

Factors affecting feeding activity of grey herons in a reservoir during the breeding season

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Abstract

To examine factors affecting feeding efficiency of grey herons (*Ardea cinerea*), the foraging behavior was studied at a reservoir in Asan city, Chungcheongnam-do, South Korea during the breeding seasons (from April to July) of 2006 and 2007. Four factors (age of foraging birds, time of day, breeding stage, and microhabitat type) were analyzed. Adults were more efficient foragers than recently fledged juveniles, and they had a higher success rate than juveniles. About half of the adults caught large prey, whereas most juveniles caught only small prey. Adult grey herons had different feeding efficiency according to the breeding stage. Pecking and capture rates were high during the late period (fledging stage), and biomass intake rates were high during the early (incubating stage) and late periods. However, time of day had no significant effect on foraging activity of adult grey herons. Feeding activities of adult grey herons also showed significant variation among microhabitat types. Pecking and capture rates were higher in the submerged plants area, but capture success rate and biomass intake rate were not different according to microhabitat type.

Key words: age, *Ardea cinerea*, foraging, grey herons, microhabitat, period, reservoir, time of day

INTRODUCTION

Feeding activity of waterbirds is of ecological interest, because the ability of parents to secure food for their broods is linked to reproductive success (Hafner et al. 1993), and foraging success affects survival of both adult and juvenile birds (Frederick and Spalding 1994). Thus, foraging is directly related to ecological fitness for survival, and, hence, to factors that control bird population trends. Understanding factors affecting foraging activity can provide important information for evaluating the life history of birds.

Several ecological studies have been conducted on foraging of herons and egrets. Feeding behavior and efficiency of ardeids are affected by several factors, including prey density and availability (Draulans 1987, Richard-

son et al. 2001), time of year (Erwin 1985) and day (Fasola 1984, Kersten et al. 1991), bird age (Quinney and Smith 1980, Cezilly and Boy 1988, Papakostas et al. 2005), weather conditions (Quinney and Smith 1980), habitat characteristics (Maccarone and Parsons 1994, Dimalexis et al. 1997), hydrological regimes including tidal cycles (Sawara et al. 1990, Strong et al. 1997, Matsunaga 2000), and social behaviors (Wiggins 1991, Master 1992). Additionally, the spatiotemporal variation in feeding efficiency of ardeids may reflect a difference in habitat quality and/or their physiological needs for nesting and survival (Dimalexis and Pyrovetsi 1997).

The grey heron (*Ardea cinerea*) is a large common breeding ardeid species with a wide distribution in Ko-

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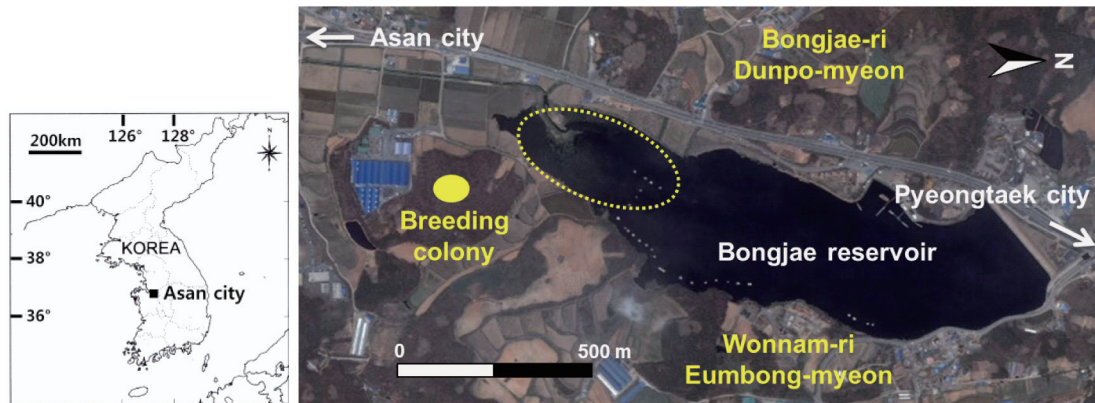


