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SHORT COMMUNICATION

Foraging of Saddle-billed Storks *Ephippiorhynchus senegalensis* during the dry season in western Zambia

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Abstract The Saddle-billed Stork *Ephippiorhynchus senegalensis* has been described as a generalist carnivore yet no field study has quantified its diet and foraging ecology. We conducted a brief study in western Zambia on foraging of Saddle-billed Storks using focal animal sampling to address this knowledge gap. From 14 observation periods totaling 255 min, we found storks averaged 8.3 foraging attempts per minute that resulted in 0.3 prey captures per minute. Tactile foraging accounted for 71% of successes and 29% were from visual foraging. Storks primarily captured small (≤10 cm) fish and invertebrates in shallow (~17.5 cm) water. Despite the limitations of our small sample, this study is the first to quantify Saddle-billed Stork foraging. Future work should investigate the influence of seasonality and human activity on foraging ecology in this highly dynamic system..

Keywords Africa, diet, *Ephippiorhynchus senegalensis*, Liuwa Plain, prey, wetland.

Introduction

Diet and foraging behaviour are important life history components that contribute to an understanding of habitat requirements and therefore conservation threats (Depkin et al. 2005; Lantz *et al*. 2011). The Saddle-billed Stork *Ephippiorhynchus senegalensis* (hereafter, Saddlebill) occurs in a variety of wetland and savanna habitats throughout its sub-Saharan African range (Hancock *et al*. 1992). The Saddlebill has been described as a generalist carnivore based on a diversity of prey taken in disparate incidental sightings (e.g., Pienaar 1969; Broadley 1974; Randall 1994; Rockingham-Gill 1997). Although the foraging behaviour and diet of the closely related Black-necked Stork *E. asiaticus* has been studied in India and Australia (Dorfman et al. 2001; Maheswaran and Rahmani 2002), no field research has quantified foraging by Saddlebills. We undertook a brief field study on foraging of Saddlebills in a highly seasonal pan system in western Zambia to describe characteristics of foraging and prey capture.

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Methods

We collected foraging observation data on Saddlebills in Liuwa Plain National Park in Western Province, Zambia, between 20 July and 4 August 2021 (Figure 1). This study area has been described elsewhere (see Gula *et al*. 2021). Briefly, the park is characterised by highly seasonal hydrology in which the plain becomes inundated during the wet season (November–April) and then subsequently dries out during the dry season (May–October). As water recedes during the dry season, a network of ephemeral pans remains where fish, frogs, and aquatic invertebrates become concentrated. Characteristics of pans vary from shallow, sandy depressions that dry rapidly to deep basins with thick mats of floating vegetation that hold water throughout the dry season (pers. obs.; Figure 2a). Approximately

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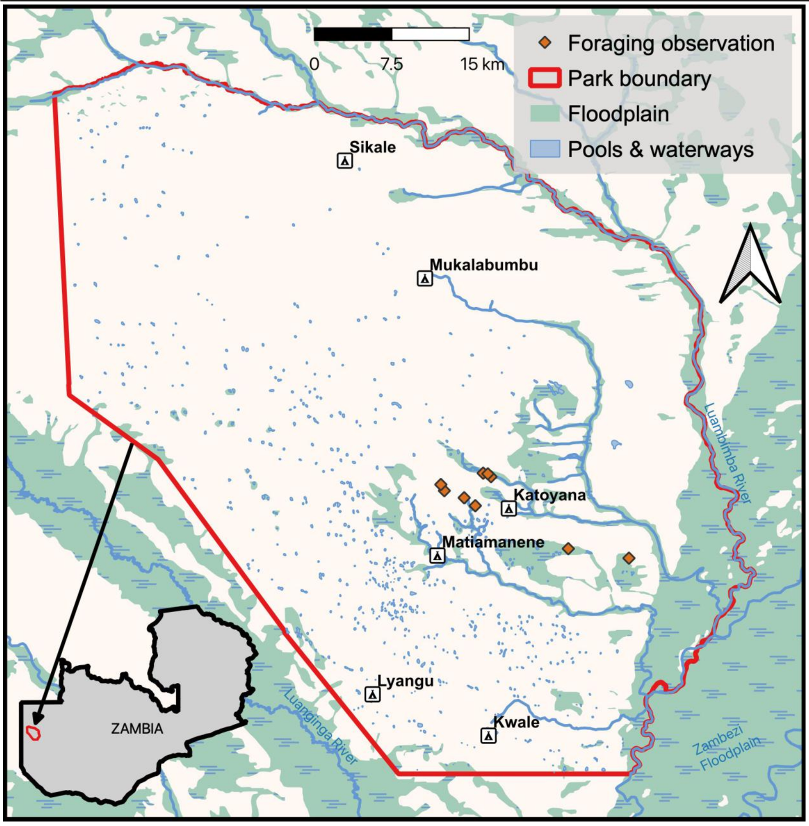

Figure 1. Locations of foraging observation sites in Liuwa Plain National Park, Zambia, in July-August 2021.

