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Effects of Urbanization on Bird Species Richness and Community Composition

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Abstract. - Surveys were conducted from November 2004 to July 2005 in three habitat types in southwestern China. A total of 7,628 individuals of 123 bird species were recorded. By comparing our results to those of a previous study in the same area, we found that urbanization was likely responsible for decreasing species richness. Although some endangered water bird species vanished in the River habitats, there was higher species richness and diversity in this habitat than in other habitats, due to high nutrient availability. Additionally, small and isolated forest fragments in suburban areas failed to sustain high diversity, even though the heterogeneity of this environment favours local bird richness. Interestingly, we found signs of recovery of some vanishing native bird species, possibly due to a reduction of pesticide usage in Agricultural habitats.

Key words: Urbanization, species richness, habitat heterogeneity, southwestern China.

INTRODUCTION

Composition and long-term persistence of many avian populations depends upon the precise habitat requirements, abundance and dispersal strategies of individual species. The presence of a species in a particular habitat patch is influenced not only by the size and structure of the patch, but also by the landscape surrounding the patch (Wegner and Merriam, 1979; Saunders *et al*., 1991). It is commonly accepted that heterogeneity of natural environments is one of the most important factors that contribute to biodiversity (Karr, 1976; Manhães and Loures-Ribeiro, 2005).

The urbanization processes leads to a reduction in biodiversity (Blair, 1996; McKinney and Lockwood, 1999) due to the transformation of natural habitats into agricultural, industrial and urbanized areas. Thus, urban development reduces available habitat and has resulted in declines in animal populations (Foster 1996; Kahn and McDonald, 1997; Hostetler and Knowles-Yanez, 2003). For example, urban riparian patches are embedded in a matrix of human-modified habitat, and bird diversity declines as this matrix becomes increasingly fragmented (Wilcove *et al*., 1986). Small forest fragments in suburban and rural areas and the introduction of native or exotic plant species are common landscape features in southwestern China. In addition, highly toxic pesticides have been used extensively to control pests since the 1970s (Guo and Zheng, 2001), which has often been thought to explain the decline in abundance and diversity of birds in agricultural habitats.

Despite this background information, our comprehension of how bird communities respond to urbanization is still rudimentary (Marzluff *et al*., 2001). The goals of the work presented here were: (1) to quantify the bird assemblages in three habitats in order to investigate any differences in species richness and diversity among these habitat types and (2) to compare the results to those of a previous study at the same study site in order to identify how urban development has influenced the animal populations at this site.

MATERIALS AND METHODS

Study area

Nanchong, the third largest city in Sichuan, covers an area of 12,500 km^2, has a human population of 7,120,000 inhabitants (Huang *et al*., 2009), and has a 1.60‰ natural population growth rate. From 1957 to 2010, the urban population of Nanchong increased 10-fold from 90,000 to 900,000. The main area of urban construction has increased

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28-fold since the beginning of liberation, as much of this population growth has manifested as urban and suburban sprawl.

The climate in the study area is typically subtropical and influenced by monsoons. Mean annual rainfall is 822.58 mm, with most rain falling between June and July. The area experiences dry, hot summers (27.5°C August average daily maxima) and cool, damp winters (6.4°C January average daily maxima).

Plot characterization

To parallel the Deng *et al.* (1980) study, we selected three types of well-defined habitats in this area: (1) River habitat (along the Jia ling River) with dense surrounding vegetation, (2) Agricultural areas, and (3) Woodlot (secondary forest) habitat. River habitats are composed of the river itself, washland and swamp. *Eichhornia crassipes*, *Saccharum arundinaceum*, *Saccharum spontaneum*, *Cymbopogon dactylon*, *Imperata cylindrical*, *Eleusine indica* and *Polypogon fugax* are the dominant plant species, together constituting 80% of the cover in River habitats (Hao *et al.*, 2006). A few *Morus alba* and *Cunninghamia lanceolata* individuals surround the Agricultural areas. In addition to seasonal vegetables (*e.g.*, *Solanum tuberosum*, *Glycine max*, and *Brassica oleracea*), *Oryza sativa*, *Zea mays*, *Triticum aestivum*, *Arachis hypogae* and *Brassica campestri* predominate in the Agricultural areas. In Woodlot habitats, dominant tree species include *Sabina chinensis*, *Neosinocalamus afinis*, *Ficus virens*, and *Pinus massoniana*. Additionally, *Robinia pseudoacacia*, *Rosa laevigata*, *Myrsine Africana*, *Festuca ovina*, *Pteris vittata*, *Dicranopteris dichotoma*, and *Duchesnea indica* grow beneath trees or at the forest margins.

Bird surveys

Surveys were conducted from November 2004 to July 2005 in the three habitat types. Point counts were conducted in both plantations along transects using distance sampling (Styring *et al.*, 2011). Transects were randomly situated in each habitat type. Each transect was 1000 m long and consisted of 20 points at 50-m intervals. Points were spaced relatively closely together to provide a comprehensive inventory. The number of transects varied among the three habitat types: we used 4 transects in River habitats, 5 transects in Agricultural areas, and 4 transects in Woodlot habitats (< 2 ha, Fig. 1). Once every two weeks, surveys were conducted in one, two or all three of the habitat types. Generally, each transect was visited on 8-9 occasions, for a total of 2080 point counts across 104 samplings. The counting session at each point lasted 5 min, during which the observer counted all birds seen or heard without recording the distance from the point. Bird surveys were conducted between sunrise and approximately 0830 hours on days with no rain and with wind speeds below 32 km/h. Nocturnal surveys were not undertaken, and therefore, species active at night (*e.g.*, owls and nightjars) were poorly sampled.