Fig. 1. The study area at the Bongjae reservoir in Asan city, Chungcheongnam-do, South Korea. The dotted line indicates the main feeding site of grey herons. The map was obtained from Daum (<http://local.daum.net/map>).

rea and also occurs throughout the year, although their numbers decline during the winter (Lee et al. 2000). Grey herons are typically found in and around shallow water, along watercourses and shorelines, and usually in locations with roost trees nearby. Availability and richness of food are important factors influencing the distribution and habitat selection of foraging birds. As herons often forage far from nesting or roosting sites, they use various habitats (or patches) within their foraging range. Although their habitat preference varies among regions and seasons, they prefer shallow areas of rivers and reservoirs as feeding habitats in inland areas of Korea (Lee et al. 2000). In particular, some agricultural reservoirs provide good feeding habitat for grey herons (Choi et al. 2007). Although grey herons may play an important role as a bioindicator to monitor changes in local and regional environments in Korea, there is still a lack of information regarding their feeding behavior and ecology.

In this study, we compared the feeding efficiency between adults and recently fledged juvenile grey herons during the late breeding season. Second, we analyzed the effect of time and space on grey heron feeding activity in a reservoir, because the distribution and density of fish may differ with time and microhabitat. Finally, as the demand for food may vary according to breeding stage, we also analyzed the effect of breeding stage on feeding efficiency in grey herons.

MATERIALS AND METHODS

This study was conducted at a reservoir (36°52'34.6" N, 127°01'53.9" E) in Asan city, Chungcheongnam-do, South Korea (Fig. 1). The reservoir was constructed for agricul-

tural use and has been mainly used for sport fishing. This reservoir is small (38.6 ha) and comprises several microhabitat types, including open water, submerged and emergent vegetation, and artificial construction such as fishing plates and buildings. Most grey herons foraging in this reservoir nest in the deciduous forest near the reservoir. During our study, 90-110 pairs of grey herons nested in the area, in a mixed-species colony, together with great egrets (*Ardea modesta*), intermediate egrets (*Egretta intermedia*), little egrets (*E. garzetta*), cattle egrets (*Bubulcus ibis*), and black-crowned night herons (*Nycticorax nycticorax*). However, few egrets and night herons use the reservoir for feeding habitat, whereas many grey herons forage at the reservoir (Choi et al. 2007).

The feeding behavior of grey herons was studied from April to early July in 2006 and 2007. Data were collected mainly from adult herons throughout the study, but data collecting of juveniles started in early June, when they first appeared at the study site. Daily observations were made from 07:00 to 19:00 h, under favorable weather conditions (no rain or string wind). Feeding activity of each heron was recorded using digital video cameras (Sony DCR TRV-20 and DCR HC-40; Sony Electronics Inc., Tokyo, Japan) or was observed directly with a 20-60× spotting scope. One observation bout lasted more than 8 minutes based on the bird's activity, and, finally, 190 observations totaling 2,090 minutes (average, 11.0 min/individual) for adults and 31 observations totaling 313 minutes (average, 10.1 min/individual) for juveniles were recorded.

The following information was recorded for each observation: age class, date, time of day, microhabitat type, observation duration, number of steps during feeding activity, feeding attempts (pecks), success (captures), and prey size captured by each heron. Moving rate (steps/

min) was estimated by dividing the total number of steps by the observation duration. The number of pecks and captures was divided by the duration of observations to calculate pecking rate (pecks/min) and capture rate (captures/min), respectively. Successful feeding rate was calculated as captures/peck. In this study, most grey herons fed mainly on fish. We recognized several fish species in the study reservoir, and the dominant species were *Pseudorasbora parva* (size, 2-6 cm), *Hemiculter eigenmanni* (size, 8-10 cm), *Cyprinus carpio* (size, > 20 cm), and *Carassius auratus* (size, > 15 cm), and grey herons could catch them readily (Choi unpublished data). Captured fish size was measured at 3 cm intervals by estimating the size relative to bill length (exposed culmen, ca. 12 cm) of grey herons to estimate biomass intake rate (Bayer 1985, Maekawa and Sawara 1996). A volume index was used to estimate relative biomass of consumed fish and was calculated by squaring body length (Sato and Maruyama 1996). Although fish volume is affected by body shape and body length, we considered only fish length to estimate volume, because most fish captured by grey herons in this study had similar body shapes (four dominant species belonging to Cyprinidae). Finally, total biomass taken by each individual was divided by observation time to calculate biomass intake rate per minute.

