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Individual differences in bait-fishing by the Green-backed Heron *Ardeola striata* associated with territory quality

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Individual differences were found in the feeding sites, frequency of bait fishing, and fishing success in three individual Green-backed Herons in southern Japan. The differences in the use of bait fishing and in fishing success seemed to be related primarily to differences in feeding sites, which were associated with territory quality. Bait fishing was used most frequently by the individual which fished often in open water with fewer suitable rocks, where the heron has to overcome the handicap of being easily seen by fish. Bait fishing was least common in the individual which fished most often from high branches. The leaves and twigs dropped from high branches rarely reached the spot the heron intended, and the fishing success was low. Individuals probably also differed in their skill at bait fishing.

Bait fishing, i.e., fishing with the use of bait by the Green-backed Heron *Ardeola striata* is reported from southern USA (Lovell 1958, Sisson 1974, Norris 1975, Keenan 1981, Preston *et al.* 1986), southern Japan (Higuchi 1986) and western Africa (Boswall 1983a,b, Walsh *et al.* 1985). It would be interesting to know why the behaviour appears to be restricted to certain areas within the vast distribution of the species. However, we have to collect much more data on the behaviour to clarify the reason. The data should include the development of the behaviour, factors affecting the frequency of the behaviour, and the features of the places where the behaviour is used.

This paper presents the results of observations of individual differences in bait fishing by Green-backed Herons in Japan. Here I report the feeding sites, frequency of bait fishing, kind of bait and effectiveness of bait fishing in three individuals. It is suggested that individual differences in the frequency of bait fishing and the fishing success are mainly related to their territory quality and feeding sites. It is also reported that in most cases the time needed to catch a fish after throwing the bait is much shorter than reported in Higuchi (1986).

Methods

The study was conducted at a pond in Suizenji Park, the same area as in Higuchi (1986), in Kumamoto (32°45′N, 130°45′E), Kyushu. The pond occupies about 15% of the 7·6 ha park. Maples and pines are scattered in the park, and ornamental rocks of various sizes are placed in the pond. Both native and introduced species of fish live in the pond; these include pale chub *Zacco platypus*, dace *Tribolodon hakonensis*, carp *Cyprinus carpio*, gudgeon *Pseudogobio esocinus* and golden fish *Carassius auratus*.

Observations were made with binoculars (× 8) and a scope (× 20) on 14–16 May, 8–9 June, 29–31 July and 27–29 August 1985. No birds were banded, but three adult individuals could be distinguished by their leg colour: one bright orange (individual A), one pale yellow (B), and the other pinkish (C). The leg colour did not change during the study period. These three individuals were usually the only herons that used the pond as their main feeding place. The maximum number of adult herons feeding at the same time in the pond was four.

Three observation points, 20–30 m apart, were visited in turn every hour or two. The feeding points of each individual were recorded on a 1 : 1,500 scale map. One individual was observed for 30 min in a single observation sequence, although there were a few incomplete sequences of less than 30 min when the heron left the pond. Time spent in fishing with and without bait was measured in minutes in every observation sequence. When the heron was fishing with bait the kind of bait, fishing success, and time to catch a fish after the bait was thrown was noted. The catching time was measured using a stopwatch to 0·01 s.

In analysing data, bait materials were grouped into two classes, i.e., 'live bait' and 'lure bait'. 'Live bait' included flies and other insects, which can be eaten by fish. They were considered to be alive when caught by herons, though it was not certain whether the items were alive or not when used as bait. 'Lure bait' included parts of plants, such as twigs and leaves, and feathers, which are not eaten by fish. Some unidentified objects were also included here. They appeared to be pieces of twigs and leaves. Although the type of bait used and fishing success may be expected to differ by season (Higuchi 1986) and feeding site (e.g., by the height of the site) for each individual, the data were insufficient to analyse these questions. The frequency of use of different types of feeding sites was not investigated in the field. It was estimated later from timed observations recorded on field maps.