Species were identified using binoculars and field guides (MacKinnon *et al.*, 2000; Zheng *et al.*, 1996; Li, 1995). Taxonomical classification and scientific names are those suggested by Zheng (2005) and its supplements (The CBR Checklist of Birds of China v1.1 2010). Bird species were classified in habitat guilds based on published literature (Hang *et al.*, 1986, Wang *et al.*, 2001) and personal observations.

Statistical analyses

The relative abundance (%) of each bird species was estimated using the following expression: $n/N \times 100$, where n is the number of individuals counted in a particular bird species and N is the total observations detected for all species. One-way ANOVAs were used to compare species richness and species diversity (Shannon Weiner diversity index) values. If the overall ANOVA results were significant, we did pairwise multiple comparisons (Tukey's HSD) to evaluate differences among the three habitat types. A Chi-square test was used to test for differences in the distribution of foraging guilds and exclusive species. Similarly, we used Chi-square tests to analyze the influence of urbanization on bird species richness.

RESULTS

Relative abundance of birds

During the study period, a total of 7,628 individual birds, comprising 123 species in 43

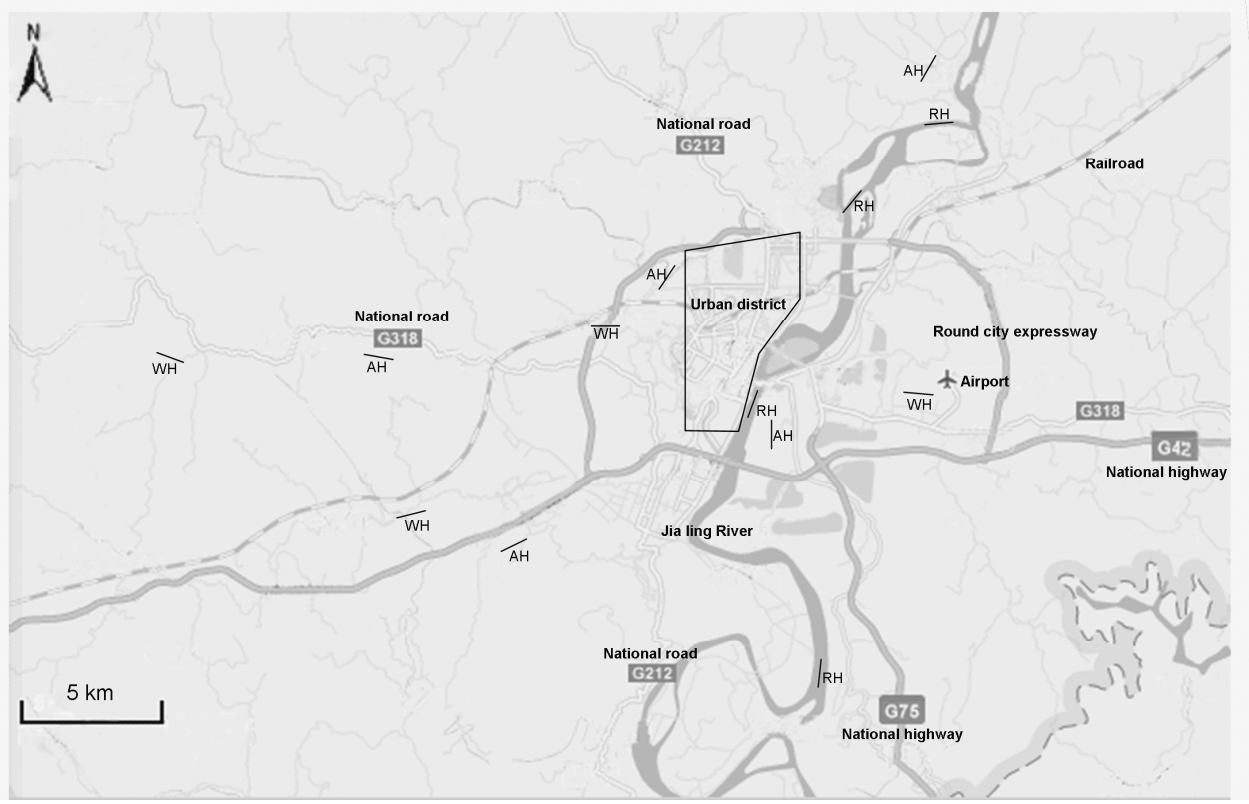

Fig. 1. Map of the study transects in three habitat types in Nanchong, Southwest China (RH: River habitats; WH: Woodlot habitats; AH: Agricultural habitats).

families, were recorded. In River habitat, a total of 3,001 bird observations (39.3% of all detections) were recorded. These birds were of 79 species in 33 families. Six species, *Anas zonorhyncha* (5.7% of all detections), *Riparia riparia* (4.3%), *Anas platyrhynchos* (3.0%), *Anas crecca* (3.0%), *Egretta garzetta* (3.0%) and *Motacilla alba* (2.1%), showed the highest relative abundances in this habitat. Twelve bird species showed the lowest relative abundances, each observed only once (0.01% each) in River habitat (*Ardeola bacchus, Buteo hemilasius, Fulica atra, Tringa nebularia, Megaceryle lugubris, Upupa epops, Motacilla cinerea, Lanius cristatus, Oriolus chinensis, Copsychus saularis, Chaimarrornis leucocephalus* and *Cettia fortipes*) (Table I).

