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Foraging Behaviour of the Black-Headed Heron at Kibimba Rice Scheme, Eastern Uganda

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors designed the study, collected data. Author SN performed the statistical analysis and wrote the first draft of the manuscript. Authors PMM gave comments. Both authors read and approved the final manuscript before submission.

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ABSTRACT

Variations in the factors affecting prey availability directly impact on the spatial dispersion of foraging birds. The feeding success and efficiency of the Black-headed Heron (Ardea melanocephala) was examined in the different growth stages/phases of paddy rice, namely: Ploughed fields, Phase 1 fields (2 weeks-1 month after sowing) and Harvested fields. Feeding success of the Black-headed Heron varied significantly across the rice growth stage. This variation was explained by a combination of factors such water depth, waterbird abundance, Nearest Neighbor Distance (NND) and food or prey abundance (except amphibian abundance). Statistical analysis were conducted using Genstat Version 8.1 (VSN Intl.2003, in which a General Linear Mixed Model were used to examine the variation in each behavioural measure. Foraging in aggregations on rice paddies seems to be more beneficial to the Black-headed Heron. The closeness to a conspecific had a positive effect on the feeding efficiency of the Black-headed Heron as they foraged on fields with abundant prey (Phase 1) and a negative effect on fields with less abundant prey (Ploughed fields). Generally, the data seem to suggest that there is a functional relationship between the Black-headed Heron, and prey abundance, and the absence of interference competition on rice fields.

Keywords: Foraging; success; efficiency; rice phase; NND; black-headed heron; statistical analysis.

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1. INTRODUCTION

Ecologists are interested in understanding the way in which animals distribute themselves over different habitats. According to the theory of habitat selection, individuals select habitat patches where they maximize fitness [1]. Studying the foraging success of birds may reflect the resources available to foragers. Feeding success among animals varies depending on habitat characteristics such as water depth [2-4], vegetation structure [5], and prey characteristics [6,7]. For example, dispersion and availability of prey are known to have a strong bearing on foraging strategies within a habitat [8].

In addition to the above-mentioned factors, the amount of competition that occurs between foraging individuals can affect their feeding success [9,10]. Competition between individuals is usually most prominent when animals forage in large aggregations, which bring them into close proximity [11]. Therefore animals reserve a feeding space by continuing to defend individual distances.

The foraging ecology of waterbirds, such as herons, in rice fields has been studied in the Mediterranean region [11-14], in North America [15], and in Japan [16], with no such studies in Africa and specifically Uganda. This study aimed to examine the functional relationships between waterbirds and prey abundance using the Black-headed Heron (*Ardea melanocephala*) as a model species. We predicted that:

1) Feeding success and efficiency varied among rice stages, and that this was related to prey abundance, and
2) Feeding success and efficiency were related to bird abundance and distance to conspecifics. We have used foraging success (number of captures per minute) and efficiency (number of successful pecks per attempt) of the Black-headed Heron to try and explain this relationship. The relationships between foraging behaviour, waterbird abundance and Nearest Neighbour Distance (NND) will be discussed in the context of interference competition.

2. MATERIALS AND METHODS

2.1 Study Site and Study Species

The study was conducted at Kibimba rice scheme over a period of four months (April to July 2019). I examined foraging habitat use by the Black-headed Heron. This species was chosen because it constitutes part of a major guild of predators that exploit rice fields at Kibimba rice scheme, and its behaviour can be sampled easily. The Black-headed Heron feeds in groups facilitating the gathering of behavioural data in a relatively short time [17]. It is also easy to identify their prey because the birds spend some time handling it. They are visual foragers, catching prey by bill thrusts [18,19]. The Black-headed Heron has a bill of approximately 12 cm long and a potential wading depth of about 40cm [20]. They typically forage in open habitats, capturing prey while wading slowly or standing motionless in water.

2.2 Data Collection Methods

Data were collected from 64 plots each measuring 4 hactares. Of these, 19 had been Ploughed, 23 had rice in stage one of its growth cycle, and 22 had been Harvested. Single observations were made for each plot (no repeat sampling) and focal individuals were chosen randomly from those present. Data on waterbird numbers, foraging observations and food numbers were collected over a period of ten days in each month. Data on foraging observations and waterbird numbers from the 64 plots were collected over the first five days, with an average of three plots per day. Water depth measurements were taken at four randomly selected points in each plot. This was then followed by another five days of food/prey abundance from the same plots.

2.3 Foraging Observations

Up to 6 foraging individuals of the Black-headed Herons were observed consecutively from each plot. Data on foraging behaviour were collected using focal animal sampling [21], a method that has been employed in field situations to study wading birds [22-24]. The maximum observation time per foraging bird was 15 minutes. A telescope and pair of binoculars were used for bird observations. A hand-held tally counter and a dual timer and stopwatch with alarms were used for timing. Observations were made far enough away from the individual birds (ca. 150m) that my presence did not alter the birds' foraging behaviour. Observations were concentrated on actively foraging adult birds only. Only one observation period was recorded for any individual in a day.

