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The application of camera trapping to assess Rallidae species richness within palustrine wetland habitat in South Africa

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Wetlands are vital habitats for a variety of organisms and ecosystem services, but the health of these valuable habitats is declining worldwide. The Rallidae species that rely on these habitats are typically elusive, cryptic and difficult to monitor accurately, especially in dense wetland vegetation. To date, invasive survey techniques such as rope dragging have largely been applied in surveying species within these genera. A survey of palustrine wetland habitat using camera traps was implemented to ascertain the efficacy of this non-invasive monitoring technique for surveying elusive wetland avian species. The survey yielded a total of 445 independent sightings across 15 target wetland species, including four Rallidae species. Our results clearly display that camera trapping as a non-invasive survey technique can effectively determine the presence and monitor arguably the most cryptic and elusive of the Rallidae genera within southern Africa. In addition, data sets produced through this survey technique are unique in that robust data are collected incorporating numerous aspects of species biology and behaviour. Our study further demonstrated the ability of camera trapping to produce accurate, reliable and rapid species inventories within palustrine wetland habitats.

L'application de pièges photos pour évaluer la richesse des espèces du genre Rallidae dans l'habitat des zones humides en Afrique du Sud

Les zones humides sont un habitat vital pour une grande variété d'organismes et par conséquent pour l'écosystème, mais l'état de ces habitats à forte valeur décline dans le monde entier. Les espèces du genre Rallidae dépendent de ces habitats. Elles sont particulièrement difficiles à trouver et à surveiller avec précision, surtout dans les végétations denses des zones humides. A ce jour, ce sont en grande partie des techniques d'études invasives, qui dérangent les individus, qui ont été appliquées dans le comptage de ces espèces, comme faire glisser une corde sur le sol. Une enquête sur les zones humide, utilisant des pièges photos, a été mise en œuvre pour vérifier l'efficacité de ces techniques de comptage de ces insaisissables espèces aviaires des zones humides. L'enquête a donnée au total 445 observations indépendantes, à travers 15 espèces habitant les zones humides et incluant 4 espèces de Rallidae. Nos résultats affichent clairement que les pièges photos peuvent, sans déranger, déterminer efficacement la présence et surveiller sans doute les individus les plus farouches de ce genre au sein du Sud de l'Afrique. Aussi, l'ensemble des données recueillies grâce à cette technique de comptage est unique et les résultats sont solides : ces informations contiennent de nombreux aspects sur la biologie des espèces et leur comportement. Notre étude prouve également la capacité et la précision des pièges photos, qui produisent un fiable et rapide inventaire des espèces présentes dans les zones humide.

Keywords: camera trapping, conservation, non-invasive, rallid, species richness, wetlands

Introduction

Wetlands provide vital habitats for a variety of bird species, but the health of these valuable habitats is declining worldwide (Aynalem and Bekele 2008). The need to protect both habitat and the specialist species that are dependent on them is of critical global importance. The Rallidae family is comprised of a diverse assemblage of primarily small and medium-bodied birds. This family in a southern African context includes rails, crakes, gallinules, swamphens, moorhens and coots (Hockey et al. 2005). The flufftail and crake genera are the smallest-bodied and most elusive species within this family that generally forage on the ground, particularly the *Sarothrura*, *Porzana*, *Rallus* and *Crex* genera (Taylor 1994, 1997a, 1997b). These particular genera utilise a wide range of habitats, but the majority of species are usually associated with wetlands (Taylor and van Perlo 1998; Hockey et al. 2005). Subsequently, their elusive, cryptic and ground-foraging behaviour in often dense wetland vegetation have resulted in them being relatively difficult to accurately study (Masterson 1971; Allan et al. 2006; Davies et al. 2015). To date, the most widely utilized method of surveying these species have involved point counts (Fletcher et al. 2000, Haselmeyer and Quinn 2000; Wilson et al. 2000), line transects (Mendelsohn et al. 1983; Bibby et al. 1998; Fletcher et al. 2000; Wilson et al. 2000; Allan et al. 2006; Davies et al. 2015), rope dragging surveys (Green 1985; Bibby et al. 1998; Allan et al. 2006; Davies et al. 2015) and auditory surveys (Taylor 1994, 1997a, 1997b; Taylor and van Perlo 1998; Haselmeyer and Quinn 2000).

Auditory surveys have proved effective at determining species presence across numerous avian guilds and habitat types, particularly during the breeding season (Taylor and van Perlo 1998; Haselmeyer and Quinn 2000). Rallidae are noted as a generally highly vocal family group and as such some species can be surveyed through auditory surveys in the breeding season (Masterson 1971; Taylor and van Perlo 1998). However, some species are noted to have inconspicuous calls that can be either drowned out by other avian calls or associated environmental noise. Furthermore, the calls of some priority rallid species are unknown or unrecorded, making it difficult to accurately ascertain presence on call alone (Davies et al. 2015). Species noted as having auditory survey limitations include the Critically Endangered White-winged Flufftail *Sarothrura ayresi* in Africa (Davies et al. 2015), Vulnerable Yellow Rail *Coturnicops noveboracensis* in North America (Taylor and van Perlo 1998), Vulnerable Swinhoe's Rail *Coturnicops exquisites* in East Asia (Taylor and van Perlo 1998) and Speckled Rail *Coturnicops notatus* in South America (Taylor and van Perlo 1998). Point counts are generally noted as ineffective at recording elusive species in the absence of distinctive auditory cues (Fletcher et al. 2000). Furthermore, studies conducted in wetland and grassland habitat have found that line transects are generally more effective than point counts in recording species richness and density estimations (Fletcher et al. 2000; Wilson et al. 2000).