In Woodlot habitat, a total of 2,417 bird observations (31.7% of all detections) were recorded, representing 70 bird species in 30 families. The results indicated that *Pycnonotus sinensis* (5.1%), *Aegithalos concinnus* (4.4%), *Spodiopsar cineraceus* (3.4%), *Egretta garzetta* (2.7%), *Carduelis sinica* (2.3%), and *Sinosuthora webbiana* (2.2%) were the three most dominant bird species in this habitat. In contrast, *Buteo hemilasius, Buteo buteo, Acridotheres cristatellus, Saxicola ferreus, Leucodioptron canorum, Cisticola juncidis, Phylloscopus affinis, Phylloscopus inornatus, Cettia fortipes, Seicercus burkii, Myophonus caeruleus, Ficedula albicilla* and *Sitta europaea* were the rarest birds, each recorded only once (0.01%) in Woodlot habitat (Table I).

In Agricultural habitat, we recorded a total of 2,210 bird observations (29.0%). These birds were of 55 species in 32 families. *Spodiopsar cineraceus* (8.4%) and *Riparia riparia* (2.8%) were the two most common birds in Agricultural habitat, whereas 8 bird species, *Tachybaptus ruficollis, Ardea cinerea, Ixobrychus cinnamomeus, Buteo buteo, Calidris temminckii, Dicrurus leucophaeus,*

Table I.- **Relative abundances of bird species recorded in three habitats in Nanchong, Southwestern China (N_1: number of bird species in this study; N_2: number of bird species in Deng *et al.* (1980); TG, Trophic guild; C, carnivore; F, frugivore; G, granivore; GF, granivore/Frugivore; I, insectivore; O, omnivore; P, piscivore).**

Family name	N_1	N_2	Scientific name	TG	River habitats		Woodlot habitats		Agricultural habitats	
					Observation	% of all detection	Observation	% of all detection	Observation	% of all detection
Podicipedidae	1	3	*Tachybaptus ruficollis*	P	19	0.25	0	0.00	1	0.01
Phalacrocoracidae	1	1	*Phalacrocorax carbo*	P	26	0.34	0	0.00	0	0.00
Ardeidae	7	9	*Egretta garzetta*	C	223	2.92	203	2.66	30	0.39
			Egretta eulophotes	C	29	0.38	0	0.00	0	0.00
			Ardea cinerea	C	111	1.46	0	0.00	1	0.01
			Bubulcus coromandus	I	5	0.07	0	0.00	0	0.00
			Nycticorax nycticorax	C	0	0.00	50	0.66	0	0.00
			Ardeola bacchus	C	1	0.01	28	0.37	0	0.00
			Ixobrychus cinnamomeus	C	2	0.03	0	0.00	1	0.01
Ciconiidae	0	1	—	—	—	—	—	—	—	—
Threskiorothidae	0	1	—	—	—	—	—	—	—	—
Anatidae	10	15	*Aythya nyroca*	O	8	0.10	0	0.00	0	0.00
			Aythya ferina	O	3	0.04	0	0.00	0	0.00
			Anas zonorhyncha	O	435	5.70	0	0.00	6	0.08
			Tadorna ferruginea	O	119	1.56	0	0.00	0	0.00
			Anas crecca	O	227	2.98	0	0.00	0	0.00
			Anas platyrhynchos	O	232	3.04	0	0.00	0	0.00
			Anas falcata	O	10	0.13	0	0.00	0	0.00
			Anas clypeata	O	49	0.64	0	0.00	0	0.00
			Mergus merganser	P	4	0.05	0	0.00	0	0.00
			Tadorna tadorna	O	13	0.17	0	0.00	0	0.00
Accipitridae	2	8	*Buteo hemilasius*	C	1	0.01	1	0.01	0	0.00
			Buteo buteo	C	4	0.05	1	0.01	1	0.01
Falconidae	1	3	*Falco amurensis*	I	0	0.00	2	0.03	0	0.00
Phasianidae	1	4	*Phasianus colchicus*	O	14	0.18	11	0.14	4	0.05
	0	1	—	—	—	—	—	—	—	—
Rallidae	3	4	*Gallicrex cinerea*	O	2	0.03	0	0.00	0	0.00
			Amaurornis phoenicurus	O	2	0.03	0	0.00	6	0.08
			Fulica atra	O	1	0.01	0	0.00	0	0.00
Otididae	0	2	—	—	—	—	—	—	—	—
Rostratulidae	1	1	*Mycteria leucocephala*	I	0	0.00	0	0.00	4	0.05
Charadriidae	5	9	*Charadrius dubius*	I	16	0.21	0	0.00	0	0.00
			Charadrius hiaticula	I	48	0.63	0	0.00	0	0.00