Results

Territory and feeding sites

Each of the three individuals occupied an exclusive feeding territory in the pond (Fig. 1), from which other individuals were expelled. When the owner was absent part of the territory could be invaded. The shape and size of each territory remained almost the same throughout the observation period.

The three territories were somewhat different from each other in their environmental features. There were many rocks and bushes of various sizes in the territory of individual C. These rocks were 0·5–1·5 m wide and 0·1–1·5 m high from

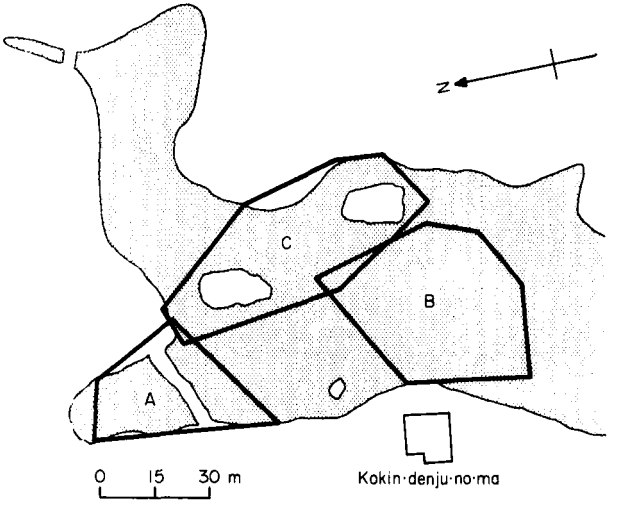

Figure 1. Territories of three individual Green-backed Herons in the pond (shaded area) of Suizenji Park, Kyushu. Each territory was drawn by connecting the outermost observation points at which each individual was not threatened by its neighbours.

the surface of the water. The bushes were 1·5–3·5 m high, with some branches as low as 0·4–1·0 m from the surface of the water. There were fewer rocks and bushes in the territories of A and B. In particular, small rocks between 0·1 and 0·3 m high and bushes with lower branches less than 1·0 m above the water were scarce, except those on the edge of pathways. Moreover, in more than 80% of the territory of B the water was too deep for a heron to stand, while A could stand comfortably in more than 70% of the territory.

The three individuals tended to forage at different types of sites. Although detailed measurements were not made (see Methods), individual A spent more than 70% of its foraging time fishing in the water, and the rest of the time fishing from branches 1·5–3·0 m above the water. B spent about 80% of its foraging time fishing from branches 1·5–2·0 m above the water, and the rest of the time fishing from the bank of the pond and from 0·5 to 1·0 m high rocks. C spent about 60% of its foraging time fishing from branches 0·4–0·6 m above the water, and the rest of the time fishing from 0·1 to 0·3-m-high rocks.

Frequency of use of bait

The frequency of bait fishing was significantly different between the three individuals (Table 1; Mann-Whitney $U=25$, $z=-7{\cdot}187$ for A *v.* B; $U=105$, $z=-2{\cdot}669$ for A *v.* C; $U=21$, $z=-4{\cdot}578$ for B *v.* C; $P<0{\cdot}01$ in all cases, two-tailed). Individual A spent 83·5% of its foraging time on an average using bait fishing, while B used bait fishing only 14·3% of the time. C was intermediate, using bait fishing 63·0% of the time on average.

The frequency of use of live bait and lure bait was not significantly different between the three individuals [Table 2; Fisher's exact probability test, two-tailed (FEPT hereafter)]. Every individual used about 80% lure bait and 20% live bait. For all individuals, more than 80% of the lure bait were twigs, leaves and berries, and more than 90% of the live bait were flies and other insects. Additional bait materials that were not reported in Higuchi (1986) include a small dragonfly, pieces of mushroom (individual A) and a tiny stone (C).

The size of bait could not be investigated in detail, but six leaves and two feathers used by A and three leaves used by B were apparently too large to lure fish. Those objects were more than 4 cm in length. All the objects used by C were less than 2 cm in length.

