ASIAN ROSY FINCH *Leucosticte arctoa*
COMMON BULLFINCH *Pyrrhula pyrrhula*
SNOW BUNTING *Plectrophenax nivalis*
PINE BUNTING *Emberiza leucocephalos*

FORKTAIL 7 (1992): 125-130

Food-niche relationships of five sympatric north Indian herons

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In a study in Northern India, the pivotal prey groups for Cattle Egret were flies (by number) and toads (by biomass), for Little Egret fishes (both by number and by biomass), for Indian Pond-Heron frogs (by number) and fishes (by biomass), for Intermediate Egret bugs (by number) and fishes (by biomass), and for Black-crowned Night-Heron fishes (both by number and biomass). Low overlaps in number of prey categories consumed by the herons were found. However, there were high overlaps in shared prey categories, suggesting such prey may not be limited in nature. Indian Pond-Heron had the highest niche width and Cattle Egret the lowest. The size of a heron was not considered with mean langth of the prey consumed.

There has been extensive documentation of the feeding habits of various herons, but such studies on herons from the Oriental region remain meagre. Here I report food resources utilized, food-niche width and overlap in food used by five sympatric north Indian herons, the Black-crowned Night-Heron *Nycticorax nycticorax,* Intermediate Egret *Egretta intermedia,* Indian Pond-Heron *Ardeola grayii,* Little Egret *Egretta garzetta,* and Cattle Egret *Bubulcus ibis.*

METHODS

Food samples were obtained from and around Chandigarh (30°42'N 76°54'E), India, between March 1984 and March 1985. Two methods were used to obtain food samples, collecting adults in the field and gathering regurgitated food samples from heronries. Both samples were lumped in analyses because adult herons deliver the same size and composition of prey to nestlings that they have themselves consumed (Kushlan 1978: 271).

For comparison. I used high levels of prey identification as suggested by Greene and Jaksic (1983). Such food analyses of these species have been reported elsewhere (Sodhi 1985, 1986, 1989, Sodhi and Khera 1986, Singh *et al.* 1988). Food samples of Black-crowned Night-Heron were obtained only during the breeding sensor and of Intermediate Egret during March (2) and September (1). Data on these species were compared with samples collected from other species during that period.

Overlaps in prey categories were calculated as:– Number of common prey categories consumed by both species/total number of prey categories consumed by both species X 100. Overlap among common prey categories (see Appendix) of any two species was calculated by Horn's measure ($2\Sigma p_i\ q_i/p^2_i + q^2_i$), where p_i is the frequency of a given prey and q_i is the frequency of the same prey in the second species. (This formula renders values between 0 to 1, signifying null to complete overlap.)

Food-niche width, i.e. diet diversity, was computed as: $B = \Sigma(p^2_i)^{-1/2}$, where p_i is the relative occurrence of prey i in a given specie's diet. (This index gives values between 1 to n; see Levins 1968 for explanation.) Further, to remove differential sample-size bias, I calculated the standardized version of food-niche width as proposed by Colwell and Futuyama (1971):

$B_{sta} = (B_{obs} - B_{min}) / (B_{max} - B_{min})$. Where B_{obs} is the observed niche width, B_{min} is the minimum niche width possible (=1), and B_{max} is the maximum width possible (=n, which is the number of prey categories actually taken by a given species). B_{sta} ranges between 0 and 1.

Weight, bill length, tarsus length, and wing length of herons were obtained from Cramp and Simmons (1977). Usually, mean values were given separately for sexes but I combined them into a single figure for each species. I calculated weight ratios between neighbouring species along an increasing axis, the weight of the lightest species in any pair was in the denominator

Table 1. Major prey categories consumed by five species of herons. Data given as percentage of number. + = values less than 0.1%; * signifies adults and young

	Cattle Egret (n=5049)	Little Egret (n=332)	Indian Pond-Heron (n=249)	Intermediate Egret (n=34)	Black-crowned Night-Heron (n=106)
Earthworms	1.2	–	8.0	–	2.8
Dragonflies*	1.0	8.4	14.8	–	0.9
Damselflies*	0.1	1.5	+	–	–
Grasshoppers	16.7	6.0	1.2	2.9	0.9
Crickets	4.5	–	3.2	–	–
Earwigs	1.1	–	–	–	–
Cockroaches	+	–	–	–	–
Praying Mantis	0.1	–	–	–	–
Termites	1.3	–	–	–	–
Bugs	0.2	30.9	3.6	35.2	–
Beetles*	5.8	4.8	11.6	29.3	–
Flies	48.7	+	8.0	–	–
Caterpillars	10.8	–	3.6	–	–
Moths	0.4	+	+	–	–
Butterflies	+	–	–	–	–
Ants	0.4	–	–	–	–
Wasps	+	–	+	–	–
Spiders	6.2	3.3	6.4	–	–
Centipede	+	–	–	–	–
Crustaceans	–	5.1	–	–	0.9
Snail	–	+	–	–	–
Frogs*	0.1	+	25.2	–	26.4
Toads	0.5	+	–	–	–
Fishes	–	31.9	4.8	32.3	67.5
Lizards	0.2	–	–	–	–
Shrew	+	–	–	–	–
Rat	+	+	–	–	–
Sample size	95	29	22	3	20
Niche width (B_{sta})	0.058	0.112	0.267	0.133	0.234