Individuals orienting towards prey were observed by telescope until a strike occurred. Following a successful strike, we recorded the identity of the prey and its length estimated against the heron's 12 cm bill whenever possible, for example half of the bill, twice the bill, etc. [22-24]. Prey items were identified within broad taxonomic categories (e.g. fish, frog, snake, or unidentified). For each focal individual the following data were obtained:

(1) Time the focal bird spent foraging
(2) The number of feeding attempts within this period and their outcome,
(3) The type and approximate size of captured prey,
(4) Aggression, defined as any observable change in behaviour of the focal bird in response to the presence of another bird (e.g. chases).

It was not always possible to observe an individual for the whole 15 minutes because it ceased to forage. Sometimes, cessation was apparently voluntary, and also due to disturbance by humans; it was rarely from other species. Disturbance by humans occurred mainly after 0900 hours when the farmers came into the field, and under such circumstances, we terminated the observation, allowed the birds to resettle and started again. An attempt was defined as when a bird jabbed the water or mud with its bill in search of prey. Successful prey capture, even of small items can easily be detected in herons by the conspicuous swallowing action [23,25,26]. Attempts were considered successful if:

(1) A prey item was seen to be captured and swallowed, or
(2) The bird showed evidence of swallowing by 'head-throwing'.

2.4 Non-Behavioural Data

2.4.1 Water depth and nearest neighbour distance

Water depth has been observed to influence feeding performance through its effects on prey, i.e. it may influence prey availability for foraging birds [27]. This is normally estimated in relation to leg length (Tarsus + tibia) [22,28]. However our first attempts showed that there was no variation in individual depth among foraging birds within plots. Therefore we decided to take water depth measurements using a cm-marked stick at 4 randomly-selected points, for which mean values have been used. Nearest Neighbour Distance (NND), which was an estimate of distance (m) between the foraging bird and its nearest conspecific. To ensure accuracy, NND distances were estimated using broad categories (less than 1m, 1-10m and greater that 10m). These broad categories were adopted after our attempt to record the exact distances proved impractical.

2.4.2 Fish and amphibians abundance

We used conventional fishnets (dip nets) to assess the abundance of fish. Two dip nets (25.4mm stretched mesh size and 6m long and 1m deep were set at 1800h and left overnight in the field. These were placed at random locations within the plot and were fixed in position with the aid of sticks. These were checked the next day starting at 0600 hours. Dip nets were only used in plots that had water depth of >5cm. All plots that had <5cm in depth (5 plots) were assumed to have no fish. Amphibians avoided the fishnets so their abundance was assessed by a combination of the Timed Constrained method and systematic sampling [29,30]. A modified version of the Timed Constrained method was used for this study. Rather than searching and collecting amphibians in a specified area of habitat, I timed my systematic sampling which consisted of flushing amphibians by walking on internal earthen levees for a period of 1 hour, and all frogs and toads that jumped were counted and recorded. Having confined myself to the levees, this method may have under-estimated the abundance of amphibians within the plot.

2.4.3 Invertebrate abundance

Soil invertebrates were sampled using a stainless steel cylindrical corer (10 x 5 cm, height x width). Four soil cores were randomly taken from each plot and combined in a single sample. These were collected by coring to a depth of about 10cm (approximate length of most shorebird bills). The samples were sieved using a 0.5mm mesh sieve. In case of any sticky mud, the sample was first diluted in a bucket of water and then sieved [31]. Dry soil samples were sorted by hand [32,33]. This method was clearly biased to soil macroinvertebrates. Although Herons were occasionally seen gleaning insects from rice vegetation, we did not collect data on aerial insects. However, it was clear that grasshoppers and locusts were very common on fields with rice at Phase 1, and other insects e.g. dragonflies, were common on ploughed, and

Harvested rice fields that had been flooded. This also places some limitations on the conclusions drawn from this study.

2.5 Treatment of Samples

Collected prey items from each stratum were identified to broad taxonomic categories (e.g. fish, amphibians, worms etc.) and counted, numbers of which have been used in the analysis. Sub-samples, especially for the most abundant prey of each type were collected and preserved in 70% alcohol for further identification. Identification of fish was done following descriptions by [34], while amphibians were identified by use of a guide book to amphibians. Soil samples contained mainly earthworms, leaches and a few mole crickets, which we could easily identify, so we did not collect any invertebrate food items. All the fish collected in each plot were lumped together and weighed.