Although rope dragging is noted as an accepted method of surveying cryptic waterbirds (Green 1985; Bibby et al. 1998), there is a noted low detection probability associated with some elusive species (Schieck 1997). The reluctance of some Rallidae species to take flight (flush) is of particular importance regarding the detection bias within rope-dragging surveys. This reluctance to take flight by some species, particularly those of the *Sarothrura* genera, is evident in that Red-chested Flufftail *Sarothrura rufa*, which were heard calling from multiple locations at a given wetland during Rallidae surveys conducted in South Africa in 2014 (Davies et al. 2015) and 2015 (Drummond et al. 2015), were not flushed whilst rope dragging during the same period. In addition, the Davies et al. (2015) study highlights the elusive and skulking nature of flufftails as being a potential restraint to the success of rope-dragging and walk-transect surveys. Furthermore, if birds are flushed, additional rope dragging efforts over the area where the bird re-entered vegetation seldom results in a second sighting (Mendelsohn et al. 1983). Of additional significance is the potential disturbance impact of extensive rope dragging and walked transects on both target species and respective wetland habitat (Davies et al. 2015). The development of an accurate non-invasive method of surveying Rallidae species within wetland habitat would therefore be beneficial to respective conservation efforts.

Excluding auditory surveys, other recommended methods include surveying with pointer dogs and using passive walk in traps (Davies et al. 2015). However, both methods are invasive and are relatively labour-intensive survey techniques. Camera trapping is noted as a non-invasive survey method and has been utilised on a wide range of species and ecological applications (Rovero et al. 2010; O'Connell et al. 2011; Jansen et al. 2014). Although its use has largely been focused on medium to large terrestrial mammalian species (Silveira et al. 2003; Srbek-Araujo and Chiarello 2005; Kelly 2008, Ahumada et al. 2013; Araujo and Chiarello 2013), extensive studies have been conducted on aspects of nest predation and breeding ecology of bird species through remote photography (Cutler and Swan 1999; Sanders and Maloney 2002). In addition, avian camera trap studies focused on ground-dwelling birds within forest habitats have successfully assessed species richness estimations (Dinata et al. 2008) and aspects of species social organisation and activity patterns (Srbek-Araujo et al. 2012). Camera trapping is also noted as a cost-effective and easily replicable survey technique that limits survey bias to the development of the survey design and identification of photographs (O'Connell et al. 2011). The aim of this study was to assess if camera trapping could be utilised as an accurate and reliable non-invasive survey technique to target Rallidae species within wetlands.

Materials and methods

Study site

The study site is located within Ingula Nature Reserve, which straddles the Klein Drakensberg escarpment between eastern Free State and KwaZulu-Natal, South Africa (Figure 1). The broader area is largely comprised of Eastern Free State Sandy Grassland (c. 4 400 ha) and high-altitude palustrine wetland habitat (c. 1 400 ha) associated with the Upper Wilge River water catchment area (Mucina and Rutherford 2006). Wetland types present within the study site are classed as perennial unchannelled valley bottom and floodplain wetlands, whilst falling within the Mesic Highveld Grassland Group 1 Wetland Ecoregion (Wetland Consulting Services 2006; Ollis et al. 2013). Three broad wetland vegetation communities are present, namely *Cyperus rupestris*–*Eriocaulon dregei* (sheetrock seepages), *Cyperus fastigiatus*–*Hemarthria altissima* (marsh wetland) and *Cyperus fastigiatus*–*Gunnera perpensa* (hummocked marsh wetlands) (Wetland Consulting Services 2006). The dominant vegetation species identified were *Cyperus fastigiatus*, *Phragmites australis*, *Schoenoplectus corymbosus*, *Carex acutiformis* and *Leersia hexandra* (Wetland Consulting Services 2006).

The study site falls within an internationally recognised Important Bird and Biodiversity Area (IBA), namely the Ingula IBA (Figure 1). The pooled species list compiled between 2006 and 2016 for the conservation area includes 310 avian species, of which 22 are classified as regionally threatened and 18 as globally threatened (Taylor et al. 2015). Of these regionally threatened species, 12 are associated with wetland habitats, including species such as the Critically Endangered White-winged Flufftail, Critically Endangered Wattled Crane *Bugeranus carunculatus*, Endangered Grey Crowned Crane *Balearica* *regulorum*, Endangered African Marsh Harrier *Circus ranivorus* and Vulnerable African Grass Owl *Tyto capensis* (Taylor et al. 2015). A total of 10 Rallidae species have been recorded within the respective nature reserve and IBA, including seven resident and three migratory species.

Survey design

The survey design was tailored to estimate species richness of a target avian family, namely Rallidae. The survey design was therefore structured to allow intensive sampling over a small area, which is one of two recommended approaches if species richness estimates are the objective of the study (O'Brien 2011). Sampling was focused over numerous sampling points to increase the potential efficacy of capturing rare species (MacKenzie and Royle 2005). Furthermore, this survey design would also indirectly include other species of appropriate size co-occurring in the same habitat types sampled.

Fine-scale habitat community classification

Within the study area, it was noted that several different vegetation communities were present yielding varied vegetation structure in terms of cover and height. As such, the wetlands were mapped in line with the methodology adopted by Davies et al. (2015) during surveys conducted (Figure 2). These were classed into four different fine-scale habitat community types (Table 1) in accordance with dominant vegetation species present (Kotze 1998).

Camera placement

Considering the lack of information regarding survey design relative to avian species richness assessments within wetland habitats, a pilot survey approach was implemented (Bibby et al. 1998; Woog et al. 2010). Survey design included a random camera placement across all four fine-scale habitat classes that were identified as suitable habitat for expected rallid species (Urban et al. 1986; Taylor 1994, 1997a, 1997b; Davies et al. 2015).

Suggested camera placement height for medium to large (>2 kg) mammalian species is 30–50 cm (Tobler et al. 2008; Ancrenaz et al. 2012; Jansen et al. 2014). In addition, cameras are generally set facing horizontally towards an area of interest, with camera height and distance adjusted to the target species (Nelson and Scroggie 2009; Jansen et al. 2014). A problem inherent with the recommended heights and angles as mentioned above is a lower resultant detection probability for smaller-bodied animals (Ancrenaz et al. 2012). Therefore, due to the significantly smaller height (mean = 20 cm) and weight (mean = 83 g) of Rallidae species in this study, an alternate

