig. 7). Accounting for heterogeneity in detection probabilities generally improved occupancy probabilities over naïve occupancy estimates (Table 3; up to 60%). Predicted occupancy maps show the high affinity of serval with wetland areas (Fig. 8).

Table 3. Model selection analysis and parameter estimates

Model name	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL	ψ (SE)*	p (SE)*	Naïve occpancy
p(DistWet) ψ(Jackal)	4	252.13	0	0.71	0.71	-121.51	0.93 (0.22)	0.24 (0.050)	0.61
p(DistWet) ψ(DistWet + Jackal)	5	254.24	2.11	0.25	0.96	-121.26	0.88 (0.121)	0.25 (0.035)	0.61
p(DistWet) ψ(1)	3	258.85	6.71	0.02	0.98	-126.1	0.67 (0.088)	0.27 (0.038)	0.61
p(DistWet) ψ(DistWet)	4	259.39	7.25	0.02	1	-125.14	0.74 (0.123)	0.26 (0.039)	0.61

* ψ and p estimates at mean log values of Distance to wetland (0m) and Jackal RAI (0)

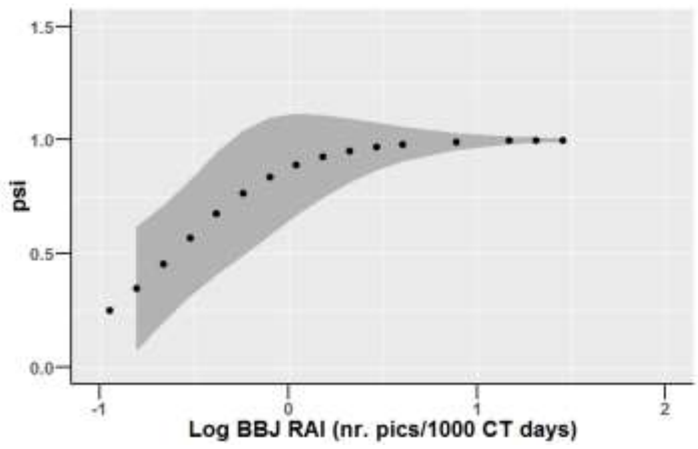

Fig. 7. Effect black back jackal RAI (log) on serval occupancy (psi)

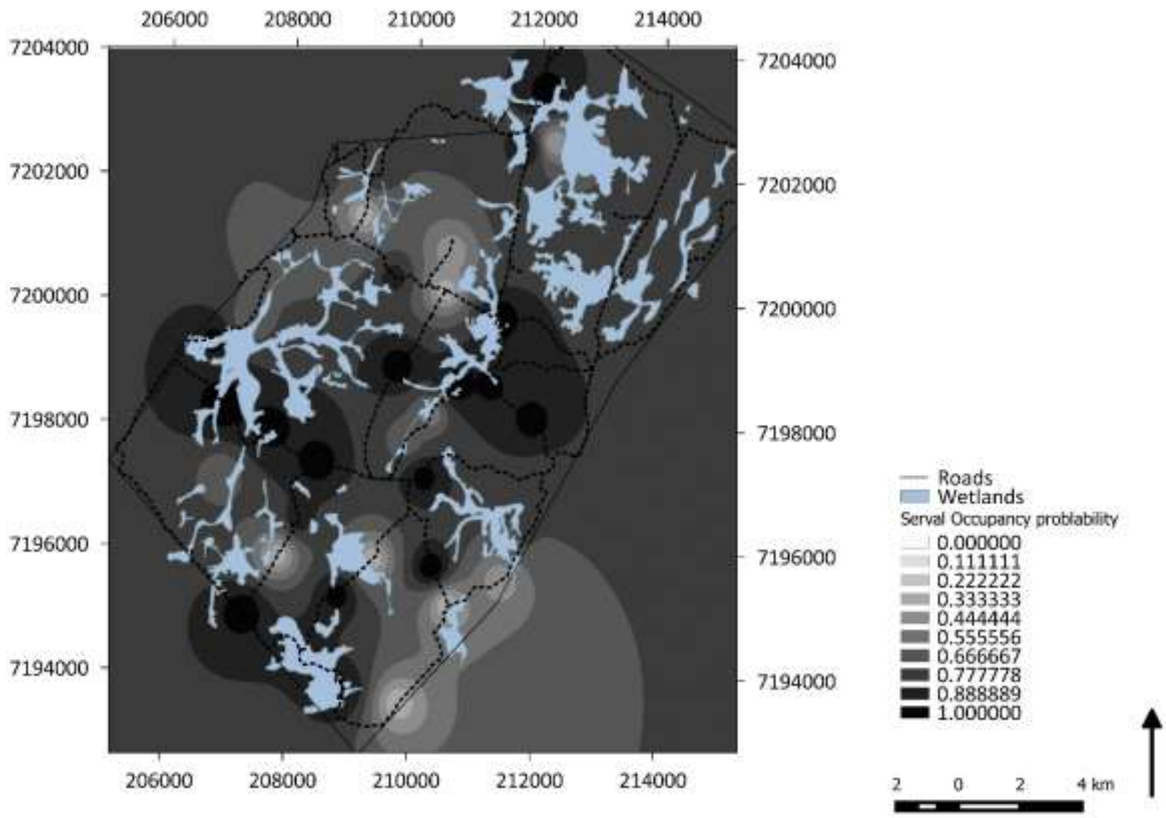

Fig. 8. Average predicted site occupancy for serval at Verlorenvallei Nature reserve

Discussion

This is the first camera trapping survey for Verlorenvallei Nature reserve and we detected a wide variety of mammal and bird species. Our survey were intensive enough to achieve adequate survey penetration both spatially and temporally. As such our approach emphasised the feasibility of combing camera trapping to estimate species richness, while still rigorously addressing detection probabilities to improve occupancy estimates that can be used for long term monitoring programs.