2.6 Data Analysis

We considered each individual bird observation as an independent sample during the behavioural data analysis. We converted the number of feeds (successful attacks) to rates by dividing by the time (in minutes) the focal bird spent feeding. In addition, we calculated feeding efficiency by dividing the number of feeds by the number of attacks. We then examined the variation in each behavioural measure using a General Linear Mixed Model. Rice phase and NND were used as fixed effects (factors) and food abundance, bird abundance and water depth as covariates. Plot was used as a random effect. Incidents of aggression were too few to warrant any statistical analysis. Statistical analyses were conducted using Genstat Version 8.1 (VSN Intl.2003). One-sample Kolmogorov tests were used to test whether feeding success and efficiency had a homogeneous variance. Data on the different food types eaten by the herons and their average estimated length were also summarized.

3. RESULTS

We observed 379 individuals of the Black-headed Heron foraging. Aggression between individuals was infrequent. Aggression was witnessed in just 10% of the 379 focal samples and these were mainly incidents of passive aggression, in which birds jumped away on the arrival of others.

3.1 Variation in Foraging Behaviour

Feeding success and efficiency of the Black-headed Heron varied with rice phase (Table 1. χ^2 = 8.08, df = 3, *P*= .01). Individuals were more successful on Ploughed fields than harvested fields (Fig. 1). There were significant effects of all the explanatory variables on both feeding success and efficient except water depth (Table 2). Feeding success and efficiency increased with increasing abundance of invertebrates, fish biomass and the abundance of other bird species.

3.2 Foraging Behaviour and Nearest Neighbour Distance (NND)

Distance from conspecifics had a significant effect on the feeding success of the Black-headed Heron (Table 1: χ^2 = 15.08, df = 1, *P*<.001). Black-headed Herons captured

Table 1. Generalized linear mixed model of feeding success of the Black-Headed Heron

Variables in the model	Coefficient ± SE	χ^2	df	*P*-value	R^2
Growth stage of rice	A. 0	8.08	2	.01	56.5
	B. -0.06 ± 0.002				
	C. -0.14 ± 0.002				
Waterbird abundance	0.00008 ± 0.0003	7.08	1	.008	
Water depth	-0.0057 ± 0.0035	1.85	1	.17	
Invertebrate abundance	0.0052 ± 0.002	22.38	1	< .001	
Vertebrate biomass	0.001 ± 0.0004	7.53	1	.006	
NND	A. 0	15.08	2	< .001	
	B. -0.04 ± 0.003				
	C. 0.10 ± 0.003				

Growth stage of rice codes: A = Ploughed fields, B = Phase 1 fields, and C = Harvested fields, NND codes: A = >5m, B = 5-10 m, and C = <10 m

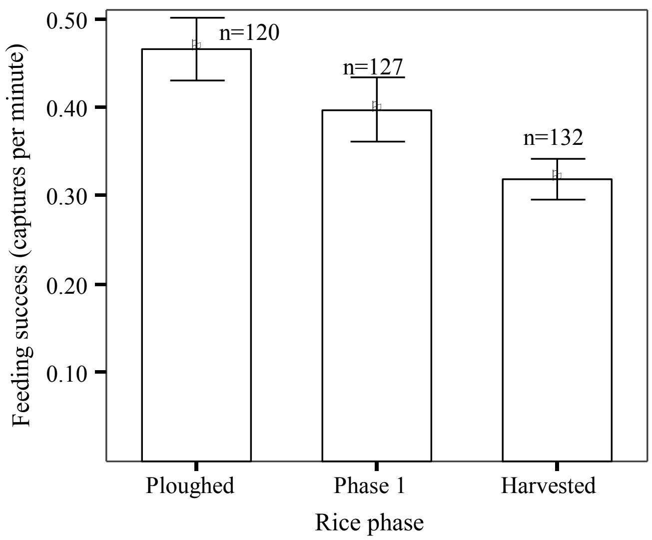

Fig. 1. Feeding success (mean ± SE) of the Black Headed Heron in each rice phase

Table 2. Generalized linear mixed model of feeding efficiency of the Black-Headed Heron

Variables in the model	Coefficient ± SE	χ^2	df	*P*-value	R^2
Rice phase	A. 0 B. 0.114 ± 0.008 C. 0.029 ± 0.008	5.49	2	.06	45.5
Waterbird abundance	0.0002 ± 0.0002	60.73	1	< .001	
Water depth	-0.0087 ± 0.0035	1.85	1	.27	
Invertebrate abundance	0.0052 ± 0.002	22.38	1	< .001	
Vertebrate biomass	0.001 ± 0.0024	7.53	1	.05	
NND	A. 0 B. -0.08 ± 0.003 C. 0.13 ± 0.003	25.34	2	< .001	