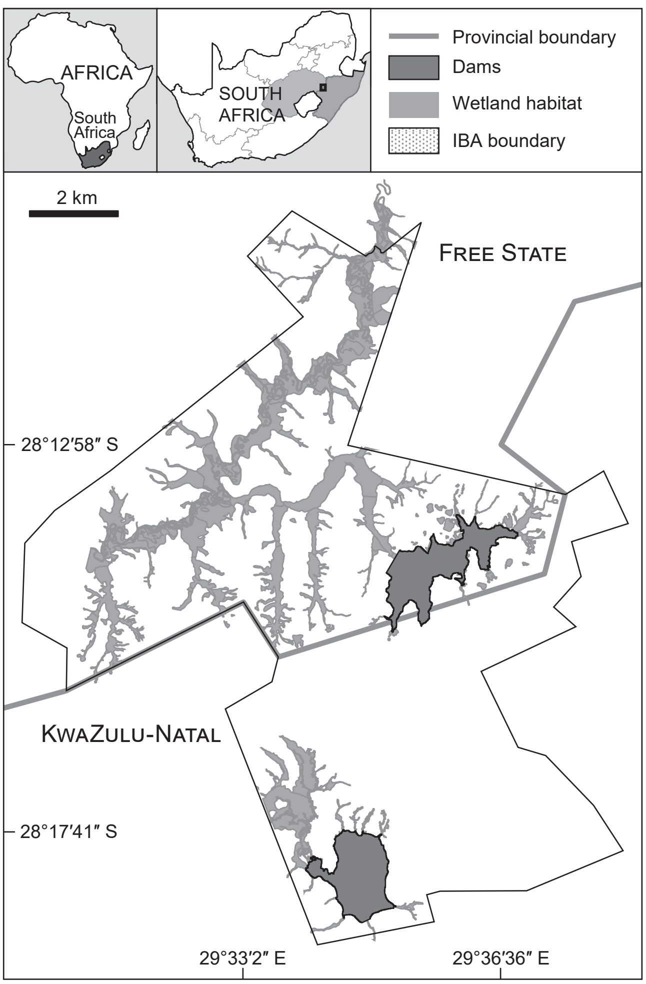

Figure 1: Location of Ingula Nature Reserve and delineation of the respective Important Bird and Biodiversity Area (IBA) and wetland habitat present

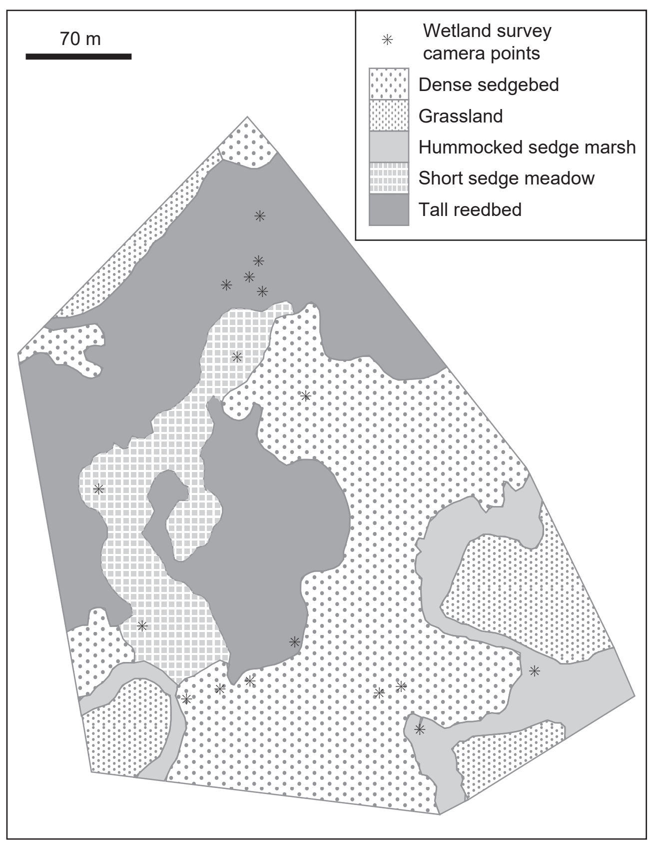

Figure 2: Fine-scale habitat community within the Bedford Wetland study area, with the locations of camera traps indicated by asterisks

camera placement height and angle was tested. Placement height was therefore adjusted to allow the camera detection arc to be concentrated on focal areas of activity related to the target Rallidae species. This often resulted in cameras being placed relatively higher, and mounted between horizontal (De Bondi et al. 2010) and vertical (Nelson and Scroggie 2009) angles (Figure 3). Variation in camera height, angle and focal distance was required to allow for optimal camera placement across varied wetland habitat structures, including vegetation cover, height and density. It is suggested that cameras be placed orientated towards north or south (Jansen et al. 2014) to eliminate the influence of sunrise and sunset on the captured images. However, within our study dense wetland vegetation limited the alteration in camera orientation surrounding the identified focal area and hence became secondary during placement. Due to this limiting factor, our study also aimed to understand if sunrise and sunset overexposure (Jansen et al. 2014) is indeed a factor needing consideration in palustrine wetland habitats.

Cameras were secured with straps and cable ties to metal fencing droppers of varied thickness and length, depending on water depth, substrate solidity and cattle presence. Often, due to the waterlogged and muddy conditions of the soil, it was necessary to join two droppers together with cable ties in order to achieve a stable camera placement. The malleable nature of metal droppers allows for the easy manipulation of vertical angles (Table 4, Figure 3). Ltl Acorn HD IR camera traps were used and settings included normal sensor sensitivity, high infrared flash intensity, three photos per capture and a capture interval of 20 s. In order to limit excessive false trigger rates associated with moving vegetation (Kelly and Holub 2008; Tobler et al. 2008; Rovero et al. 2010; Ancrenaz et al. 2012; Jansen et al. 2014), selected vegetation directly within the focal area was cropped. None of the vegetation species cropped are listed as threatened.

Given limitations in the number of cameras at our disposal, cameras were moved to new camera positions once the desired survey effort was achieved. Data collection commenced on 4 March 2016 and concluded on 24 May 2016, occurring within one season, namely autumn (South African Weather Service 2016). A summer survey would have been preferable, but the study was delayed to autumn due to a poor summer rain season and delayed rains in this particular year. Resultant survey effort totalled 82 consecutive days across 17 camera trap locations (Figure 2) using seven cameras.