Table 2. Major prey categories consumed by five species of herons. Data presented as percentage of biomass (wet weight). + = Values less than 0.1%; * signifies adults and young

	Cattle Egret	Little Egret	Indian Pond-Heron	Intermediate Egret	Black-crowned Night-Heron
Earthworms	2.2	–	1.7	–	+
Dragonflies*	1.2	1.5	7.8	–	+
Damselflies*	+	+	+	–	–
Grasshoppers	10.9	1.4	2.0	+	+
Crickets	8.1	–	1.7	–	–
Earwigs	0.2	–	–	–	–
Cockroaches	+	–	–	–	–
Praying Mantis	0.2	–	–	–	–
Termites	0.4	–	–	–	–
Bugs	+	1.5	+	10.9	–
Beetles*	0.9	+	1.3	15.0	–
Flies	7.6	+	+	–	–
Caterpillars	14.7	–	1.7	–	–
Moths	+	+	+	–	–
Butterflies	+	–	–	–	–
Ants	+	–	–	–	–
Wasps	+	–	+	–	–
Spiders	1.7	+	1.5	–	–
Centipede	0.2	–	–	–	–
Crustaceans	–	2.0	–	–	0.1
Snail	–	+	–	–	–
Frogs*	10.8	+	37.5	–	10.3
Toads	25.7	11.7	–	–	–
Fishes	–	67.0	44.2	74.0	88.8
Lizards	6.3	–	–	–	–
Shrew	0.3	–	–	–	–
Rat	1.0	10.7	–	–	–

(Hutchinson 1959, Diamond 1975, Jaksic and Braker 1983).

I performed correlation analyses using Spearman's rho correlation coefficient (Sokal and Rohlf 1969).

RESULTS AND DISCUSSION

Tables 1 and 2 show that the most important prey groups for Cattle Egret were flies (by number) and toads (by biomass), for Little Egret fishes (both by number and biomass), for Indian Pond-Heron frogs (by number) and fishes (by biomass), for Intermediate Egret bugs (by number) and fishes (by biomass) and for Black-crowned Night-Heron fishes (both by number and biomass). It has been postulated that prey selection in herons may be dependent upon four factors (Sodhi 1988): (a) prey availability, (b) prey vulnerability, (c) physiological stimuli of the predator, and (d) competition for food resources among sympatric herons.

There were no high overlaps in the number of prey categories consumed by the herons (Table 3). This supports the expectation that values of overlaps should be low as a consequence of past competitive interactions that have led the consumer species to differ in their pattern of resource utilization (Lawlor and Maynard-Smith 1976, Lawlor 1980). But overlaps in prey categories that were common to any pair of species were high (76-99%), particularly among aquatic herons (Tables 4 and 5), suggesting that those prey categories may not be limited in availability. Such overlaps of aquatic herons with the only terrestrial heron – Cattle Egret – were low, perhaps due to differential habitat utilization.

Table 3. Overlaps in prey categories consumed by the herons (values range between 0 and 100).

Little Egret – Indian Pond-Heron	21.9
Indian Pond-Heron – Cattle Egret	9.0
Little Egret – Cattle Egret	7.8
Black-crowned Night Heron – Indian Pond Heron	8.0
Black-crowned Night Heron – Little Egret	14.2
Black-crowned Night Heron – Cattle Egret	0.7
Intermediate Egret – Indian Pond-Heron	7.1
Intermediate Egret – Little Egret	9.7
Intermediate Egret – Cattle Egret	0.8

Table 4. Overlaps in common prey categories consumed by the herons.

Species	Black-crowned Night-Heron	Intermediate Egret	Indian Pond-Heron	Little Egret	Cattle Egret
Black-crowned Night-Heron	–	–	0.763	0.811	0.198
Intermediate Egret		–	0.990	0.951	0.024
Indian Pond-Heron			–	0.916	0.272
Little Egret				–	0.628
Cattle Egret					–

Table 5. Feeding-niche dimensions of five herons. See Hancock and Kushlan (1984) for description of feeding behaviours.

Species	Frequently used feeding behaviour	Feeding habitat	Feeding situation
Black-crowned Night Heron	Waiting	Aquatic	Solo
Intermediate Egret	Slow walking	Aquatic	Flock
Little Egret	Fast walking	Aquatic	Flock
Indian Pond-Heron	Waiting	Aquatic	Solo
Cattle Egret	Slow walking	Terrestrial	Flock

Table 6. Weight ratios between herons.