10,000 people live within the park and strongly rely on fishing these pans for subsistence, using a variety of fishing techniques depending on the season, including weir construction, gill nets, and active spearing.

Foraging observations took place between 0600 h and 1200 h when Saddlebills are most active at pans. Observations were largely opportunistic because fieldwork was not specifically focused on foraging. Nonetheless, when time allowed we followed an observation protocol similar to Maheswaran and Rahmani (2002) using focal animal sampling for recording foraging. Sexual dimorphism (females with yellow irises) and unique bill patterns (see Gula *et al.* 2021) ensured observations were collected from the focal stork if it was in a pair or a group (e.g., Figure 2c). Observations were made by a consistent observer (JG) using 10 x 42 binoculars while sitting in a vehicle.

A single foraging observation period was between 15 and 30 min, and each was subdivided into 5-min foraging bouts, which allowed for easier data capture in case an observation was interrupted. When a foraging observation period commenced, start time, location, and sex of the focal stork were recorded. Characteristics of the pan were noted but not measured in any way. A digital stopwatch was used to help divide observations into the 5-min bout periods. A hand tally counter was used by the observer to record the number of foraging attempts, which were defined as a chase, a lung, or a bill probe. Both successful and unsuccessful attempts were included in this estimate. Within a bout period, the observer verbally reported details of each foraging success (i.e., prey capture) of the focal stork to the person recording data (AM) to allow for continuous data collection on attempts.

The capture mode was recorded as either visual or tactile upon each foraging success. A visual capture was defined as a success when the stork watched the water without a submerged bill and struck the prey or chased and caught it. A tactile success was when a stork caught prey while probing with its bill in the water. The prey type was recorded as invertebrate, fish, herptile, or unknown. Fish size was visually estimated in relation to the bill–which is about 30 cm in length (Hancock *et al.* 1992)–as either small (≤10 cm), medium (10-20 cm), or large (>20 cm). Water depth where a foraging success occurred was visually estimated as ¼, ½ (pink tibiotarsus joint), ¾, or the full leg length of the stork. We assumed that the average depth at the tibiotarsus joint was 35 cm based on a measurement of a dead captive Saddlebill (D. Ialeggio, Philadelphia Zoo, pers. comm.). The end time of each observation was recorded. Finally, focal individuals were identified using unique bill patterns.

Foraging bouts for an individual observation period were pooled to summarise foraging metrics. Given different lengths of observation periods, raw data on attempts and successes were converted to rates. Foraging rate was estimated as the number of attempts per minute of observation. Similarly, success rate was estimated as the number of successful prey captures per minute of observation. We only report summary statistics due to a limited sample size. Finally, we report anecdotal observations related to foraging.

Results

We recorded foraging observations on 11 unique Saddlebill individuals (4 males, 6 females, 1 unknown subadult) during 14 separate observation

