FORAGING ECOLOGY OF GREY HERON (*Ardea cinerea*) IN RESPONSE TO HABITAT, SHEKHA LAKE, ALIGARH, INDIA

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Abstract: We studied the response of Grey heron species (*Ardea cinerea*) to the foraging habitat of Shekha wetland (27.8575, 78.2185), Identified Under National Wetland Conservation Programme, GoI. Methods were designed to provide a complete picture of heron diet whilst ensuring minimal disturbance thrice a week through direct observation in early morning (sunrise + 3 hours), noon (3 hours) evening (sunset - 3 hours) from January 2015 to January 2017 using direct observation. This lake has different hydrology, productivity and vegetation cover throughout the year. Parameters of foraging tactics-such as strike rate, foraging effort expended per min and effort expended per strike-as well as parameters of foraging efficiency-such as striking efficiency, captures per unit effort and biomass intake per unit effort were analysed in relation to the lake. Grey Herons foraged mainly on the two main prey classes (almost exclusively fish), avoiding smaller items even in wet meadows where smaller prey (invertebrates and amphibian larvae) were more abundant. Grey Heron achieved a variable striking efficiency. Open water edges proved to be more profitable than marshes for this species, while wet meadows seemed to play a complementary role for herons' foraging.

Keywords: Ardea, foraging tactics, striking efficiency, wading bird.

Introduction: The principle of competitive exclusion occupies the central belief in ecology and the foundation for much of the current understanding of niche theory (Gause 1934, Hutchinson 1959). It remains a hypothesis, however, which cannot be verified solely by observing ecological differences among coexisting species (Cole 1960, Hardin 1960). Recently, the role of interspecific competition in natural selection and community structure has generated considerable debate and sustained critical re-examination (Wiens 1977, Schoener 1982, 1983). Despite these serious limitations, the interspecific comparison of resource use has led to a better understanding of community ecology (Schoener 1974). The adaptive behavior of many species of wading birds enable them to exploit various permanent or ephemeral wet land resources, and their relatively large body size-combined with their conspicuous foraging methods-makes them useful field subjects for ecological studies (Kushlan 1978, 1981; Erwin 1983). Many studies have focused on parameters such as feeding rates, biomass intake and energy gain (Hafner et al. 1982, Rodgers 1983, Fasola 1986, Kent 1986a, Moser 1986, Draulans et al. 1986, Draulans 1987, van Vessem and Draulans 1987, Wiggins 1991, Master et al. 1993) to estimate the efficiency of foraging for a particular species. Other research (Quinney and Smith 1980; Recher et al. 1983; Rodgers 1983; Kent 1986b, 1987) used striking efficiency as an indicator of foraging efficiency. Foraging success has also been the subject of comparisons between adults and juveniles (Recher and Recher 1969, Cezilly and Boy 1988), between sympatric heron species (Recher and Recher 1980, Hom 1983, Kent 1986a) or between individuals of the same species in different wetlands (Hafner et al. 1982, 1986; Erwin et al. 1985, Fasola 1986). To compare the foraging resources used by herons, I observed the Grey heron (*Ardea cinerea*) to different foraging habitat characteristics investigated at Shekha Lake in Uttar Pradesh, India. Despite being a small wetland, Shekha Lake (27.8575 N, 78.2185 E) supports sustainability of over 35 resident birds throughout the year and around 40 migratory species during winter. As various ecological studies and bird banding exercises have demonstrated (Yahya 1988, Abbasi F.2001, Abbasi and Yahya 2003, Kumar, S 2010, Yahya 2014). Shekha lake is a very important birds' refuge. Large congregation of migratory species of birds during winter months is the focal attraction of Shekha lake for local people and wildlife authorities. We conducted a long-term study between Jan 2015-Jan 2017 on all four species of herons occurring at Shekha Lake namely Black Crowned Night Heron (*Nycticorax Nycticorax*), Pond heron (*Ardeola grayii*), Purple Heron (*Ardea purpurea*), and Grey Heron (*Ardea cinerea*). In the present paper, we have discussed the foraging ecology of Grey Heron (*Ardea cinerea*). Shekha lake is the most important inland water body for colonial water birds in Aligarh. It present differences in its hydrologic regimes but, retains a normal water regime, with seasonal fluctuations of its water level with an amplitude of less than 0.60 m to 2 m at some places. Such differences in hydrologic conditions affect not only the composition and distribution of vegetation (Mitch and Gosselink 1986, Richardson et al. 1995) and the productivity and concentration of prey (fish and invertebrates); they also determine habitat availability and variability (Kushlan 1986, Smith et al. 1995). The species chosen was present in the lake during spring and summer, foraged in similar habitats on similar types of prey, were observable while foraging for relatively long periods of time, and their attempts and captures were easily quantified. We examined the effect of lake and habitat on foraging tactics and efficiency of the species.