Continued

Family name	N_1	N_2	Scientific name	TG	River habitats		Woodlot habitats		Agricultural habitats	
					Observation	% of all detection	Observation	% of all detection	Observation	% of all detection
			Charadrius alexandrinus	I	14	0.18	0	0.00	0	0.00
			Vanellus vanellus	I	20	0.26	0	0.00	6	0.08
			Charadrius leschenaultii	I	10	0.13	0	0.00	4	0.05
Scolopacidae	7	11	*Himantopus himantopus*	I	7	0.09	0	0.00	0	0.00
			Tringa ochropus	I	4	0.05	0	0.00	5	0.07
			Actitis hypoleucos	I	3	0.04	0	0.00	0	0.00
			Tringa glareola	I	24	0.31	0	0.00	0	0.00
			Tringa nebularia	I	1	0.01	0	0.00	0	0.00
			Calidris temminckii	I	2	0.03	0	0.00	1	0.01
			Gallinago gallinago	I	9	0.12	0	0.00	0	0.00
Laridae	1	5	*Chroicocephalus ridibundus*	P	82	1.07	0	0.00	0	0.00
Columbidae	3	4	*Streptopelia tranquebarica*	GF	0	0.00	2	0.03	3	0.04
			Streptopelia orientalis	G	0	0.00	4	0.05	0	0.00
			Spilopelia chinensis	G	56	0.73	15	0.20	86	1.13
Cuculidae	4	5	*Eudynamys scolopaceus*	I	0	0.00	2	0.03	0	0.00
			Hierococcyx sparverioides	I	2	0.03	3	0.04	0	0.00
			Cuculus canorus	I	0	0.00	9	0.12	6	0.08
			Cuculus micropterus	I	0	0.00	4	0.05	4	0.05
Strigidae	1	5	*Asio flammeus*	C	0	0.00	0	0.00	0	0.00
Caprimulgidae	0	1	—	—	—	—	—	—	—	—
Alcedinidae	2	3	*Megaceryle lugubris*	P	1	0.01	0	0.00	0	0.00
			Alcedo atthis	P	6	0.08	0	0.00	4	0.05
Upupidae	1	1	*Upupa epops*	I	1	0.01	0	0.00	7	0.09
Picidae	1	4	*Picus canus*	I	0	0.00	2	0.03	0	0.00
Alaudidae	1	2	*Alauda gulgula*	O	34	0.45	0	0.00	6	0.08
Hirundinidae	3	3	*Hirundo rustica*	I	5	0.07	0	0.00	21	0.28
			Cecropis daurica	I	6	0.08	6	0.08	0	0.00
			Riparia riparia	I	325	4.26	0	0.00	210	2.75
Motacillidae	9	9	*Motacilla alba*	I	160	2.10	35	0.46	103	1.35
			Motacilla tschutschensis	I	5	0.07	0	0.00	0	0.00
			Motacilla citreola	I	9	0.12	0	0.00	0	0.00
			Dendronanthus indicus	I	0	0.00	2	0.03	0	0.00
			Motacilla cinerea	I	1	0.01	0	0.00	0	0.00
			Anthus hodgsoni	I	29	0.38	31	0.41	59	0.77
			Anthus spinoletta	I	27	0.35	2	0.03	49	0.64
			Anthus rufulus	I	16	0.21	0	0.00	8	0.10
			Anthus roseatus	I	6	0.08	0	0.00	0	0.00

Continued

Family name	N_1	N_2	Scientific name	TG	River habitats		Woodlot habitats		Agricultural habitats	
					Observation	% of all detection	Observation	% of all detection	Observation	% of all detection
Campephagidae	2	2	*Coracina melaschistos*	O	0	0.00	2	0.03	3	0.04
			Pericrocotus cantonensis	I	0	0.00	4	0.05	0	0.00
Pycnonotidae	3	3	*Pycnonotus xanthorrhous*	O	0	0.00	3	0.04	0	0.00
			Pycnonotus sinensis	O	43	0.56	386	5.06	88	1.15
			Spizixos semitorques	F	0	0.00	11	0.14	0	0.00
Laniidae	3	3	*Lanius cristatus*	I	1	0.01	2	0.03	3	0.04
			Lanius tigrinus	I	0	0.00	14	0.18	0	0.00
			Lanius schach	C	25	0.33	35	0.46	45	0.59
Oriolidea	1	1	*Oriolus chinensis*	I	1	0.01	4	0.05	7	0.09
Dicruridea	2	3	*Dicrurus macrocercus*	I	4	0.05	4	0.05	10	0.13
			Dicrurus leucophaeus	I	0	0.00	0	0.00	1	0.01
Sturnidae	3	3	*Spodiopsar cineraceus*	O	148	1.94	262	3.43	644	8.44
			Spodiopsar sericeus	O	0	0.00	14	0.18	40	0.52
			Acridotheres cristatellus	O	12	0.16	1	0.01	149	1.95
Corvidae	1	5	*Garrulus glandarius*	O	0	0.00	5	0.07	0	0.00
Troglodytidea	0	1	—	—	—	—	—	—	—	—
Turdidae	12	16	*Tarsiger cyanurus*	I	0	0.00	4	0.05	0	0.00
			Rhyacornis fuliginosa	I	5	0.07	0	0.00	0	0.00
			Zoothera dauma	I	0	0.00	0	0.00	1	0.01
			Copsychus saularis	I	1	0.01	16	0.21	8	0.10
			Phoenicurus auroreus	I	6	0.08	11	0.14	10	0.13
			Turdus eunomus	I	0	0.00	2	0.03	2	0.03
			Chaimarrornis leucocephalus	I	1	0.01	0	0.00	0	0.00
			Phoenicurus frontalis	I	0	0.00	2	0.03	3	0.04
			Turdus merula	O	32	0.42	100	1.31	148	1.94
			Myophonus caeruleus	I	0	0.00	1	0.01	0	0.00
			Enicurus leschenaulti	I	2	0.03	0	0.00	0	0.00
			Saxicola ferreus	O	0	0.00	1	0.01	0	0.00
Timaliidae	4	7	*Pterorhinus sannio*	O	3	0.04	42	0.55	51	0.67
			Leucodioptron canorum	O	0	0.00	1	0.01	0	0.00
			Ianthocincla cineracea	O	0	0.00	5	0.07	0	0.00
			Yuhina diademata	O	0	0.00	7	0.09	0	0.00
Paradoxornithidae	1	1	*Sinosuthora webbiana*	O	15	0.20	170	2.23	9	0.12
Muscicapidae	2	5	*Ficedula albicilla*	I	0	0.00	1	0.01	0	0.00
			Niltava davidi	I	0	0.00	2	0.03	0	0.00
Monarchidae	1	1	*Terpsiphone paradisi*	I	0	0.00	0	0.00	0	0.00
Cisticolidae	2	3	*Cisticola juncidis*	I	3	0.04	1	0.01	3	0.04
			Prinia polychroa	I	32	0.42	3	0.04	6	0.08