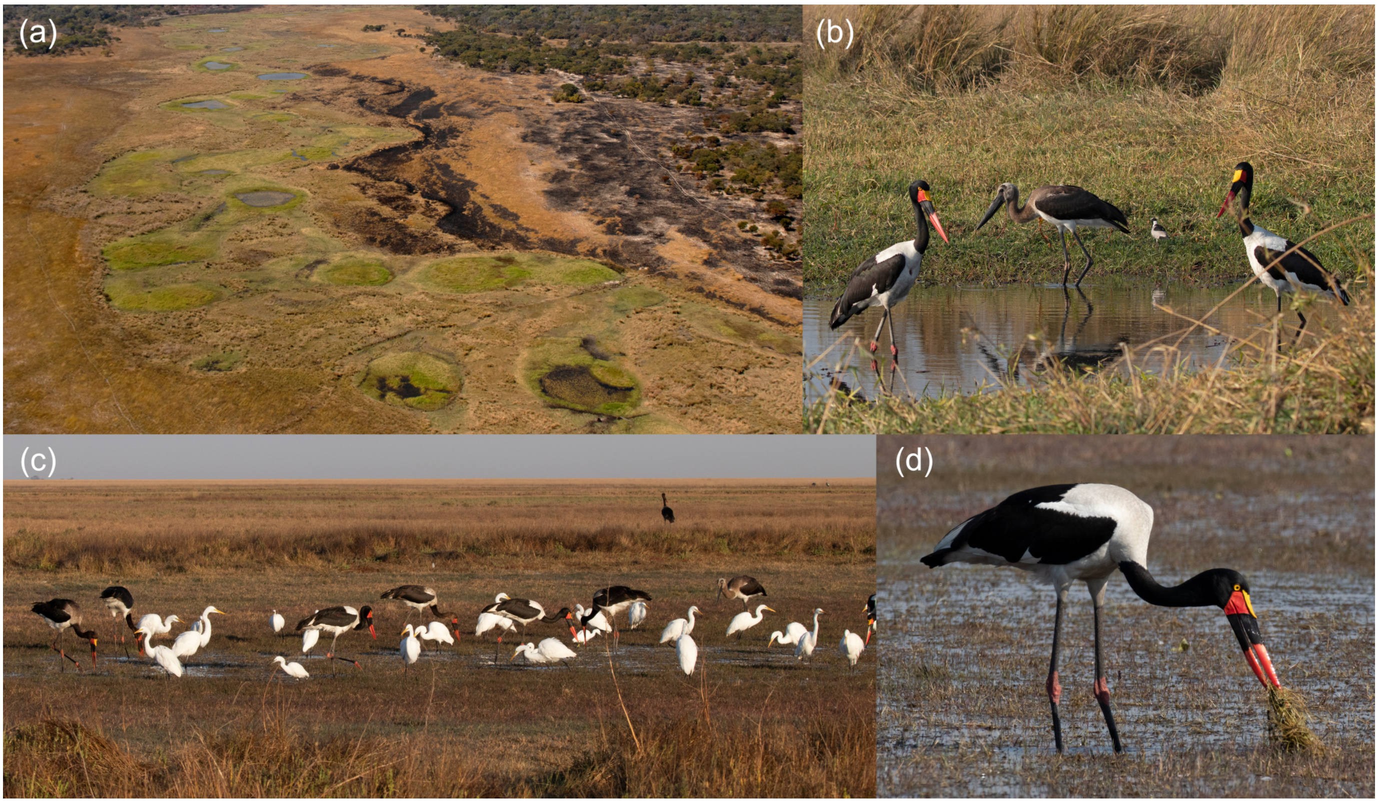

Figure 2. (a) An example of a network of vegetated pools where some Saddle-billed Stork foraging observations were conducted in Liuwa Plain National Park, Zambia. (b) A family group of Saddle-billed Storks foraging in one of the pools along the drying stream in Figure 2a. (c) A concentration of foraging Saddle-billed Storks and egrets at another foraging observation site. (d) Saddle-billed Storks primarily used tactile foraging, which regularly caused them to capture fish in tangles of aquatic vegetation.

periods totaling 255 min of observation. Storks in 13 observations foraged along the margins of shallow pools with submerged vegetation mats and one foraged among floating pond weed. Mean foraging rates of observations of males and females were 6.8 and 10.7 attempts per minute, respectively, for a total mean of 8.3 attempts per minute. Mean success rate for both sexes was 0.3 prey captures per minute. Tactile foraging accounted for 71% of successes and 29% were from visual foraging. Forty-four percent of prey captured were fish, 20% were invertebrates (snails and aquatic beetles), and 36% were unknown prey items (Figure 3). No large (>20 cm) fish were observed being captured, and 89% of captured fish were classified as small (≤10 cm). Ninety percent of successes were in a water depth less than or equal to ~17.5 cm (half the tarsus; e.g., Figure 2d)). No successes were recorded in water deeper than the tibiotarsus joint (35 cm).

On 13 occasions we observed adults from three different pairs feeding their fledged young (estimated to be 2–3 months old). The male fed the young in 77% of these instances. In two cases, the young were foraging (or attempting to) in the same area as their father (e.g., Figure 2b), all the while emitting whistle-like begging calls characteristic of chicks in the nest. Only three of these observations were while collecting foraging data, and in each case the male captured the same number of fish as juveniles he had to feed before going to them. The juveniles were never more than 200 m from the male's foraging site when he went to feed them.

Discussion

Although with the caveat of small sample size, ours is the first study to quantify foraging of the Saddlebill anywhere in its range. Our limited sample did not allow for statistical analyses, but overall we found Saddlebills captured mostly small fish and invertebrates, the latter of which probably accounted for the majority of the unknown prey items given their small size and difficulty in identifying from a distance. Storks also were most successful in shallow water, which probably influenced the size of prey captured. While our findings are only a brief glimpse into Saddlebill foraging ecology, we must acknowledge that they likely are not representative of the species' ecology elsewhere given that Liuwa's aquatic system is unique. Therefore, comparative research is required in other types of wetlands in the species' range.