Four variables representing potential effects on foraging activity of grey herons were examined: age class, calendar date, time of day, and microhabitat type. Age class was distinguished in adults and juveniles according to their plumage type. Time of day was divided into three levels: early (07:00-11:00 h), middle (11:00-16:00 h), and late (16:00-19:00 h). Calendar period had three levels, which were based on the nesting stage of the breeding population: 1 April-10 May (incubating stage), 11 May-10 June (nestling stage), and 11 June-10 July (late nestling and fledging stage). Four microhabitat types were distinguished: 1) open water, where herons often stood and walked; 2) vegetated, where birds foraged within densely vegetated emergent plants such as reeds (*Phragmites*

communis Trinius) or wild rice (*Zizania latifolia* Turcz.); 3) the vegetation edge, where birds stood and walked within 1 m from the edge of dense tall vegetation; and 4) submerged, where herons foraged within submerged aquatic plants.

All statistical analyses were performed using STATISTICA (StatSoft Inc. 2004) following the guidelines of Zar (1999). None of the feeding activity variables followed a normal distribution (Shapiro-Wilk test); therefore, comparisons of feeding activities were analyzed with the non-parametric Mann-Whitney U and Kruskal-Wallis tests, depending on the number of factor levels. Multiple pairwise comparisons were conducted with Dunn's test after a statistically significant Kruskal-Wallis test. To analyze prey size preference, two categories (small, < 1/2 of bill size and large, > 1/2 of bill size, respectively) were divided and trends were analyzed with contingency tables (chi-square test). In most cases, the large fish were *Cyprinus carpio*, *Carassius auratus*, and *Hemiculter eigenmanni*, whereas small fish were *Pseudorasbora parva*. Only adult data were used in the analysis, except for comparisons between age classes. We used only the last data period (11 June-10 July) for adults when the effect of age on feeding activity was analyzed, because juvenile foraging data were only collected during this period.

RESULTS

Age effect

The comparison of feeding activity between adult and juvenile grey herons is shown in Table 1. Moving rate did not differ between adults and juveniles (Mann-Whitney U test, $Z = 0.77$, not significant [n.s.]). Although juveniles attempted more pecks per unit time than adults ($Z = -4.06$, $P < 0.001$), mean capture rate did not differ between the two age classes ($Z = 0.72$, n.s.). Thus, adults had higher mean success rates per attempt than juveniles ($Z = 5.63$,

Table 1. Comparisons of feeding efficiency between adult and juvenile grey herons

Age (N)	Steps/min	Pecks/min	Captures/min	Success rate	Biomass/min
Adult (65)	5.25 ± 3.81	0.34 ± 0.28	0.23 ± 0.20	0.72 ± 0.27	6.48 ± 10.34
Juvenile (31)	4.90 ± 4.88	0.48 ± 0.17	0.16 ± 0.07	0.36 ± 0.16	2.05 ± 1.18
Statistics	$Z = 0.77$ NS	$Z = -4.06$ $P < 0.001$	$Z = 0.72$ NS	$Z = 5.63$ $P < 0.001$	$Z = 3.07$ $P < 0.01$

Values are mean ± standard deviation, and numbers in parentheses are sample sizes. Variables between adults and juveniles were compared using the nonparametric Mann-Whitney U test. NS, not significant.

$P < 0.001$). As a result, biomass intake per unit time taken by adults was three times higher than that of juveniles ($Z = 3.07$, $P < 0.01$). Furthermore, some adults (30 of 65, 46.2%) caught large prey (larger than half of their bill size), whereas most juveniles caught only small prey, and only two juveniles (two of 31, 6.5%) caught large prey (chi-square test with Yate's correction, $\chi^2_1 = 13.15$, $P < 0.001$).