To assess the relationship between species presence and habitat characteristics, covariate data were collected at each camera point. Data collected included water depth, water cover, vegetation cover (basal), vegetation height, canopy cover, fine-scale habitat communities (Figure 2, Table 1), trail presence/absence, trail width and trail type.

Data analysis

All cameras were serviced and data were downloaded every 14 d. This iteration period allowed for vegetation cropping in front of the camera that regrew during the period, assessment of false trigger rates and, if required, correcting cameras that had been disturbed through cattle and downloading data for collation. Data were collated and filtered to include all target species, which excluded only those small passerines (<20 g) that could be difficult to identify from images. Species of this size range would include wetland warblers *Acrocephalus* and *Bradypterus*, waxbill *Estrilda* spp., bishop *Euplectes* spp., widowbird *Euplectes* spp. and weaver *Ploceus* spp., which due to their foliage gleaning behaviour, could exhibit lower detection probabilities to that of ground-foraging Rallidae species.

If multiple sightings of the same species were captured concurrently across a short period, sightings would be deemed independent when separated by 60 min intervals (Tobler et al. 2008). For the purposes of this study, the measure of capture success is defined as capture frequency, which is the number of independent sightings per 100 camera days (Kelly and Holub 2008). The software EstimateS (Colwell 2013) was utilised to conduct species richness analyses and compile rarefied species accumulation curves. To assess the relationship between species presence and habitat characteristics, Spearman's rank correlations were conducted on presence and covariate data.

To evaluate the efficiency of the survey in terms of species richness estimations achieved, an expected species richness inventory was collated from four sources linked to the specific study site (Table 2). Sources included results from a line transect survey conducted in February 2015 within the study site using the rope dragging

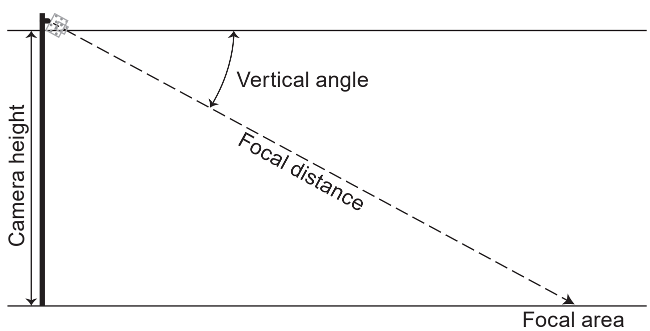

Figure 3: Camera placement indicating the vertical angles altered to survey target avian species

Table 1: Fine-scale habitat communities classed according to dominant wetland vegetation species present

Type	Species	Average height range (cm)	Wetland diagnostic features
Habitat 1	*Phragmites australis*, *Cyperus fastigiatus*, *Leersia hexandra*	50–140	Tall reedbeds
Habitat 2	*Schoenoplectus corymbosus*, *Cyperus fastigiatus*, *Carex acutiformis*	14–60	Dense sedgebeds
Habitat 3	*Carex acutiformis*, *Leersia hexandra*, *Schoenoplectus corymbosus*	15–23	Short sedge meadows
Habitat 4	*Schoenoplectus corymbosus*, *Cyperus fastigiatus, Leersia hexandra*	20–50	Hummocked sedge marsh

Table 2: The expected wetland target species list compiled for the study from four sources of survey results for the Bedford Wetland. Regionally threatened species (Taylor et al. 2015) are highlighted in bold

Common name	Data source			Pooled reserve species list
	Davies et al. (2015)	Line transects 2015	Taylor (1997)	
Bittern, Eurasian		x		x
Bittern, Little			x	x
Cormorant, Reed	x			x
Crake, Ballion's	x			x
Crane, Grey Crowned (EN)	x	x	x	x
Duck, Yellow-billed	x			x
Flufftail, Red-chested			x	x
Flufftail, White-winged (CR)				x
Goose, Spur-winged	x			x
Harrier, African Marsh (EN)	x	x		x
Heron, Grey			x	x
Heron, Purple	x		x	x
Kingfisher, Malachite	x			x
Owl, African Grass (VU)		x		x
Rail, African	x		x	x
Snipe, African	x			x
Swamphen, African			x	x
Total		17		

technique (Drummond et al. 2015), wetland survey results for the greater Bedford wetland published in Davies et al. (2015), wetland survey results for the greater Bedford wetland from Taylor (1997b) and the pooled Ingula Nature Reserve species list. The expected list included non-Rallidae wetland avian species that exhibited similar elusive behaviour and/or were classified as threatened and of conservation concern.

Results

Our study yielded a total of 566 camera days across 17 camera survey locations (Figures 2 and 4). The resultant survey effort yielded 445 independent avian sightings of target species, including 15 species across nine families (Table 3). Sightings also included four regionally threatened species (Taylor et al. 2015), namely Wattled Crane, Grey Crowned Crane, African Marsh Harrier and African Grass Owl. The species most recorded included African Snipe *Gallinago nigripennis* (CF = 42.54), African Rail *Rallus caerulescens* (CF = 16.22) and Grey Crowned Crane (CF = 10.27). Significantly, the study recorded four Rallidae species, namely African Rail, Black Crake, Spotted Crake and Red-chested Flufftail. With the exception of Black Crake, all other Rallidae species were within the five most recorded species across the survey (Table 3).

Results indicated that vegetation class and associated structure influenced multiple aspects of camera placement, including camera height, camera angle and focal distance (Table 4). Wetland vegetation height and density, as well as the focal area required for target species resulted in a camera height of 40–60 cm (mean = 57 cm) (Table 4). Similarly, taller and denser vegetation necessitated larger vertical camera angles and shorter focal distances (Table 4, Figure 3). Camera angle varied between 19.6° for the shortest vegetation class, namely hummock vegetation (mean = 4.4 cm), through to 26.9° for the tallest vegetation class, namely reedbeds (mean = 21.8 cm). Focal distance ranged from 190 cm for the shortest vegetation class through to 123.3 cm for the tallest vegetation class (Table 4). Camera orientation varied greatly, largely as a result of the limited availability of suitable areas within dense wetland vegetation to place cameras facing the point of interest. As a result, although east and west orientations were avoided due to sunset and sunrise overexposure concerns (Jansen et al. 2014), a number of cameras were orientated towards an eastward (n = 2) and westward (n = 3) direction. However, data collation revealed a negligible quantity of overexposed images (<1%) and those that were overexposed still allowed for the identification of respective species.