Table 1. *The frequency of use of bait fishing by three individual Green-backed Herons*

Individual	Observation sequences* *n*	Percentage of time spent in fishing with bait: Range	with bait: Mean ± s.d.	without bait: Range	without bait: Mean ± s.d.
A	39	33·3–100	83·5 ± 20·6	0–66·7	13·6 ± 19·5
B	34	0–73·3	14·3 ± 19·8	26·7 – 100	83·2 ± 21·7
C	11	33·3–100	63·0 ± 23·2	0 – 66·7	30·6 ± 22·7

* Most of the observation sequences were 30 min long. For a few sequences of less than 30 min, the ratio of fishing with and without bait was weighted by the length of the observation sequences.

Efficiency of bait fishing

Individual C was most successful at catching fish with bait (Table 2). The success of C when using lure bait (70·0%) was significantly higher than that of A (6·4%) and B (11·1%) (FEPT, $P = 0{\cdot}001$ for A *v.* C and $P = 0{\cdot}030$ for B *v.* C), though the success rate when using live bait was not significantly different. There were no significant differences in fishing success with different bait materials between A and B. The differences in fishing success between live and lure baits were only significant in A (19·4% *v.* 6·4%) (FEPT, $P = 0{\cdot}047$).

The high efficiency of bait fishing by C can be seen in Table 3, which shows the number of bait and fish taken per hour as well as the number of bait per fish. C caught about 2·6 fish with 3·8 pieces of bait per hour, while A used 10·8 pieces of bait to catch approximately one fish per hour, and B used 4·5 pieces of bait to catch 0·8 fish per hour. The average number of pieces of bait used to catch one fish was significantly smaller in C (1·4) than in A (11·0) and B (5·5) (FEPT, $P = 0{\cdot}001$ for A *v.* C, $P = 0{\cdot}034$ for B *v.* C), but the efficiency of bait use of A and B was not significantly different.

Table 4 shows the efficiency of fishing with and without bait in the three individuals. The number of fish caught per unit time is the best index of the efficiency of fishing without bait, because it is difficult to determine the duration of individual feeding trials in which bait is not used. In A, the number of fish caught per 10 min while bait fishing was significantly larger than the number caught while fishing without bait (Mann-Whitney $U = 273$, $z = -2{\cdot}454$, $P < 0{\cdot}05$, two-tailed). In B and C, the success rate was not significantly different between fishing with and without bait. The success rate while bait fishing was also significantly greater in C than in A or B (Mann-Whitney $U = 109$, $z = -2{\cdot}744$ for A *v.* C; $U = 37$, $z = -2{\cdot}697$ for B *v.* C; $P < 0{\cdot}01$ in both cases, two-tailed).

Table 2. *Frequency of use and effectiveness of two classes of bait by three individual Green-backed Herons*

Individual	Total bait used *n*	Live bait *n* (% of total)	Live bait % success	Lure bait *n* (% of total)	Lure bait % success
A	176	36 (20·5)	19·4	140 (79·5)	6·4
B	11	2 (18·2)	50·0	9 (81·8)	11·1
C	13	3 (23·1)	66·7	10 (76·9)	70·0

Table 3. *Efficiency of bait fishing by three individual Green-backed Herons*

Individual	Hours of observation	Bait used *n*	Fish caught *n*	Bait/hour *n*	Bait/fish *n*	Fish/hour *n*
A	16·28	176	16	10·81	11·0	0·98
B	2·44	11	2	4·51	5·5	0·82
C	3·47	13	9	3·75	1·4	2·59

Table 4. *Comparison of fishing efficiency with and without bait by three individual Green-backed Herons*

	No. of fish caught per 10 min in fishing					
	with bait			without bait		
Individual	Observation sequences* *n*	Range	Mean ± s.d.	Observation sequences* *n*	Range	Mean ± s.d.
A	39	0–0·95	0·18 ± 0·29	20	0–0·67	0·03 ± 0·15
B	15	0–1·43	0·14 ± 0·39	34	0–1·25	0·19 ± 0·28
C	11	0–2·00	0·56 ± 0·58	9	0–1·67	0·26 ± 0·57

* The length of observation sequences differs from case to case, depending on the ratio of fishing with and without bait (see Table 1).