Temporal effect

A significant difference was observed in the heron's moving rate according to breeding stage. Adult grey herons walked more during the fledging stage than during the incubating and nestling stages (Kruskal-Wallis test,

$H_2 = 6.11$, $P < 0.05$) (Table 2). Pecking and capture rates of adult grey herons were high during the fledging period ($H_2 = 23.37$, $P < 0.001$ for pecking rate; $H_2 = 16.54$, $P < 0.001$ for capture rate, respectively). However, prey volume taken by adults per unit time was high during the incubating period and low during the nestling period ($H_2 = 7.61$, $P < 0.05$). Relative frequencies of fish size caught by adult grey herons also varied significantly ($\chi^2_2 = 9.53$, $P < 0.01$) (Table 3). Adults caught small fish more frequently during the nestling stage (71.2%) than during the incubating stage (43.9%) and fledging stage (53.8%). In contrast, time of day had no significant effect on foraging efficiency of adult grey herons (Table 4).

Table 2. Feeding efficiency of adult grey herons during three different periods

Period (N)	Steps/min	Pecks/min	Captures/min	Success rate	Biomass/min
1 April-10 May (66)	4.97 ± 3.92 ^{ab}	0.19 ± 0.16 ^a	0.12 ± 0.05 ^a	0.79 ± 0.27	7.59 ± 12.18 ^a
11 May-10 June (59)	4.03 ± 4.31 ^b	0.21 ± 0.17 ^a	0.13 ± 0.07 ^a	0.76 ± 0.28	4.71 ± 8.83 ^b
11 June-10 July (65)	5.25 ± 3.80 ^a	0.34 ± 0.28 ^b	0.23 ± 0.20 ^b	0.72 ± 0.27	6.48 ± 10.34 ^{ab}
Statistics	$H = 6.11$ $P < 0.05$	$H = 23.37$ $P < 0.001$	$H = 16.54$ $P < 0.001$	$H = 2.17$ NS	$H = 7.61$ $P < 0.05$

Values are mean ± standard deviation, and numbers in parentheses are sample sizes. Variables among the three periods were compared using the non-parametric Kruskal-Wallis test. Periods with the same letter are not significantly different based on Dunn's test ($P > 0.05$). NS, not significant.

Table 3. Percentage of adult grey herons that caught only small fish and large fish in relation to period and habitat type

Fish size *	Period [†]			Microhabitat type [‡]			
	E (66)	M (59)	L (65)	E (40)	O (78)	S (56)	V (16)
Only small	43.9	71.2	53.8	42.5	57.7	62.5	56.2
Large	56.1	28.8	46.2	57.5	42.3	37.5	43.8
Statistics [§]	$\chi^2_2 = 9.53$, $P < 0.01$			$\chi^2_3 = 4.00$, NS			

Numbers in parentheses are sample sizes.

*Fish size: small, < 1/2 of bill size; large, > 1/2 of bill size.

†Period: E, early (1 April-10 May); M, middle (11 May-10 June); L, late (11 June-10 July).

‡Microhabitat type: E, vegetation edge; O, open water; S, submerged plants; V, densely vegetated emergent plants.

§Chi-square test; NS, not significant.

Table 4. Feeding efficiency of adult grey herons by time of day

Time of day (N)	Steps/min	Pecks/min	Captures/min	Success rate	Biomass/min
07:00-11:00 (59)	5.26 ± 4.36	0.23 ± 0.18	0.16 ± 0.08	0.80 ± 0.25	7.05 ± 12.69
11:00-16:00 (85)	4.76 ± 4.00	0.25 ± 0.23	0.16 ± 0.15	0.74 ± 0.28	6.71 ± 10.90
16:00-19:00 (46)	4.18 ± 3.57	0.26 ± 0.25	0.16 ± 0.16	0.73 ± 0.28	4.64 ± 6.29
Statistics	$H = 1.76$ NS	$H = 0.17$ NS	$H = 2.68$ NS	$H = 2.80$ NS	$H = 1.09$ NS

Values are mean ± standard deviation, and numbers in parentheses are sample sizes. Variables were compared using the nonparametric Kruskal-Wallis test. NS, not significant.