Growth stage of rice codes: A = Ploughed fields, B = Phase 1 fields, and C = Harvested fields, NND codes: A = >5 m, B = 5-10 m, and C = <10 m

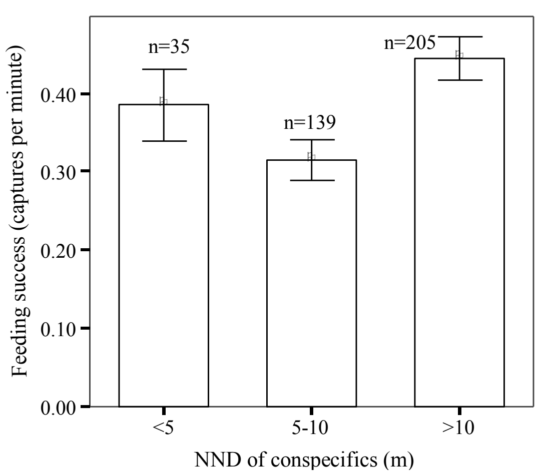

Fig. 2. Variation in feeding success (mean ± SE) of the Black-Headed Heron with nearest neighbor distance (m) between conspecifics

Table 3. Prey types eaten by the black-headed heron at Kibimba rice scheme

Prey type	Number (%proportion)	Estimated average length
Fish	110 (14)	8.0
Amphibians	406 (52)	6.1
Insects	120 (15)	3.2
Snakes	9 (1)	24.0
Unidentified	138 (18)	-
Total	783 (100)	

more prey when conspecifics were >10 m and <5m away and fewer prey when 5-10 m apart from each other (Fig. 2). The presence of conspecifics had significant effects on the feeding efficiency as well (Table 2).

3.2.1 Prey types

There Black-headed Heron feed mainly on five different prey items: fish, amphibians, insects, snakes and a collection of unidentified prey Table 3. Amphibians were the most preferred and constituted 52%.

Prey length was estimates in relation to bill length.

4. DISCUSSION

4.1 Variation of Foraging with Rice Phase

Black-headed Herons caught more prey on Ploughed fields than on Phase 1 and Harvested fields. This is possibly because Ploughed fields are flooded and lack vegetation/rice plants [35]. These two conditions seem to make prey on Ploughed fields more available and accessible to the Black-headed Heron. The low feeding success on Harvested fields may be due to the fact that these fields are mostly dry and have a lot of rice stubble that may obstruct the vision of the foraging birds [35].

4.2 Variation of Foraging Behaviour with Waterbird Abundance and Nearest Neighbour Distance (NND)

Our data suggest that the presence of large numbers of birds (mixed feeding aggregations or social foraging) increased the feeding success and efficiency the Black-headed Heron. This is possibly not surprising because aggregations of foraging birds have been observed either to increase prey intake rates [11]. However, this will depend on the feeding tactics employed by the bird species [36] and the type of habitat and prey [11]. The Black-headed Heron is a solitary and visual feeder, and because of this, we would expect its foraging success and efficiency to decrease with increasing bird numbers. However, the presence of other birds appears to make prey more vulnerable and easier to catch by the Black-headed Heron. This seems to suggest that these birds probably change their foraging behaviour while feeding on rice paddies a case for further investigation. Alternatively, foraging birds could just be aggregating in areas of more prey items (numerical response).

The Black-headed Heron caught more prey when conspecifics were >10 m away, which seems to suggest that conspecifics avoided foraging close to each other, probably to avoid aggression. However, there was no serious evidence of aggression. These results therefore seem to suggest that interference competition is not a significant issue on rice fields: foraging Black-headed Herons simply aggregate in habitats with abundant prey (prey was highly abundant on Phase 1) and spread out in habitats where prey are dispersed (Ploughed fields). Therefore, this further confirms the presence of a numerical relationship between foraging birds and their prey on this habitat type.

4.3 Variation of Foraging Behaviour with Food Abundance

There was a positive correlation between feeding success and efficiency of the Black-headed Heron and prey abundance. The positive relationship is due to the fact that individuals have greater chances of having a successful attempt when prey are abundant.

5. CONCLUSION

The high prey capture rates of the Black-headed Heron on Ploughed fields seems to be facilitated by the presence of water and the open nature of these fields. The presence of abundant prey items (Fish and invertebrates) increased the chances of having a successful peck among foraging individuals of the Black-headed Heron. The positive relationship between waterbird abundance and foraging behaviour suggests that increased density among birds results in subtle commensal benefit i.e. neighbouring birds make prey vulnerable by exposing them or flushing them, thereby making them easier to capture. Foraging efficiency of was higher on fields with abundant prey items when conspecifics where in close proximity suggesting that interference competition has a positive effect on the feeding behaviour of the Black-headed Heron on rice paddies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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