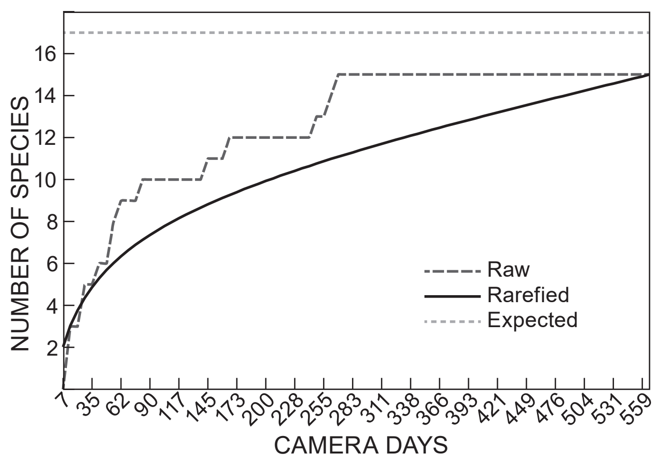

Figure 4: Species accumulation trends represented as both raw and rarefied species accumulation curves for the camera trap survey

The most significant habitat factors influencing the number of species recorded across the study were the presence of a trail (r_s = 0.73, p < 0.001, df = 15), type of trail (r_s = 0.69, p = 0.002, df = 15), associated trail width (r_s = 0.64, p = 0.006, df = 15) and water depth (r_s = −0.49,

p = 0.044, df = 15). The number of species captured per camera location varied between 0 and 6 (2.4 ± 1.69). Similarly, the habitat factors influencing the number of independent sightings recorded across the study were the presence of a trail (r_s = 0.68, p = 0.002, df = 15) and water depth (r_s = −0.50, p = 0.044, df = 15) (Table 5). Cameras on trails yielded an average of 2.8 species and 31.4 independent sightings, whilst cameras off trails yielded an average of 0.3 species and 1.7 independent sightings.

Species accumulation trends reached an asymptote at approximately 300 camera days, with no new species being added following 269 camera days (Figure 4). However, the rarefied species accumulation curve does also indicate that further survey effort could produce a steeper initial growth and more defined plateau following the asymptote. When compared with the expected species list, the survey managed to accumulate 88% of the total number of expected species (Table 2). Of the 17 expected species, five were not recorded during this specific study, whilst three new target species were recorded that were not on the expected list. Species not recorded included Eurasian Bittern *Botaurus stellaris*, Baillon's Crake *Zapornia pusilla*, White-winged Flufftail, Purple Heron *Ardea purpurea* and African Swamphen *Porphyrio porphyrio* (Table 2). New species recorded included Black Crake, Spotted Crake and Critically Endangered Wattled Crane (Table 3).

In addition to the 15 target species recorded, 14 non-target avian species were recorded and were filtered out based on average body weights falling below 20 g and/or opposing foraging strategies to target species (Table 6). Furthermore,

Table 3: All target species recorded during the camera-trap survey, with regionally and globally threatened species highlighted in bold. Capture frequency is defined as the number of independent sightings per 100 camera days (Kelly and Holub 2008)

Common name	Scientific name	Family	Capture frequency (CF)	Regional conservation status	Global conservation status
Bittern, Little	*Ixobrychus minutus*	Ardeidae	0,18	Least Concern	Least Concern
Cormorant, Reed	*Microcarbo africanus*	Phalacrocoracidae	0,90	Least Concern	Least Concern
Crake, Black	*Amaurornis flavirostra*	Rallidae	0.18	Least Concern	Least Concern
Crake, Spotted	*Porzana porzana*	Rallidae	5,05	Least Concern	Least Concern
Crane, Grey Crowned	***Balearica regulorum***	**Gruidae**	**10,27**	**Endangered**	**Endangered**
Crane, Wattled	***Bugeranus carunculatus***	**Gruidae**	**0,18**	**Critically Endangered**	**Vulnerable**
Duck, Yellow-billed	*Anas undulata*	Anatidae	0,72	Least Concern	Least Concern
Flufftail, Red-chested	*Sarothrura rufa*	Rallidae	3,06	Least Concern	Least Concern
Goose, Spur-winged	*Plectropterus gambensis*	Anatidae	0,18	Least Concern	Least Concern
Harrier, African Marsh	***Circus ranivorus***	**Accipitridae**	**0,18**	**Endangered**	**Least Concern**
Heron, Grey	*Ardea cinerea*	Ardeidae	0,18	Least Concern	Least Concern
Kingfisher, Malachite	*Alcedo cristata*	Alcedinidae	0,18	Least Concern	Least Concern
Owl, African Grass	***Tyto capensis***	**Tytonidae**	**0,36**	**Vulnerable**	**Least Concern**
Rail, African	*Rallus caerulescens*	Rallidae	16,22	Least Concern	Least Concern
Snipe, African	*Gallinago nigripennis*	Scolopacidae	42,52	Least Concern	Least Concern

Table 4: Resultant aspects of camera placement in relation to vegetation class

	Vegetation class mean placement values			Mean	SD
	Reedbeds	Sedgebeds	Hummocks		
Camera height (cm)	60.0	54.4	64.0	60.0	3.9
Camera vertical angle (°)	25.9	20.7	19.6	20.7	2.8
Focal distance (cm)	123.3	153.3	190.0	153.3	27.3
Mean vegetation height (cm)	21.8	6.0	4.4	6.0	7.8

Table 5: Spearman's rank correlations between habitat variables assessed and species capture frequencies. Statistically significant values (p < 0.05) are highlighted in bold

Habitat feature	Spearman's rank correlation coefficient				
	African Snipe	African Rail	Red-chested Flufftail	Spotted Crake	Grey Crowned Crane
Water depth	**−0.46**	−0.25	0.06	0.10	−0.24
Water cover	−0.26	−0.06	−0.28	0.08	−0.16
Vegetation height	0.08	0.11	**0.66**	0.05	−0.46
Vegetation cover	0.26	0.06	0.28	−0.08	0.16
Canopy cover	0.02	−0.12	**0.79**	−0.18	−0.33
Trail	**0.65**	**0.63**	0.25	0.12	**0.65**
Trail type	**0.64**	0.52	0.09	0.16	−0.01
Trail width	0.34	**0.74**	0.26	**0.59**	0.23
Habitat type	0.14	0.05	**0.64**	−0.08	−0.15

extensive independent sightings of five mammalian non-target species were identified across multiple camera points, including three carnivorous and two herbivorous species (Table 6).