Microhabitat effect

Feeding activities of adult grey herons varied significantly among the four microhabitats (Table 5). The moving rate of grey herons did not differ among the four habitat types (Kruskal-Wallis test, $H_3 = 6.22$, n.s.), although the rate was slightly higher in open water areas. Pecking and capture rates were lowest at the edge of tall vegetation, intermediate in tall vegetation and in open water, and highest in the submerged plant area ($H_3 = 10.74$, $P < 0.05$ and $H_3 = 8.64$, $P < 0.05$, respectively), but the capture success rate did not differ ($H_3 = 4.58$, n.s.). Biomass per unit time taken by adults did not differ significantly among the four microhabitats ($H_3 = 0.47$, n.s.). No significant difference was observed for prey size by microhabitat ($\chi^2_3 = 4.00$, n.s.) (Table 3).

DISCUSSION

In this study, grey herons completed an average of five steps per minute when they had feed in the reservoir, and moving rate was not affected by age, time of day, or habitat type, although some differences were observed among periods. Grey herons usually have less conspicuous foraging habits than those of other ardeids, and they stand and wait for several minutes to catch prey (Choi et al. 2008). Thus, their typical feeding strategy is to catch a few large prey during the course of the day, even in the nesting period (Dimalexis et al. 1997, Kushlan and Hancock 2005).

Adult grey herons were more efficient foragers than juveniles; adults had higher successful capture rates than those of juveniles. Juveniles attempted more pecks than adults, but many attempts failed to capture prey. Thus, juveniles attempted to capture prey more often to satisfy their daily energy demands (Brandt 1984). Less successful feeding attempts by young herons has been reported by

several authors (Quinney and Smith 1980, Lo and Fordham 1986, Burger and Gochfeld 1989, Papakostas et al. 2005). The lower feeding success of young herons may result from a lack of foraging experience (Draulans and van Vessem 1985, Burger and Gochfeld 1989, Marchetti and Price 1989) and sensorimotor maturity (Cezilly and Boy 1988, Marchetti and Price 1989). Juveniles also tend to capture smaller prey than adults, because they are less skillful at catching and handling large prey and, thus, have a lower food intake rate (Quinney and Smith 1980, Draulans and van Vessem 1985). In contrast, adult grey herons are specialists on larger prey. Low feeding efficiencies of juveniles may affect their survival after fledging and also affect fat reserves for the autumnal migration.

Temporal changes in the feeding efficiency of herons may be related to their breeding stage (Matsunaga 2000, Papakostas et al. 2005) and may also reflect changes in prey availability within the foraging range (Matsunaga 2000, Richardson et al. 2001). In this study, most grey herons were incubating eggs during the early period (from April to 10 May) and, therefore, only needed food for themselves. However, as chicks hatch in May, some pairs had small chicks that required additional food; thus, the energy demand increased gradually to reach a peak in June. Our results showed that total biomass intake taken by adult grey herons was high during the incubating and fledging periods. During the incubation period, adult grey herons frequently caught large fish that were more than twice as long as their bills despite the low capture rate. Many adults caught a few large prey and then rested during this period. In April and May, big fish such as carp (*Cyprinus carpio* and *Carassius auratus*) crowded into shallow water areas filled with submerged or emergent plants to spawn, and these fish were easily caught by the adult herons. In contrast, though small fishes were frequent, adult herons had high prey capture rates during the fledging period, resulting in high biomass intake. As