We restricted our occupancy analysis to serval since it is both a charismatic and conservation concern species. Our results concurs with others that serval showed a high affinity with wetland habitats, highlighting the importance of wetland conservation for serval persistence [20]. Interesting it has been suggested that interspecific completion with back blacked jackal can limit serval populations [21]; however we found that black backed jackal presence were positively related to serval occupancy. This can suggest that either abundant food resources or other resource partitioning mechanisms to limit competition between the two species.

Black backed jackal were the most widely and commonly detected carnivore species. This suggest that there are a healthy population on Verlorenvallei. Since we failed to detected any large carnivore species, back blacked jackal can be the apex predator at the site [4]. We detected a wide variety of other carnivores, highlighting the diversity of carnivores on site. Especially we detected side striped jackal which are classified as near threatened in South Africa [8] and the Verlorenvallei population can contribute to the national population.

Nonetheless we failed to detect a large number of small carnivores that should be common in South Africa. This either suggest that these species are truly absent (True negatives) or that we failed to detect those (False negatives). True absences of these species can be due to various reasons including, but not limited to; interspecific completion from black backed jackal [22], habitat not suited to species, resource limitations and locally extinct due to habitat fragmentation and isolation [23]. Equally plausible is that we failed to detect these species due to inappropriate camera placement [24], camera avoidance and interspecific carnivore completion [25].

Finally our results here can be seen as the first attempt to quantify the density and distribution of carnivore at Verlorenvallei. As such our results give a broad but crude estimate of relative carnivore abundance on site. We must highlight that the occupancy approach can easily be extended to include all the carnivore species, pending adequate spatial and temporal sampling. This approach will add increased robustness to estimates upon which management decisions can be based.

Recommendations

Based on these early findings we make the following recommendations regarding future surveys and analysis:

1. Extent the occupancy analysis to black backed jackal, side striped jackal and cape fox – all species had equate captures to allow for robust estimates of occupancy
2. Undertake a serval population estimates based on capture recapture models
3. Improve camera trap placement to areas under sampled – some sites we limited due to wet conditions and in future these sites should be included to avoid biased estimates
4. Investigate the feasibly of reducing camera trap grid size even more to allow for better detection smaller carnivores
5. Extent this survey to an annual basis to establish long term rates in occupancy, extinction and colonisation
6. Investigate the feasibility of including some farm land bordering the reserve
7. Investigate the feasibly of including small mammal surveys to better understand the resource base of carnivores
8. Start a systematic collection protocol for carnivore scats to investigate resource partitioning among carnivore species

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Appendix 1: Camera trap locations

Survey Name	StationID	X	Y	CamNumber1
VV 2015	1	30.1379	-25.3224	C1
VV 2015	2	30.1252	-25.3326	c1.1
VV 2015	3	30.1276	-25.3115	c2
VV 2015	4	30.1268	-25.3007	c3
VV 2015	5	30.1406	-25.3158	c3.1
VV 2015	6	30.1387	-25.3057	c4
VV 2015	7	30.1338	-25.329	c4.1
VV 2015	8	30.1215	-25.3139	c5
VV 2015	9	30.1185	-25.3087	c6
VV 2015	10	30.1322	-25.3008	c7
VV 2015	11	30.1226	-25.3048	c8
VV 2015	12	30.1227	-25.327	c9
VV 2015	13	30.1049	-25.2703	cb 29
VV 2015	14	30.089	-25.3133	cb 36
VV 2015	15	30.1174	-25.3467	cb 38
VV 2015	16	30.0976	-25.2814	cb 47
VV 2015	17	30.0968	-25.3068	cf 1
VV 2015	18	30.1414	-25.2581	cf 10
VV 2015	19	30.1065	-25.2787	cf 11
VV 2015	20	30.098	-25.3252	cf 13
VV 2015	21	30.1132	-25.3258	cf 14
VV 2015	22	30.1075	-25.331	cf 15
VV 2015	23	30.0879	-25.2939	cf 16

VV 2015	24	30.1083	-25.3447	cf 17
VV 2015	25	30.1381	-25.2661	cf 19
VV 2015	26	30.0893	-25.3034	cf 2
VV 2015	27	30.1014	-25.32	cf 20
VV 2015	28	30.125	-25.2868	cf 21
VV 2015	29	30.1259	-25.2812	cf 22
VV 2015	30	30.1044	-25.3117	cf 23
VV 2015	31	30.1337	-25.2908	cf 24
VV 2015	32	30.1168	-25.2848	cf 25
VV 2015	33	30.1425	-25.2652	cf 26
VV 2015	34	30.1141	-25.27	cf 27
VV 2015	35	30.1369	-25.2761	cf 3
VV 2015	36	30.1118	-25.2757	cf 31
VV 2015	37	30.0934	-25.2912	cf 4
VV 2015	39	30.1174	-25.2979	cf 6
VV 2015	40	30.1025	-25.3384	cf 7
VV 2015	41	30.1249	-25.2603	cf 8
VV 2015	42	30.0925	-25.3334	cf 9