Continued

Family name	N_1	N_2	Scientific name	TG	River habitats		Woodlot habitats		Agricultural habitats	
					Observation	% of all detection	Observation	% of all detection	Observation	% of all detection
Sylviidae	8	11	*Phylloscopus affinis*	I	0	0.00	1	0.01	0	0.00
			Phylloscopus inornatus	I	0	0.00	1	0.01	0	0.00
			Phylloscopus proregulus	I	0	0.00	4	0.05	0	0.00
			Cettia fortipes	I	1	0.01	1	0.01	0	0.00
			Phylloscopus reguloides	I	0	0.00	6	0.08	0	0.00
			Phylloscopus fuscatus	I	2	0.03	6	0.08	0	0.00
			Seicercus burkii	I	0	0.00	1	0.01	0	0.00
			Abroscopus albogularis	I	0	0.00	11	0.14	0	0.00
Paridae	1	3	*Parus major*	I	0	0.00	115	1.51	22	0.29
Acanthizidae	1	1	*Aegithalos concinnus*	I	13	0.17	333	4.37	42	0.55
Sittidae	1	2	*Sitta europaea*	I	0	0.00	1	0.01	2	0.03
Certhiidae	0	1	—	—	—	—	—	—	—	—
Remizidae	0	1	—	—	—	—	—	—	—	—
Nectariniidae	0	2	—	—	—	—	—	—	—	—
Zosteropidae	1	1	*Zosterops japonicus*	I	0	0.00	12	0.16	0	0.00
Estrildidae	1	1	*Lonchura striata*	G	2	0.03	29	0.38	3	0.04
Emberizidae	3	6	*Emberiza pusilla*	G	21	0.28	37	0.49	53	0.69
			Emberiza spodocephala	O	0	0.00	5	0.07	0	0.00
			Emberiza cioides	O	0	0.00	0	0.00	1	0.01
Fringillidae	4	5	*Carduelis sinica*	O	4	0.05	178	2.33	65	0.85
			Eophona migratoria	GF	53	0.69	105	1.38	73	0.96
			Carduelis spinus	GF	0	0.00	36	0.47	0	0.00
			Eophona personata	GF	0	0.00	0	0.00	0	0.00
Passeridae	1	2	*Passer montanus*	O	102	1.34	6	0.08	82	1.07
Total	123	205			3001	39.3	2417	31.7	2210	29.0

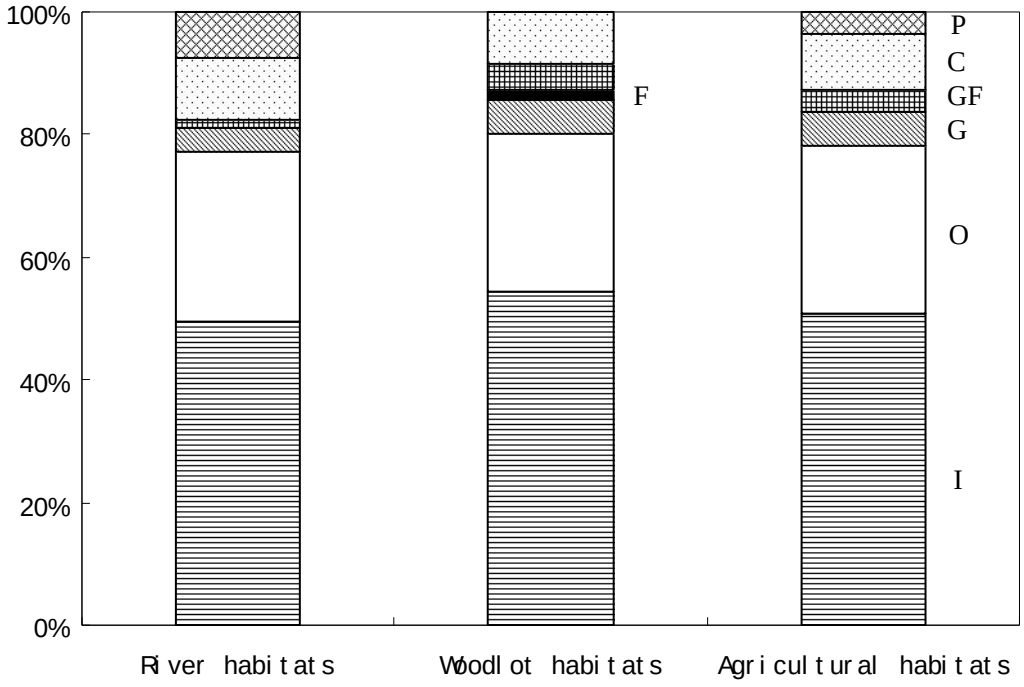

Fig. 2. Mosaic plot of bird feeding guilds by habitat. The height of each section reflects the proportion of individuals in each habitat that belong to a particular guild. The main guilds shown here are: C: carnivore; F: frugivore; G: granivore; GF: granivore/Frugivore; I: insectivore; O: omnivore; P: piscivore

Zoothera dauma, and *Emberiza cioides*, were the least common in this habitat, each recorded only once (0.01%) (Table I).

The distribution of foraging guilds did not differ significantly across habitats (SS Likelihood Ratio Chi-square = 11.87, $P = 0.46$; Fig. 2). In general, insectivorous and omnivorous bird species constituted the predominant trophic guilds in all three habitats. Moreover, the number of guilds was same in the three habitats (six guilds each).

Bird species richness and diversity

Species richness differed significantly among the three habitats (one-way ANOVA: $F_{2, 101} = 15.78$, $P < 0.001$). The River habitat exhibited significantly higher species richness (12.58 ± 0.94) than either of the other two habitats (Post Hoc test, all $P < 0.05$). Similarly, the River habitat contained 25 (31.6%) exclusive species, a significantly higher percentage than either of the other two habitats (Chi-square test: $\chi^2 = 11.00$, df = 2, $P = 0.004$). Woodlot habitat contained 18 (25.7%) exclusive species, which fed on mainly forest diets. Agricultural (6.93 ± 0.92) and Woodlot habitats (8.17 ± 0.73) showed similar species richnesses ($P = 0.19$). However, Agricultural habitat contained only 2 (3.6%) exclusive species.