Table 5. Feeding efficiency of adult grey herons by microhabitat type

Habitat type (N)	Steps/min	Pecks/min	Capture/min	Success rate	Biomass/min
Edge (40)	3.70 ± 3.32	0.18 ± 0.11 ^a	0.12 ± 0.05 ^a	0.75 ± 0.26	5.46 ± 6.44
Open water (78)	5.55 ± 4.45	0.23 ± 0.19 ^{ab}	0.14 ± 0.08 ^{ab}	0.77 ± 0.28	7.26 ± 12.67
Submerged (56)	4.53 ± 3.84	0.33 ± 0.30 ^b	0.22 ± 0.21 ^b	0.72 ± 0.28	6.43 ± 10.81
Vegetated (16)	4.53 ± 3.52	0.18 ± 0.08 ^a	0.15 ± 0.07 ^{ab}	0.88 ± 0.22	3.22 ± 2.54
Statistics	$H = 6.22$ NS	$H = 10.74$ $P < 0.05$	$H = 8.64$ $P < 0.05$	$H = 4.58$ NS	$H = 0.47$ NS

Values are mean ± standard deviation, and numbers in parentheses are sample sizes. Variables among the four habitat types were compared using the nonparametric Kruskal-Wallis test. Habitat types with the same letter are not significantly different based on Dunn's test ($P > 0.05$). NS, not significant.

a result, both large prey size (during the early period) and high capture rates (during the late period) have significant effects on increasing overall biomass intake rate of grey herons (Dimalexis et al. 1997, Campos and Lekuona 2001).

As small chicks are in nests beginning in May, adult herons must select smaller prey, because nestlings are unable to ingest large-sized fish (Moser 1986). Adult herons frequently caught small fish in May and June. However, despite the increase in food demand for growing chicks during the nestling period, the capture rate and biomass intake of adults was lower than that during the other two periods. This was probably related to the short distance between feeding and nesting sites (within 500 m from the colony). The short distance between the feeding and nesting sites could shorten the food delivery time to nests and increase the food provisioning rate, even though it was small and low volume prey.

The foraging efficiency of grey herons did not vary among times of day, although feeding intensity was low at midday in this study. Many ardeids vary their foraging intensity among times of day (Erwin et al. 1985, Lo and Fordham 1986, Kersten et al. 1991). Daily variations in feeding activity mainly occur in estuarine habitats, which are affected by the tidal cycle (Sawara et al. 1990, Matsunaga 2000) and also occur in non-tidal habitats due to the effect of daily distribution and behavior of prey species (Kersten et al. 1991). However, Sawara et al. (1990) reported continuous feeding of grey herons in non-tidal environments and Erwin (1985) reported that time of day had little influence on feeding during the breeding season in contrast to winter, because of high food demands for rearing chicks. Additionally, no daily difference in foraging activity may infer that the availability of prey did not differ significantly by time (Papakostas et al. 2005).

The feeding behavior and success of many ardeids is affected by the habitat or microhabitat type where the herons feed (Hafner et al. 1986, Draulans and Hannon 1988, Dimalexis et al. 1997, Maccarone and Brzorad 2002). This may be due to differences in habitat structure (Dimalexis et al. 1997) or prey availability (Richner 1986, Maccarone and Parsons 1994). Higher pecking and capture rates in submerged plant areas indicated that this area was a suitable feeding microhabitat for herons, probably due to the high density of small fish. Submerged aquatic plants provided spawning sites for several fish and also provided protection and feeding area for small and young fish. Additionally, we found that the moving rate of adult grey herons tended to be higher on open water areas than in vegetated areas, although the difference was not significant.

Thick vegetated areas (emergent and submerged plants) probably prevented grey herons from walking.

In conclusion, a reservoir provided important feeding habitat for breeding herons, and the feeding efficiency of grey herons was affected mainly by the microhabitat with a small time effect. These results suggest that the distribution of fish depended on microhabitat type and that time of day had less of an effect. In addition, the difference in feeding efficiency in relation to breeding stage reflected the change in food demand during the breeding period. Consequently, we found that grey herons foraging at a reservoir achieved different efficiencies in response to microhabitat and breeding stage. However, the direct effect of spatiotemporal variation in prey density on feeding activity of grey herons at reservoirs still remains to be analyzed.

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