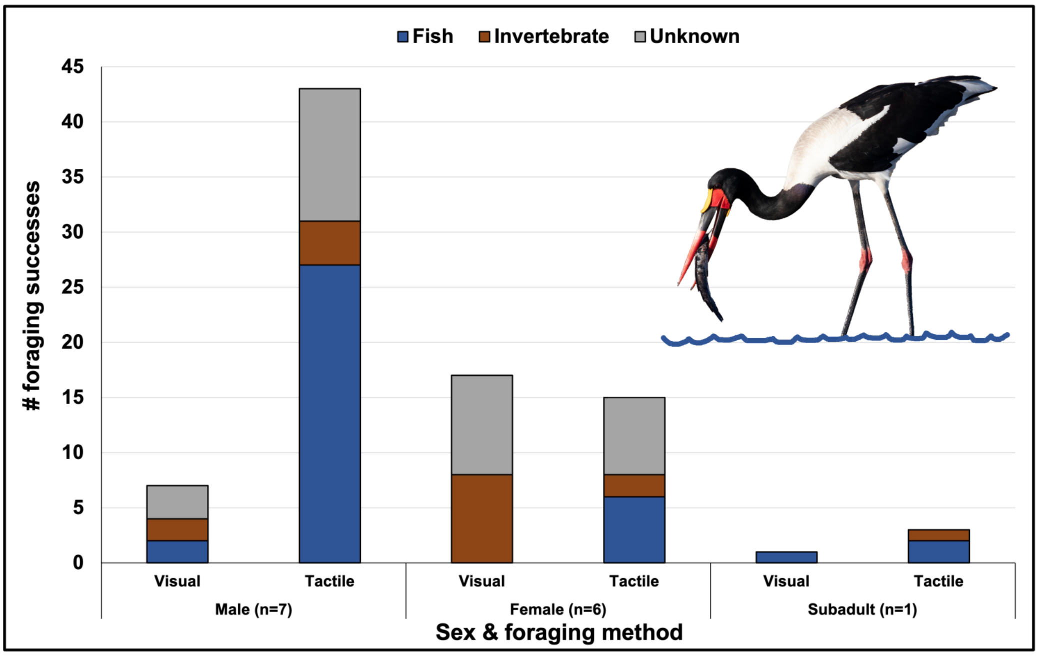

Figure 3. Results from foraging observations on Saddle-billed Storks in Liuwa Plain National Park, Zambia, in July-August 2021. (Photograph by Jonah Gula.)

We found Saddlebills using visual foraging in a greater proportion of observations than a study on the Black-necked Stork, which almost exclusively used tactile foraging (Maheswaran and Rahmani 2002). Whereas foraging success rates in that study did not differ appreciably from our study on Saddlebills, Black-necked Storks overall preferred deeper water (>30 cm) and were least successful in shallow water (15 cm). Like our limited observations, Maheswaran and Rahmani (2002) also observed male Black-necked Storks feeding fledged young more frequently than females did, which resulted in a greater foraging rate for males. Unfortunately, our limited sample size and repeated observations on the same provisioning males did not allow for appropriate comparison between the sexes.

Aquatic invertebrates, especially snails, are an important component of Saddlebill diet in Liuwa, which has not been described previously for the species, although it has been for the Black-necked Stork (Sundar 2011). Our finding that Saddlebills mainly catch fish that are ≤10 cm is similar to what was found with Black-necked Storks in India (Maheswaran and Rahmani 2002, 2008). However, we collected data in the early half of the dry season when large fish may still take refuge in deep parts of pools prior to water recession. A longer field study considering seasonal differences would be beneficial to identify how Saddlebill foraging and prey varies with changing water conditions. We expect that storks would have greater success later in the dry season as water levels recede and fish become more concentrated, which is also similar to what was observed with the Black-necked Stork (Maheswaran and Rahmani 2008). Surprisingly, we did not observe any captures of frogs or snakes, which may also be a result of the seasonal timing of our work.

The prevalence and seasonality of fishing by people who live in the park has the potential to influence Saddlebill foraging behaviour and success and should also be considered in future research. Anecdotally, we have observed that Saddlebills are more sensitive to disturbance by fishermen than other wading birds at pans in Liuwa. Other species, such as Grey Herons *Ardea cinerea* and Great Egrets *A. alba*, may temporarily be displaced from a pan when fishermen arrive to set or check nets, but they readily return, perhaps to take advantage of fish scraps or disturbance that could enhance their foraging success. Saddlebills, on the other hand, are easily spooked by people on foot and may not return to a given pan that day if fishermen remain active there. We also observed Saddlebills foraging around fishing weirs, which could be advantageous by helping corral fish. Therefore, it is possible that seasonality and fishing activity and technique (e.g., greater benefit of weirs in the early dry season when water levels are still high) could have interacting effects on Saddlebill foraging.

Beyond contributing basic life history information, this brief study highlights the need for a more in-depth understanding of Saddlebill foraging ecology. The dynamic hydrology of Liuwa and its large population of fishermen makes the park an ideal setting to investigate multiple environmental and anthropogenic factors that have the potential to influence foraging of Saddlebills and other waterbirds. We recommend a robust a priori approach to such a study that will both enhance our ecological understanding of specific species as well as bolster habitat management in light of increasing human pressure on wetlands.

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