Excluding African Rail, all other recorded Rallidae species were only captured at highly localised cameras points. Two of the four species, namely Spotted Crake and Black Crake, were exclusively recorded at one camera point only (Figure 5). Spotted Crake yielded 28 independent sightings across 14 survey days at the one respective camera point (Figure 5). Similarly, Red-chested Flufftail yielded 17 independent sightings across four (24%) out of the 17 camera points, which were all located adjacent to one another.

Relationships between habitat covariates and respective capture frequency were assessed for the five species that yielded sufficient data. Among the habitat variables assessed, trail presence, trail type and trail width were intercorrelated, which could be expected (Harmsen et al. 2010). African Snipe yielded positive correlations with trail presence (r_s = 0.65, p = 0.0051, df = 15) and trail type (r_s = 0.64, p = 0.0053, df = 15), whilst yielding a weaker negative correlation to water depth (r_s = −0.46, p = 0.06,

Table 6: Non-target species recorded during the study

Common name	Scientific name
Avian	
Bishop, Southern Red	*Euplectes orix*
Bishop, Yellow-crowned	*Euplectes afer*
Cisticola, Levaillant's	*Cisticola tinniens*
Longclaw, Cape	*Macronyx capensis*
Quail-finch, African	*Ortygospiza fuscocrissa*
Quelea, Red-billed	*Quelea quelea*
Stonechat, African	*Saxicola torquatus*
Wagtail, Cape	*Motacilla capensis*
Warbler, Lesser Swamp	*Acrocephalus gracilirostris*
Warbler, Little Rush	*Bradypterus baboecala*
Waxbill, Common	*Estrilda astrild*
Widowbird, Fan-tailed	*Euplectes axillaris*
Widowbird, Long-tailed	*Euplectes progne*
Widowbird, Red-collared	*Euplectes ardens*
Mammalian	
Mongoose, Water	*Atilax paludinosus*
Otter, Cape Clawless	*Aonyx capensis*
Otter, Many-spotted	*Hydrictis maculicollis*
Reedbuck, Common	*Redunca arundinum*
Cow, Domestic	*Bos taurus*

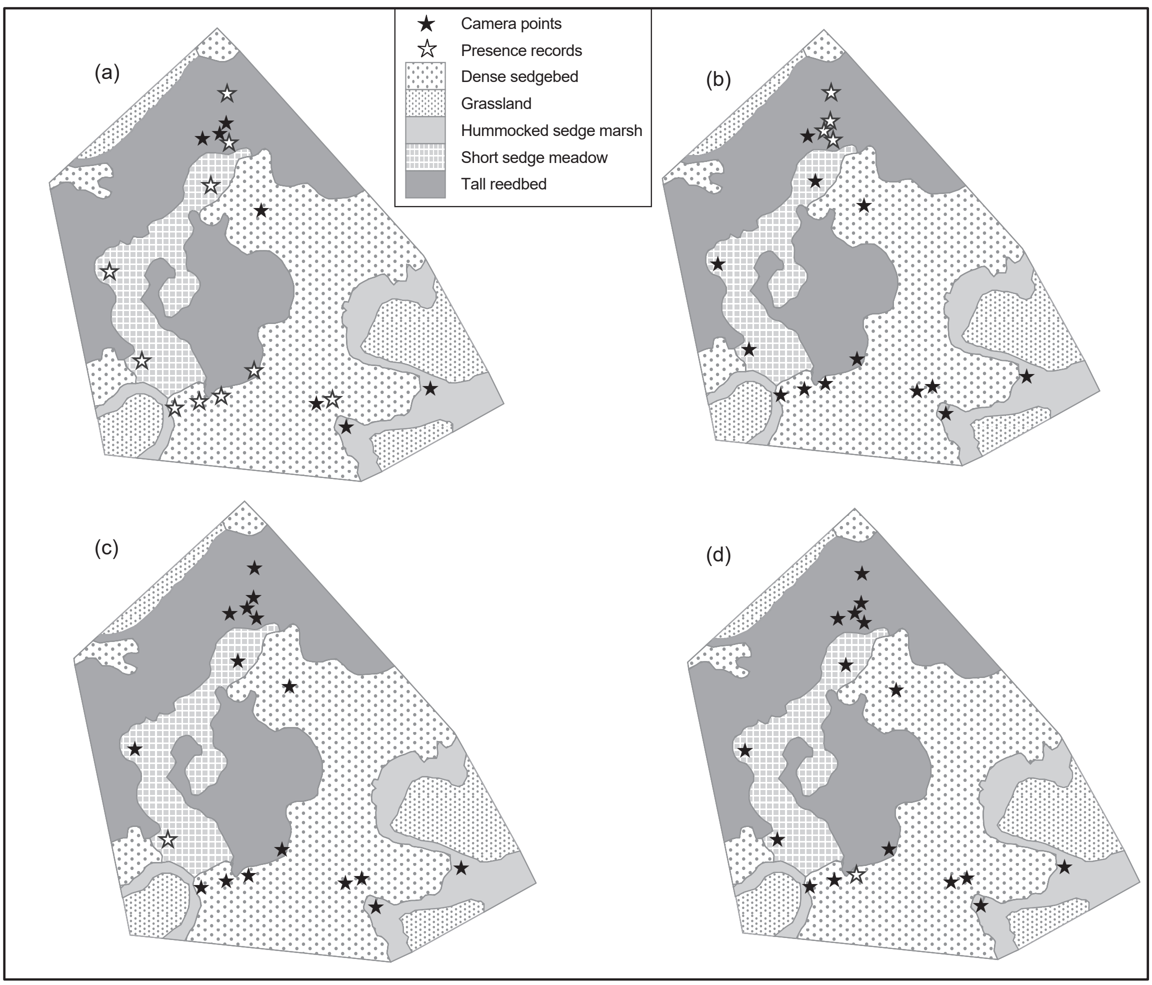

Figure 5: Presence records (white stars) of (a) African Rail (n = 10), (b) Red-chested Flufftail (n = 4), (c) Black Crake (n = 1) and (d) Spotted Crake (n = 1) in relation to camera points (black stars) across the study area