1.34	1.31	1.18	1.10

Table 7. Morphological variables (calculated from Cramp and Simmons 1977) and food length (in mm) of the herons.

Species	Wing length	Tarsus length	Bill length	Mean Food length
Black-crowned Night-Heron	291.0	77.8	70.8	63.8
Intermediate Egret	299.0	106.0	72.8	38.8
Little Egret	276.0	99.1	81.9	23.4
Indian Pond-Heron	204.5	55.5	59.7	22.4
Cattle Egret	250.5	76.5	55.5	10.5

The white-plumaged herons (Intermediate Egret, Little Egret, Cattle Egret), usually feed in flocks (Table 5). This supports Kushlan's (1978) hypothesis that white plumage acts as a social stimulus for flock-feeding in herons.

The anticipation that minimum weight ratios between adjacent-sized coexisting species should fall between 2.2 (Hutchinson 1959, MacArthur 1972) and 3.2 (Diamond 1975), was not met by my results (Table 6; see Wiens and Rotenberry 1980, Jaksic and Braker 1983, for similar results). The correlation between weight ratios and corresponding food-niche overlaps (common prey) was negative, though insignificant ($r_s = -0.200$, $p>0.05$). The expected tradeoff between body size and overlap in diet, documented for mammals (Brown 1975, Fuentes and Jaksic 1979), which is assumed to be the outcome of competitive interactions, is thus not supported.

No statistically significant relationships exist between different morphological variables and length of food items consumed by the herons (Table 7), i.e., wing length ($r_s = 0.800$, $p>0.05$), tarsus length ($r_s = 0.600$, $p>0.05$), and bill length ($r_s = 0.600$, $p>0.05$). This suggests that length of prey items consumed may be dependent upon length of available prey rather than on a heron's morphology.

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REFERENCES

Brown, J. H. (1975) Geographical ecology of desert rodents. Pp. 315-341 in M. L. Cody, and J. M. Diamond, eds. *Ecology and evolution of communities.* Cambridge: Belknap Press.

Colwell, R. K. and Futuyama, D. J. (1971) On measurement of niche breadth and overlap. *Ecology* 52: 567-576.

Cramp, S. and Simmons, K. E. L. (1977) *The birds of the western Palearctic*, 1. Oxford: Oxford University Press.
Diamond, J. M. (1975) Assembly of species communities. Pp. 324-444 in: M. L. Cody and J. M. Diamond, eds. *Ecology and evolution of communities*. Cambridge: Belknap Press.
Fuentes, E. R. and Jaksic, F. M. (1979) Latitudinal size variation of Chilean foxes: tests of alternate hypotheses. *Ecology* 60: 43-47.
Greene, H. W. and Jaksic, F. M. (1983) Food-niche relationships among sympatric predators: effects of level of prey identification. *Oikos* 40: 151-154.
Hancock, J. and Kushlan, J. (1984) *The herons handbook*. London: London Editions Ltd.
Hutchinson, G. E. (1959) Homage to Santa Rosalia, or why are there so many different kinds of animals? *Amer. Nat.* 93: 145-159.
Jaksic, F. M. and Braker, H. E. (1983) Food-niche relationships and guild structure of diurnal birds of prey: competition versus opportunism. *Can. J. Zool.* 61: 2230-2241.
Kushlan, J. A. (1978) Feeding ecology of wading birds. *Wading Birds* 7: 249-297.
Lawlor, L. R. (1980) Overlap, similarity, and competition coefficients. *Ecology* 61: 245-251.
Lawlor, L. R. and Maynard-Smith, J. (1976) The coevolution and stability of competing species. *Amer. Nat.* 110: 79-99
Levins, R. (1968) *Evolution in changing environments*. New Jersey: Princeton University Press.
MacArthur, R. H. (1972) *Geographical ecology: patterns in the distribution of species*. New York: Harper and Row.
Singh, N., Sodhi, N. S. and Khera, S. (1988) Biology of the Cattle Egret, *Bubulcus ibis coromandus* (Boddaert). *Rec. Zool. Surv. India, Occ. Pap. 104: 1-143.*
Sodhi, N. S. (1985) Food of the Black-crowned Night Heron nestlings. *Pavo* 23: 47-52.
Sodhi, N. S. (1986) Feeding ecology of Indian Pond Heron and its comparison with that of Little Egret. *Pavo* 24: 97-112.
Sodhi, N. S. (1989) Monthly variations in the diet of the Cattle Egret *(Bubulcus ibis)* in and around Chandigarh. *J. Bombay Nat. Hist. Soc. 86: 440-443.*
Sodhi, N. S. and Khera, S. (1986) Feeding habits of the Median Egret. *Res. Bull. Panjab Univ.* 37: 9-12.
Sokal, R. R. and Rohlf, F. J. (1969) *Biometry*. San Francisco: Freeman.
Wiens, J. A. and Rotenberry, J. T. (1980) Patterns of morphology and ecology in grassland and shrubsteppe bird populations. *Ecol. Monogr.* 50: 287-308.