Species diversity differed significantly among the three habitats ($F_{2, 101} = 5.53$, $P = 0.005$). Species diversity was significantly greater (all $P < 0.05$) in the River habitat ($H' = 1.84 \pm 0.09$) than in the other two habitats. However, species diversity in Agricultural habitats ($H' = 1.44 \pm 0.09$) did not significantly differ ($P = 0.58$) from that in Woodlot habitats ($H' = 1.51 \pm 0.07$).

Effects of urbanization on bird species richness

Deng *et al.* (1980) carried out bird surveys from 1957 to 1978 at this study site, and documented birds belonging to 205 species in 52 families except in low-altitude and intermediate-altitude hill habitats. Although the number of families did not differ between the present study and the Deng *et al.* (1980) investigation ($P = 0.36$), the present study documented significantly fewer species ($\chi^2 = 20.50$, $P < 0.001$). For example, significantly fewer species were documented in the

present study in Falconiformes (Accipitridae and Falconidae; $\chi^2 = 4.57$, $P = 0.033$) and Passeriformes (*e.g.*, Corvidae, Turdidae, Timaliidae, Muscicapidae, Sylviidae, Paridae, Nectariniidae, and Emberizidae; $\chi^2 = 6.22$, $P = 0.013$). In addition, we found significantly fewer bird species in the present study than in Deng *et al*. (1980) ($\chi^2 = 5.36$, $P = 0.007$) when we pooled the data for all water bird species.

DISCUSSION

Twenty-two bird species were found in all three of the habitat types studied here (these constituted 27.8% of the species observed in River habitats, 40.0% of those observed in Agricultural habitats, and 31.4% of those found in Woodlot habitats). The bird community was dominated by a few species; most other species occurred at low frequencies, probably due to the small population size. Thus, the bird community also comprised many wide-ranging and non-native species. These patterns could result from urban expansion and the concomitant loss of wildlife habitats (Hostetler and Knowles-Yanez, 2003) as reflected in a decrease in vegetation and a proportional loss of biodiversity (Savard *et al*., 2000).

Although urban development reduced bird species richness and several endangered species (*e.g.*, *Ciconia nigra*, *Platalea minor* and *Grus grus*) vanished in River habitats, species richness and diversity were higher in the River habitat than in the other habitats. Similarly, the proportion of exclusive species in the River habitat could be considered high, which may be accounted for by the number of species dependent on flooded environments. Conditions in the river zone (*e.g.*, moisture regimes, nutrient availability) often contrast strongly with those predominating in the surrounding non-river matrix (Gregory *et al.*, 1991; Malanson, 1993). This leads to distinct patterning of vegetation associations in the landscape (Austin *et al.*, 1996) and birds respond positively to such diversity of habitats (Cody, 1993; Borchert, 2003).

Food availability is a well known limiting factor in avian survival and reproductive success (Martin, 1987; Rodenhouse and Holmes, 1992; Newton, 1998; Nagy and Holmes, 2005), and forests provide key sources of food and cover that may not be sufficiently provided by conifers alone (Morrison and Meslow, 1983; Hammond and Miller, 1998; Hagar, 2004). Reif *et al*. (2008) found that species more closely associated with lowland broad-leaved forest had on average more positive population trends, whereas species more closely associated with coniferous forest had on average more negative population trends. Coniferous forest is dominant in our study area, because humans have cut down the natural forests since the 1950s. We found that Woodlot habitat did not sustain diversity larger than that of the other habitats, presumably because the available forest patches were smaller than the threshold size required by birds (Beissinger and Osborne, 1982).

Interestingly, we found some previously vanished resident birds that were recovering gradually in town and agricultural habitats. For example, *Passer montanus* had almost vanished since the 1970s (Guo and Zheng, 2001). Also, our results showed that species richness and diversity were lower in Agricultural habitats than in the other habitat types. One obvious reason is that habitat homogeneity reduced the range of bird species, especially for the forest-dependent species. Additionally, it was possible that pesticides were used in the summer in Agricultural areas, and this can negatively affect habitat for birds (Guo and Zheng, 2001). However, in the winter, Agricultural habitat provided a good supply of vegetables as food for both residents and vagrants, which would have a positive effect on species richness and diversity.

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Table I.- **Relative abundances of bird species recorded in three habitats in Nanchong, Southwestern China (N_1: number of bird species in this study; N_2: number of bird species in Deng *et al.* (1980); TG, Trophic guild; C, carnivore; F, frugivore; G, granivore; GF, granivore/Frugivore; I, insectivore; O, omnivore; P, piscivore).**