df = 15). Similarly, African Rail capture frequency correlated positively with trail width (r_s = 0.74, p = <0.001, df = 15) and trail presence (r_s = 0.63, p = 0.006, df = 15). Both these species were exclusively recorded on trails within respective wetland habitat. An additional target species that correlated positively (r_s = 0.59, p = 0.01, df = 15) with trail width was Spotted Crake, which occurred on the widest (diameter = 60 cm) recorded trail within the study site (Table 5).

Red-chested Flufftail capture frequency correlated most strongly to canopy cover (r_s = 0.79, p < 0.001, df = 15) and vegetation height (r_s = 0.66, p = 0.004), respectively (Table 5). This species was exclusively recorded within the tall reedbed habitat (Table 5), which was largely comprised of tall vegetation (mean = 125 cm) and high canopy cover (>5%). Similarly, Grey Crowned Crane yielded a positive correlation with trail presence (r_s = 0.65, p = 0.004, df = 15).

Discussion

This pilot study confirms that camera trapping can be utilised as an effective method of surveying for rare and elusive Rallidae and other ground-foraging wetland birds. This is evident in that the study, over a relatively moderate survey effort, accounted for the majority of expected Rallidae species. One priority species not accounted for, namely White-winged Flufftail, is believed to be an intra-African migrant that has primarily been recorded in South Africa between December and February (Davies et al. 2015). The earliest South African sighting was recorded on 5 September, whilst the latest sighting was recorded in late February (Davies et al. 2015). This strongly suggests that the presence of this species would have been excluded from our study based on the respective survey period (March–May). Similarly, another expected species not recorded, namely Eurasian Bittern, is noted as a highly nomadic, locally migratory and dispersive species (Barnes 2000). In light of this, a more extensive survey design might be needed to record nomadic species such as Eurasian Bittern. However, the study was successful in documenting four Rallidae species, two of which have not been recorded in these wetlands prior to this study, namely Black Crake and Spotted Crake.

A collation of the camera placement factors that yielded the highest capture frequencies (Table 4) of Rallidae species was synthesised into a placement procedure to assist with replication through future studies (Table 7). The results displayed that orientation had no detrimental effect on the recording of images with regard to overexposure, and as such does not require attention when placing cameras. Given the lack of published recommendation on camera trap survey design within wetland habitats, these recommendations could not be compared with other varied wetland types.

Of the species recorded the most within our study, African Snipe, African Rail and Grey Crowned Crane were similar to the findings of rope-dragging surveys conducted in South Africa (Davies et al. 2015) and Ethiopia (Allan et al. 2006). Species most recorded in Davies et al. (2015) were Yellow-billed Duck, African Snipe and Grey Crowned Crane, whilst in Allan et al. (2006) African Snipe, Yellow-billed Duck and Marsh Owl were most recorded. Furthermore, unlike rope-dragging studies, and of particular significance emphasising the efficacy of camera trapping for Rallidae species, are the inclusion of three Rallidae species within the five most recorded species throughout our study. The data collected in our study included numerous independent sightings (n = 136) of target Rallidae species, as opposed to generally one sighting per flushing event through rope dragging and line transect surveys (Mendelsohn et al. 1983; Davies et al. 2015).

The efficacy of camera trapping for Rallidae species is further demonstrated in that rope dragging and point surveys across a larger area of the Bedford wetlands in 2014 only yielded two Rallidae species with limited sightings of each, namely African Rail (n = 6) and Baillon's Crake (n = 1) (Davies et al. 2015). Similarly, three rope-dragging surveys conducted between 2001 and 2002 across the greater Bedford and Chatsworth wetlands yielded four Rallidae species, namely African Rail (n = 2), Corncrake *Crex crex* (n = 1), Baillon's Crake (n = 3) and Red-chested Flufftail (n = 1) (Allan et al. 2006). Furthermore, data from rope-dragging surveys within our specific study site in 2015 (Drummond et al. 2015) only yielded three target species (>20 g), namely Eurasian Bittern, African Grass Owl and Grey Crowned Crane, none of which were Rallidae species. In light of this, our results clearly display camera trapping as an effective method of compiling rapid Rallidae species richness estimates.

Numerous camera trap studies assessing mammalian species have addressed and highlighted the difference in detection probability of species relative to body weight (Carbone et al. 2002; Silveira et al. 2003; Tobler et al. 2008). In these studies detection probability and resultant capture frequency increased in relation to average body weight. Our study focusing on avian assemblages displayed high capture frequencies across species regardless of relative body size. Rallidae species with the highest capture frequency had a

Table 7: Recommended camera placement guideline for Rallidae species in a palustrine wetland habitat

Placement aspect	Hummocks	Sedge beds	Reedbeds
Sample point positioning	Focus on hummock directly	Along path or at path confluences	Along path or at path confluences
Camera height (cm)	40–60	40–60	40–60
Focal distance (cm)	150–300	120–300	110–130
Camera vertical angle (°)	9.5–18	18–22	21–24
Vegetation clearing	Crop focal area to <10 cm	Crop focal area to <10 cm	Crop focal area to <10 cm
Orientation	n/a	n/a	n/a

varied average body weight of c. 37 g (Red-chested Flufftail) to c. 170 g (African Rail) and an average height of c. 16 cm to c. 28 cm (Urban et al. 1986; Taylor 1994, 1997a, 1997b). Although camera placement was tailored for Rallidae species in terms of survey design, additional results included a wide range of other target and non-target avian species ranging in average body weight between 15 g (Lesser Swamp Warbler) and 8 kg (Wattled Crane).