Shekha Lake is a fresh water perennial water body that came into existence after the formation of the Upper Ganges Canal in 1852 which flows adjacent to it. The lake lies at an altitude of 591ft above Sea Level. It is rather shallow, with a maximum depth less than 5 m. Large water level fluctuations result in deep water habitats during high flooding in monsoon season and in the exposure of marsh bottom during water recession in summer. Because of different hydrologic regimes, it is characterized by extended reed beds (*Phragmites australis*) in its marshy area and *Syzygium cumini* around the periphery of the Lake. Patches of open water are found within the reedbeds or along the shoreline, offering habitat suitable for heron foraging. Seasonal fluctuations of water at these marshes do not exceed 0.60 m. As water level falls during summer, surface water becomes confined to topographic depressions (ponds), forcing prey to concentrate there; by the end of June most of the lake is dried out. These marshes are dominated by submerged and floating vegetation. Fish and amphibians are the main food resources at the marshes of the lake; however, large invertebrate concentrations are gathered in the lake during the summer. Herons gather there to feed on fish, which constitute the principal food resources at these habitats, it also host concentrations of invertebrate prey, amphibia and small fish.

Methods: In 2015 to 2017, we directly observed feeding Grey Herons. We made our observations in early morning (sunrise + 3 hours) and evening (sunset - 3 hours), periods when birds foraged actively.

We recorded the foraging behavior of individual birds (focal individuals) continuously on field data sheets. For the precise recording of each event continuously each observation lasted from 5 to 20 min, depending on the bird's activity. The data on feeding activity included type of foraging habitat, the number of steps and turns per min, the number of successful pecks per min, the number of unsuccessful pecks per min, prey type and size in relation to the bird's bill length and water depth at the feeding site (in relation to the bird's tarsus length) for each min of observation. For small prey, successful prey capture was determined by whether the bird performed swallowing movements. Prey was identified whenever possible. Prey were categorized into 4 size classes. The first size class (<2 cm in length) consisted of invertebrates and amphibian larvae, the second class (3-5 cm) of small fish and frogs. The 2 larger classes consisted of fish (5-7cm and 7-9 cm). A total of 402 observations were made of Grey Herons.

The foraging tactics of the heron species was described by the water depth where they foraged; the rate of foraging action or foraging effort (the sum of steps and turns) expended per min; the strike rate (the sum of successful and unsuccessful strikes per min); and the ratio of strikes per foraging action, which is an inverse measure of the effort expended per strike. Foraging efficiency was assessed in 3 ways: 1) by striking efficiency, i.e., proportion of captures in total strike attempts, 2) capture efficiency, which represented the ratio of captures per foraging action and 3) biomass intake per for aging action. We did not make any sampling of prey abundance. However, we used strike rates as a measure of heron's prey encounter rates (Draulans 1987) and as an indirect measure of prey availability (Hutto 1993). Data were analyzed by 2-way ANOVA with unequal sample sizes (Sokal and Rohlf 1981). The main factors were lake, species and behaviour. Data were transformed using ln (x + 0.0001) + 1 to approximate a normal distribution. Least square distances (LSD) comparisons were made for the significant main effects. Significance was defined as $P < 0.05$.