Family name	N_1	N_2	Scientific name	TG	River habitats		Woodlot habitats		Agricultural habitats	
					Observation	% of all detection	Observation	% of all detection	Observation	% of all detection
Podicipedidae	1	3	*Tachybaptus ruficollis*	P	19	0.25	0	0.00	1	0.01
Phalacrocoracidae	1	1	*Phalacrocorax carbo*	P	26	0.34	0	0.00	0	0.00
Ardeidae	7	9	*Egretta garzetta*	C	223	2.92	203	2.66	30	0.39
			Egretta eulophotes	C	29	0.38	0	0.00	0	0.00
			Ardea cinerea	C	111	1.46	0	0.00	1	0.01
			Bubulcus coromandus	I	5	0.07	0	0.00	0	0.00
			Nycticorax nycticorax	C	0	0.00	50	0.66	0	0.00
			Ardeola bacchus	C	1	0.01	28	0.37	0	0.00
			Ixobrychus cinnamomeus	C	2	0.03	0	0.00	1	0.01
Ciconiidae	0	1	—	—	—	—	—	—	—	—
Threskiorothidae	0	1	—	—	—	—	—	—	—	—
Anatidae	10	15	*Aythya nyroca*	O	8	0.10	0	0.00	0	0.00
			Aythya ferina	O	3	0.04	0	0.00	0	0.00
			Anas zonorhyncha	O	435	5.70	0	0.00	6	0.08
			Tadorna ferruginea	O	119	1.56	0	0.00	0	0.00
			Anas crecca	O	227	2.98	0	0.00	0	0.00
			Anas platyrhynchos	O	232	3.04	0	0.00	0	0.00
			Anas falcata	O	10	0.13	0	0.00	0	0.00
			Anas clypeata	O	49	0.64	0	0.00	0	0.00
			Mergus merganser	P	4	0.05	0	0.00	0	0.00
			Tadorna tadorna	O	13	0.17	0	0.00	0	0.00
Accipitridae	2	8	*Buteo hemilasius*	C	1	0.01	1	0.01	0	0.00
			Buteo buteo	C	4	0.05	1	0.01	1	0.01
Falconidae	1	3	*Falco amurensis*	I	0	0.00	2	0.03	0	0.00
Phasianidae	1	4	*Phasianus colchicus*	O	14	0.18	11	0.14	4	0.05
	0	1	—	—	—	—	—	—	—	—
Rallidae	3	4	*Gallicrex cinerea*	O	2	0.03	0	0.00	0	0.00
			Amaurornis phoenicurus	O	2	0.03	0	0.00	6	0.08
			Fulica atra	O	1	0.01	0	0.00	0	0.00
Otididae	0	2	—	—	—	—	—	—	—	—
Rostratulidae	1	1	*Mycteria leucocephala*	I	0	0.00	0	0.00	4	0.05
Charadriidae	5	9	*Charadrius dubius*	I	16	0.21	0	0.00	0	0.00
			Charadrius hiaticula	I	48	0.63	0	0.00	0	0.00

Continued

Family name	N_1	N_2	Scientific name	TG	River habitats		Woodlot habitats		Agricultural habitats	
					Observation	% of all detection	Observation	% of all detection	Observation	% of all detection
			Charadrius alexandrinus	I	14	0.18	0	0.00	0	0.00
			Vanellus vanellus	I	20	0.26	0	0.00	6	0.08
			Charadrius leschenaultii	I	10	0.13	0	0.00	4	0.05
Scolopacidae	7	11	*Himantopus himantopus*	I	7	0.09	0	0.00	0	0.00
			Tringa ochropus	I	4	0.05	0	0.00	5	0.07
			Actitis hypoleucos	I	3	0.04	0	0.00	0	0.00
			Tringa glareola	I	24	0.31	0	0.00	0	0.00
			Tringa nebularia	I	1	0.01	0	0.00	0	0.00
			Calidris temminckii	I	2	0.03	0	0.00	1	0.01
			Gallinago gallinago	I	9	0.12	0	0.00	0	0.00
Laridae	1	5	*Chroicocephalus ridibundus*	P	82	1.07	0	0.00	0	0.00
Columbidae	3	4	*Streptopelia tranquebarica*	GF	0	0.00	2	0.03	3	0.04
			Streptopelia orientalis	G	0	0.00	4	0.05	0	0.00
			Spilopelia chinensis	G	56	0.73	15	0.20	86	1.13
Cuculidae	4	5	*Eudynamys scolopaceus*	I	0	0.00	2	0.03	0	0.00
			Hierococcyx sparverioides	I	2	0.03	3	0.04	0	0.00
			Cuculus canorus	I	0	0.00	9	0.12	6	0.08
			Cuculus micropterus	I	0	0.00	4	0.05	4	0.05
Strigidae	1	5	*Asio flammeus*	C	0	0.00	0	0.00	0	0.00
Caprimulgidae	0	1	—	—	—	—	—	—	—	—
Alcedinidae	2	3	*Megaceryle lugubris*	P	1	0.01	0	0.00	0	0.00
			Alcedo atthis	P	6	0.08	0	0.00	4	0.05
Upupidae	1	1	*Upupa epops*	I	1	0.01	0	0.00	7	0.09
Picidae	1	4	*Picus canus*	I	0	0.00	2	0.03	0	0.00
Alaudidae	1	2	*Alauda gulgula*	O	34	0.45	0	0.00	6	0.08
Hirundinidae	3	3	*Hirundo rustica*	I	5	0.07	0	0.00	21	0.28
			Cecropis daurica	I	6	0.08	6	0.08	0	0.00
			Riparia riparia	I	325	4.26	0	0.00	210	2.75
Motacillidae	9	9	*Motacilla alba*	I	160	2.10	35	0.46	103	1.35
			Motacilla tschutschensis	I	5	0.07	0	0.00	0	0.00
			Motacilla citreola	I	9	0.12	0	0.00	0	0.00
			Dendronanthus indicus	I	0	0.00	2	0.03	0	0.00
			Motacilla cinerea	I	1	0.01	0	0.00	0	0.00
			Anthus hodgsoni	I	29	0.38	31	0.41	59	0.77
			Anthus spinoletta	I	27	0.35	2	0.03	49	0.64
			Anthus rufulus	I	16	0.21	0	0.00	8	0.10
			Anthus roseatus	I	6	0.08	0	0.00	0	0.00