Table 5. *Time in seconds needed to catch a fish after throwing the bait by three individual Green-backed Herons*

	Live bait			Lure bait		
Individual	*n*	Range	Mean ± s.d.	*n*	Range	Mean ± s.d.
A	5	0·66–3·65	1·334 ± 1·297	5	0·47–11·94	3·612 ± 4·916
B	—	—	—	2	1·11–8·95	5·030
C	4	0·62–1·36	0·850 ± 0·343	5	0·56–1·18	0·772 ± 0·241

Time needed to catch fish

The time needed to catch a fish after throwing the bait was difficult to measure accurately, and could be measured only in some of the successful bait fishing attempts (Table 5). The mean time when using live bait was 1·33 s and 0·85 s in individuals A and C, respectively, from which comparable data were obtained. The mean time when using lure bait was 3·61 s and 0·77 s in A and C, respectively. The time variation as well as the mean time was shorter in C. However, these differences in time were not significant either between A and C or between live and lure baits in each individual (Mann-Whitney *U* test).

The time to catch fish after throwing the bait was generally shorter in this study than in Higuchi (1986). Particularly in 14 of the 21 cases reported here, the time was less than 1 s. Such short times were not recorded in the earlier study. This difference may be due to increased accuracy of time measurement with the use of a stopwatch in the present study or behavioural differences between the individuals studied in the two observation periods. It appears, however, that some of the earlier measurements were not accurate.

Discussion

The differences in fishing success between the three individuals were apparently related to their territory quality and feeding sites. There were several rocks and bushes suitable for fishing in the territory of C, which showed a high fishing success. This heron could select low branches and rocks, where it could conceal its body from

fish, drop the bait accurately on the water, and strike fish easily. Since these herons take advantage of the high sensitivity of fish to the dropping of bait (Higuchi 1986), it is important for them to drop the bait accurately at the spot where they intend to catch (i.e., very close to the fish). Individuals A and B had fewer good feeding sites. A often fished in the water, where its body was easily seen by fish and its fishing success was low in spite of frequent use of bait. B fished mostly from branches because of the depth of the water in most of its territory. This heron had to use high branches available there, and its fishing success was low, even with the use of bait, because the leaves and twigs rarely reached the spot where the heron intended to dive.

The relationship between fishing success, territory quality, and feeding sites seems to account for the individual differences in the frequency of bait fishing. Individual A, which often fished in open water, had to use bait frequently to overcome the handicap of being easily seen by fish. This bird was sometimes observed to throw baits successively to the same spot. Its fishing success was greatly improved by the use of bait (see Table 4). This individual spent 84% of its foraging time in bait fishing. For B, which often fished from high branches, bait fishing was not effective, and fishing without bait was as successful as bait fishing. This heron spent only 14% of its foraging time in bait fishing. Individual C, which had good feeding sites, could easily improve its fishing success with the use of bait, but also appeared to be able to achieve a relatively high success without bait. This heron spent 63% of its foraging time in bait fishing.

However, it is improbable that all the individual differences in fishing success and in the frequency of bait fishing can be explained by the territory quality and feeding sites. For example, some leaves and feathers used by A and B were too large to lure fish, while all the objects used by C were of appropriate size as lures. In addition, the mean and variation of time taken to catch fish with bait were smaller in C than in A and B. These facts suggest that C was more skilful in bait fishing.

Skilfulness may be related to age and length of experience. Unfortunately, there are no data on the age of the three individuals. It is not known whether the difference in their leg colour reflects a difference in their age. Hancock & Elliott (1978) described the leg colour of Green-backed Herons as follows: 'legs yellowish in immature, more dusky or greenish yellow in adults and bright yellow, orange or reddish orange in the nuptial phase. Females tend to be a little less brightly coloured.' The three individuals reported here were all in full adult plumage.

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