Results: To a degree, the size of the prey items captured by each individual was determined by the forager's body size. Grey Herons foraged mainly on the 2 larger prey classes (almost exclusively fish- *Channa marulius*), avoiding smaller items even in wet meadows where smaller prey (invertebrates and amphibian larvae) were more abundant. In marshes and especially wet meadows, they searched for large prey (fish) and were present, mostly near the edge of open water habitats. The latter habitats seemed to host the largest prey sizes, wet meadows the smallest. Significant differences were found for dependant variables of foraging water depth, foraging action rates, strike rates per foraging action, for the main effects of species and habitat.

The ratio of strikes per foraging action of Grey heron was ($X = 0.10 \pm$ SE of 0.013 strikes per action). The Grey Heron is also not a very mobile species ($X = 7 \pm$ SE of 0.326 actions per min), expending the least effort per strike; it also had a low strike rate ($X = 0.48 \pm$ SE of 0.037 strikes per min) and foraged in deeper waters ($X = 0.14 \pm$ SE of 0.003 m).

Strikes per foraging action were highest at wet meadows, intermediate at the edge of open water habitats and lowest at marshes. Significant variations were found in striking efficiency, capture efficiency and biomass intake per foraging action, by habitat and individual. Being the larger species it had significantly higher biomass intake per foraging action than other herons.

Being a large species it was more efficient forager at wet meadows, the high within-habitat variation in capture efficiency among all species suggests that capture rate was not directly related to foraging effort. With respect to biomass intake per effort expended in foraging, Grey heron achieved maximum values at the edge of open water habitat of the lake. Grey Herons attained high biomass per unit effort at the marshes as well. This species seemed to be the most efficient forager at Shekha Lake.