A number of recorded Rallidae species within our study positively correlated to the presence of cattle and/or game trails. Although overgrazing and excessive trampling by herbivores, particularly domestic cattle, are noted as a potential threat to some wetland avian species (Taylor et al. 2015), our study confirms that exclusion would be of detriment as well. Most species displayed a preference to trail presence and were noted utilising trails for commuting, foraging, preening and displaying. The relationship between differential trail use and preferences across varied species has been documented across numerous studies for mammalian species in predominantly forest habitat (Harmsen 2006; Weckel et al. 2006; Harmsen et al. 2010). There is, however, a lack of published studies on trail use related to avian species, and in particular within a wetland context.

Our data displayed a preferential use of trails by African Snipe, African Rail and Spotted Crake (Table 5). African Snipe showed a particular preference for the confluence of often narrower trails (≤30 cm), whilst African Rail favoured wider (>30 cm) trails. The relationship exhibited between African Snipe and trail presence in our study supports the noted association of this species to recently disturbed wetland habitat by grazers (Masterson 1971). Similarly, the preferential use of trails by African Rail in our study corroborates published observations of this species foraging along tracks through wetlands and crossing wide trails or even roads to forage (Taylor 1997b). Our data also indicate that African Snipe avoided areas with deeper water, which corresponds to habitat preferences of this species being linked to shallow, trampled and muddy areas (Masterson 1971; Davies et al. 2015).

Our study effectively recorded Red-chested Flufftail presence across multiple camera points and collectively yielded numerous independent sightings of this elusive species. Noted habitat preferences included dense reedbed wetland, comprised of tall *Phragmites* and *Typha* species (>1 m) with a high canopy cover, which supports other studies documenting the habitat preferences of this species (Taylor 1994, 1997a; Davies et al. 2015). As a member of the *Sarothrura* genus, not only is Red-chested Flufftail one of the more cryptic and smallest-bodied target Rallidae species, its preference for closed and dense habitat structure all contribute to the difficulty of studying this species. The ability of our survey design to successfully record this species numerous times has application to other species of the *Sarothrura* genus. Of particular relevance and conservation significance is the White-winged Flufftail, which exhibits similar behavioural characteristics and is slightly smaller (c. 32 g) than the Red-chested Flufftail. However, the White-winged Flufftail prefers sedgebeds in comparison to the Red-chested Flufftail, which prefers taller reedbeds (Taylor 1994; Davies et al. 2015). The habitat preference of White-winged Flufftail being closed and dense wetland vegetation, as well as having a significantly smaller population size to Red-chested Flufftail (Taylor 1994; Taylor and van Perlo 1998; Davies et al. 2015), results in this species being notoriously difficult to study (Masterson 1971; Davies et al. 2015).

Studies attempting to ascertain the presence of this elusive and other rare and cryptic Rallidae species through line-transect and rope-dragging surveys often result in relatively low presence records across notably labour-intensive surveying periods (Masterson 1971; Allan et al. 2006; Davies et al. 2015). Through the use of associated transect methodology, species richness and density/abundance assessments are generally ascertained from these data (Fletcher et al. 2000; Wilson et al. 2000). However, the ability of camera trapping to yield robust data sets with numerous sightings, not only of the target species but of other species co-occurring in the same habitats, allows for the additional assessment of multiple facets of species and/or community ecology.

Results of our study further emphasise the value of camera trapping for target species and non-target species, as significant observations of both were made. Non-target species not only included other avian species utilising the same or different niches, but also included herbivorous mammalian species (n = 2) linked to trail formation in wetlands and carnivorous mammalian species (n = 3) known to prey on a range of wetland avian species (Whitefield and Blaber 1980; Arden-Clarke 1986). These data could allow for the assessment of activity patterns (Cutler and Swan 1999; Dillon and Kelly 2007), habitat use (Cutler and Swan 1999; Silveira et al. 2003) and foraging dynamics (O'Connell et al. 2011). In addition, our data included numerous sightings (n = 10) of newly fledged chicks of two species, namely African Rail and Yellow-billed Duck, which could contribute to nesting and/or fledgling success studies. This further emphasises the extensive application and value of camera trapping data when compared with traditional survey methods currently utilised.

Conclusion

Our data clearly display that camera trapping can effectively determine the presence and monitor arguably the most cryptic and elusive of the Rallidae genera within southern Africa, namely *Sarothrura*. Of further significance is the potential to apply this survey method to threatened species that require alternate survey techniques to ascertain presence and study aspects of species biology and behaviour. One such species that has been central to Rallidae surveys within South Africa and Ethiopia is the White-winged Flufftail (Masterson 1971; Allan et al. 2006; Davies et al. 2015). A recent study noted the requirement for further studies into alternate survey techniques for this species (Davies et al. 2015). The survey technique applied in our study and associated results are directly applicable to this species and a range of other elusive Rallidae species within southern Africa and broader afield, including but not limited to the *Sarothrura*, *Porzana*, *Crex*, *Aenigmatolimnas*, *Amaurorni* and *Coturnicops* genera.

Our study further demonstrated the ability to produce accurate, reliable and rapid species inventories within wetland habitats through camera trapping. Survey design is, however, of crucial importance to the success of a multispecies study and needs to be carefully considered (Gompper et al. 2006). Our pilot study highlighted crucial elements of camera placement that can be replicated if Rallidae species are the objective of the study. Other elements of survey design that would need to be considered for further surveys include trap density and arrangement (Gompper et al. 2006). If species inventories are the objective of the study, intensive surveys can be conducted across more localised areas, as long as the appropriate survey effort (camera days) is reached. Similarly, if occupancy estimates are required, two crucial factors would need to be maintained, namely closure and independence (MacKenzie and Royle 2005; O'Brien 2011). This generally could necessitate a more uniformly stratified camera placement across a more extensive area that is spatially representative of the broader study site.

This survey technique will not replace the need for specific invasive sampling techniques that involve the capture of individuals in order to acquire data for genetic or isotope analyses. It could, however, contribute greatly toward more reliable and accurate estimations of presence, distribution, occupancy, habitat use, breeding behaviour, life history and population dynamics studies of Rallidae species. The field of application is also not restricted to Rallidae species and could present a preferable alternative to survey a wide range of wetland and waterbird species.

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