Continued

Family name	N_1	N_2	Scientific name	TG	River habitats		Woodlot habitats		Agricultural habitats	
					Observation	% of all detection	Observation	% of all detection	Observation	% of all detection
Campephagidae	2	2	*Coracina melaschistos*	O	0	0.00	2	0.03	3	0.04
			Pericrocotus cantonensis	I	0	0.00	4	0.05	0	0.00
Pycnonotidae	3	3	*Pycnonotus xanthorrhous*	O	0	0.00	3	0.04	0	0.00
			Pycnonotus sinensis	O	43	0.56	386	5.06	88	1.15
			Spizixos semitorques	F	0	0.00	11	0.14	0	0.00
Laniidae	3	3	*Lanius cristatus*	I	1	0.01	2	0.03	3	0.04
			Lanius tigrinus	I	0	0.00	14	0.18	0	0.00
			Lanius schach	C	25	0.33	35	0.46	45	0.59
Oriolidea	1	1	*Oriolus chinensis*	I	1	0.01	4	0.05	7	0.09
Dicruridea	2	3	*Dicrurus macrocercus*	I	4	0.05	4	0.05	10	0.13
			Dicrurus leucophaeus	I	0	0.00	0	0.00	1	0.01
Sturnidae	3	3	*Spodiopsar cineraceus*	O	148	1.94	262	3.43	644	8.44
			Spodiopsar sericeus	O	0	0.00	14	0.18	40	0.52
			Acridotheres cristatellus	O	12	0.16	1	0.01	149	1.95
Corvidae	1	5	*Garrulus glandarius*	O	0	0.00	5	0.07	0	0.00
Troglodytidea	0	1	—	—	—	—	—	—	—	—
Turdidae	12	16	*Tarsiger cyanurus*	I	0	0.00	4	0.05	0	0.00
			Rhyacornis fuliginosa	I	5	0.07	0	0.00	0	0.00
			Zoothera dauma	I	0	0.00	0	0.00	1	0.01
			Copsychus saularis	I	1	0.01	16	0.21	8	0.10
			Phoenicurus auroreus	I	6	0.08	11	0.14	10	0.13
			Turdus eunomus	I	0	0.00	2	0.03	2	0.03
			Chaimarrornis leucocephalus	I	1	0.01	0	0.00	0	0.00
			Phoenicurus frontalis	I	0	0.00	2	0.03	3	0.04
			Turdus merula	O	32	0.42	100	1.31	148	1.94
			Myophonus caeruleus	I	0	0.00	1	0.01	0	0.00
			Enicurus leschenaulti	I	2	0.03	0	0.00	0	0.00
			Saxicola ferreus	O	0	0.00	1	0.01	0	0.00
Timaliidae	4	7	*Pterorhinus sannio*	O	3	0.04	42	0.55	51	0.67
			Leucodioptron canorum	O	0	0.00	1	0.01	0	0.00
			Ianthocincla cineracea	O	0	0.00	5	0.07	0	0.00
			Yuhina diademata	O	0	0.00	7	0.09	0	0.00
Paradoxornithidae	1	1	*Sinosuthora webbiana*	O	15	0.20	170	2.23	9	0.12
Muscicapidae	2	5	*Ficedula albicilla*	I	0	0.00	1	0.01	0	0.00
			Niltava davidi	I	0	0.00	2	0.03	0	0.00
Monarchidae	1	1	*Terpsiphone paradisi*	I	0	0.00	0	0.00	0	0.00
Cisticolidae	2	3	*Cisticola juncidis*	I	3	0.04	1	0.01	3	0.04
			Prinia polychroa	I	32	0.42	3	0.04	6	0.08

Continued

Family name	N_1	N_2	Scientific name	TG	River habitats		Woodlot habitats		Agricultural habitats	
					Observation	% of all detection	Observation	% of all detection	Observation	% of all detection
Sylviidae	8	11	*Phylloscopus affinis*	I	0	0.00	1	0.01	0	0.00
			Phylloscopus inornatus	I	0	0.00	1	0.01	0	0.00
			Phylloscopus proregulus	I	0	0.00	4	0.05	0	0.00
			Cettia fortipes	I	1	0.01	1	0.01	0	0.00
			Phylloscopus reguloides	I	0	0.00	6	0.08	0	0.00
			Phylloscopus fuscatus	I	2	0.03	6	0.08	0	0.00
			Seicercus burkii	I	0	0.00	1	0.01	0	0.00
			Abroscopus albogularis	I	0	0.00	11	0.14	0	0.00
Paridae	1	3	*Parus major*	I	0	0.00	115	1.51	22	0.29
Acanthizidae	1	1	*Aegithalos concinnus*	I	13	0.17	333	4.37	42	0.55
Sittidae	1	2	*Sitta europaea*	I	0	0.00	1	0.01	2	0.03
Certhiidae	0	1	—	—	—	—	—	—	—	—
Remizidae	0	1	—	—	—	—	—	—	—	—
Nectariniidae	0	2	—	—	—	—	—	—	—	—
Zosteropidae	1	1	*Zosterops japonicus*	I	0	0.00	12	0.16	0	0.00
Estrildidae	1	1	*Lonchura striata*	G	2	0.03	29	0.38	3	0.04
Emberizidae	3	6	*Emberiza pusilla*	G	21	0.28	37	0.49	53	0.69
			Emberiza spodocephala	O	0	0.00	5	0.07	0	0.00
			Emberiza cioides	O	0	0.00	0	0.00	1	0.01
Fringillidae	4	5	*Carduelis sinica*	O	4	0.05	178	2.33	65	0.85
			Eophona migratoria	GF	53	0.69	105	1.38	73	0.96
			Carduelis spinus	GF	0	0.00	36	0.47	0	0.00
			Eophona personata	GF	0	0.00	0	0.00	0	0.00
Passeridae	1	2	*Passer montanus*	O	102	1.34	6	0.08	82	1.07
Total	123	205			3001	39.3	2417	31.7	2210	29.0