Discussion: The heron species revealed significant differences in its adaptations to exploiting food resources. Grey Herons are immobile foragers, seeking scarcer, larger prey in deeper water habitats; they most frequently foraged by the "stand and wait" tactic. The energetic cost of such behavior was lower than the one adopted by Pond Heron, while the biomass consumed in relation to the foraging effort expended was substantially higher. In this respect, Grey Herons seemed to be more efficient foragers than other heron species. Beyond the species-specific characteristics in foraging, the habitat itself apparently influences the foraging tactics and efficiencies of the species studied. The marshy habitats of the lake seemed to demand relatively active foraging tactics by herons, which expended considerable effort while searching for prey. Such behaviors have been characterized as "walking slowly," "walking quickly" and "disturb and chase" (Kushlan 1978). In marshes, the birds preferred foraging in relatively deep waters; they caught rather scarce, large-or medium sized prey, obtaining a meal of considerable mass per foraging effort. Hafner et al. (1982) have shown that the seasonal drying out of marshes increases food availability for herons. The prevailing hydrologic conditions at the lower altitude and the substantial nutrient inflow from the Ganga canal create a very productive system-especially at its marshes, favouring forager strategies adapted to exploit ephemeral food resources (Kushlan 1976, 1981; Erwin 1983). At open water habitats, herons hunted at intermediate water depth and spent less effort in searching for prey, adopting the "stand and wait" and "walking slowly" foraging tactics. Although the rates of prey encounter were lower there, edges of open water habitats provided the highest biomass per foraging effort spent. Wet meadows were the shallowest and most vegetated for aging habitats in the lake, being exploited in various ways by the species. Norberg (1977) predicted that foragers would hunt less intently at low prey densities; for Grey Heron, wet meadows represented a marginal foraging habitat, since fish (its preferred food) were rather scarce there. The species invested constant effort per strike in the habitats. The species also showed an almost constant rate of capture per foraging effort. The differences in effort per strike might thus be attributed to the increase in vertebrate concentrations during different season. Compared to other heron species at Shekha Lake, Grey Herons revealed reduced plasticity in their mobility and strike rates, exhibiting low variability among habitats. This species-a fish specialist, especially during the breeding season (Moser 1986, Fasola et al. 1993)-spent little foraging effort and had low strike rates in habitats of variable water depths. Their long legs and large bills allow them to forage in all habitats and handle captured prey of all size-ranges (Moser 1986). Grey Herons used the "stand and wait" tactic almost exclusively, waiting for prey until it moved within striking range. This foraging tactic is likely associated with movement from 1 micropatch to another rather than to active search or pursuit of prey. Increased strike rates resulted in reduced rates of foraging effort. In cases of increased fish availability, wading birds have better chances of catching fish by standing and waiting for them (Kushlan 1978). In a study of Grey Herons foraging at fish farms, Draulans et al. (1986) observed that in periods of reduced disturbance, herons' foraging was of low intensity; the authors suggested that this tactic might be more advantageous for the species than intensive foraging. The species modified its foraging tactics according to habitat and prey type. Because of its long legs, it could forage in variable water depths. In deep waters the species foraged by the "stand and wait" tactic, while in shallow waters it used tactile foraging. Although its mobility was low it followed the same pattern - adjusted, to a certain degree, to prey availability. The species rescaled striking efficiencies in various habitats of the lake, indicating that it foraged on prey of various types and sizes (Kent 1987). The effort expended per strike was almost constant, but effort spent for each capture varied. The species seemed to seek microhabitat conditions that would facilitate the more efficient capture of prey. Compared to Purple Heron, another ardeid present at Shekha Lake, Grey heron spent less effort in territorial conflicts (van Vessem and Draulans 1987, Wiggins 1991, Master et al. 1993). This feature might explain their low mobility, at deep water habitats, although both species foraged using the same tactic. Shikha lake is a "hot spot" for herons during spring and late summer, when large mixed species aggregations are formed to prey on spawning fish. Wiggins (1991) observed that some herons feeding solitarily yielded lower capture rates than in group foraging but caught significantly larger fish. Recher et al. (1983) found that a low striking efficiency was typical of herons hunting relatively large fish as well as of more active foragers. In our study, Grey heron were relatively active at open water habitats, caught large prey and yet showed high striking efficiencies. It appears that the species foraged solitarily and had low striking rates in this particular habitat, hunting at a distance from the river banks and in deeper waters, where there was no submerged vegetation. Thus, the species probably had better chances of capturing a prey once it was located. The amount of biomass intake per foraging effort expended showed that edge of open water habitats were the most profitable foraging sites. This is apparently due to the increased fish availability, especially in monsoon, when large fish populations concentrate there. Kent (1986a) suggested that herons do not show preference for habitats where they can maximize their capture rates and striking efficiencies but, instead, forage in sites where they can ingest high energy prey through infrequent capture of high-quality items. Wet meadows seemed to be the least rewarding of the habitats; they play a rather complementary role as foraging habitat for the species. Considering the similarities between wet meadows and rice fields, the results of the present study are in accordance with Hafner's (1977) findings in the Camargue, where rice fields, though rich in prey items, were less important feeding grounds for herons than were marshes and lagoons. In conclusion, we found that this species adopted different foraging tactics and achieved variable efficiencies in response to particular habitat and prey characteristics. Grey Herons achieved higher values of biomass intake per unit effort. Edges of the open water habitats proved to be more profitable than marshes, while wet meadows seemed to play a complementary role for herons' foraging. In wet meadows, herons had more captures per unit effort and higher striking efficiencies, even though they received the lowest biomass per unit effort in comparison to the other habitats. Therefore, we may argue that parameters of foraging behavior, such as striking efficiency and captures per unit effort, may provide meaningful results for the actual energetic costs and benefits of foraging only when used in combination with information concerning the type and size of prey.

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