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APPENDIX

Prey categories shared by different herons.
Indian Pond-Heron – Little Egret: Naiads of dragonflies, *Crocothemus* sp., *Trithemis* sp., *Ischnura* sp., *Acheta* sp., *Hedotettix* sp., *Cybister* sp., *Erestes* sp., *Hydrophilus* sp., *Mydea* sp., *Sphaerodema* sp., *Ranatra elongata, Lycosa* sp., *Rana* sp., *Barilius* sp., *Nemacheilus* sp.
Little Egret – Cattle Egret: Naiads of dragonflies, *Crocothemus* sp., *Trithemis* sp., *Ischnura* sp., *Acheta* sp., *Mydea* sp., *Laxenera* sp., *Anomala* sp., *Calosoma* sp., *Lycosa* sp., *Rana* sp., Rat.
Indian Pond-Heron – Cattle Egret: *Pheretima* sp., Naiads of dragonflies, *Crocothemus* sp., *Trithemis* sp., *Ischnura* sp., *Gryllotalpa fossor, Tetragonoderus* sp., *Onthophagus* sp., *Episyrphus balteatus, Mydea* sp., Caterpillars, *Athalia proxima, Lycosa* sp., *Rana* sp.
Black-crowned Night-Heron – Indian Pond Heron: *Pheretima* sp., *Barilius* sp., *Nemacheilus* sp., *Ophiocephalus* sp.
Black-crowned Night-Heron – Little Egret: *Palaemonetes* sp., *Barilius* sp., *Nemacheilus* sp., *Barbus* sp., *Labeo* sp., *Lepidocephalus* sp.
Black-crowned Night-Heron – Cattle Egret: *Pheretima* sp.
Intermediate Egret – Indian Pond-Heron: *Sphaerodema* sp., *Acheta* sp., *Cybister* sp.
Intermediate Egret – Little Egret *Sphaerodema* sp., *Acheta* sp., *Cybister* sp., *Barbus* sp.
Intermediate Egret – Cattle Egret: *Acheta* sp.

FORKTAIL 7 (1992): 131-137

Breeding ecology of the Relict Gull *Larus relictus* in Ordos, Inner Mongolia, China

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Details are given of a large breeding population at Taolimiao-Alashan Nur, discovered in spring 1990, including a description of the site; attendance of the birds; breeding ecology, including descriptions of the nests, eggs, incubation period and hatching success; also population density and feeding behaviour. The site is considered to be inherently unstable because of the variable rainfall of the region.

In 1985-1988, during the course of fieldwork on the avifauna of western Inner Mongolia, we found four new sites for the Relict Gull *Larus relictus* in Ordos: at Alashan, Bayandror, and Yeekzhao, and concluded that it might breed in the area (Zhang Yin-sun *et al.* 1991). Then in spring 1990 we discovered the largest known breeding population of the gull at Taolimiao-Alashan Nur, central Ordos. Observations were carried out there in May-June, 1990 as well as some short-term surveys in April, July and August in surrounding areas.

DESCRIPTION OF THE BREEDING SITE

The Taolimiao-Alashan Nur (Nur in Mongolian language means small lake or pond usually with salt water) is located at the junction of the Koobuchi and Mausu deserts in central Ordos, 109°35'E and 39°48'N. The weather there is quite dry with much wind and sandy dust; 130-139 frost-free days a year; 35.8°C the highest and -32.6°C the lowest temperature; plenty of sunshine and the rainfall concentrated in June-August with 325 mm a year on average.

The lake is at an elevation of 1,368 m at the north-west end, rising to 1,392 m at the south-east end. The surroundings are mostly stabilised sand dunes with a poor vegetation of typical eremophytes such as *Nitraria roporowskii, Oxytropis psammocharis, Artemisia ordosica, Achnatherum splendens, Euphorbia kozlowi, Pycnostelma lateriflorum, Carex duriuscula* and the artificial windbreak woods of *Salix cheilophila* and *Caragana korshinskii.*

The lake is about 10 km^2, 6 km long from east to west and 2.5 km the maximum width, and contains hydrophytes such as *Potamogeton filiformis, P. natans, Cladophora, Mougeotia and Ulothrix.*

OCCURRENCE AND DISTRIBUTION AT THE BREEDING SITE

In 1990, the first flock of the Relict Gull arrived at the site on 6 April and all had gone by 28-29 August.