Helminths of introduced house sparrows (*Passer domesticus*) in Brazil: does population age affect parasite richness?

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ABSTRACT. Species introductions have altered host and parasite diversity throughout the world. In the case of introduced hosts, population age appears to be a good predictor of parasite richness. Habitat alteration is another variable that may impact host-parasite interactions by affecting the availability of intermediate hosts. The house sparrow (*Passer domesticus* (Linnaeus, 1758)) is a good model to test these predictions. It was introduced in several parts of the world and can be found across rural-urban gradients. A total of 160 house sparrows from Porto Alegre, state of Rio Grande do Sul, Brazil, were necropsied. Thirty house sparrows (19 %) were parasitized with at least one out of five helminth species (Digenea: *Tamerlania inopina* Freitas, 1951 and *Eumegacetes* sp.; Eucestoda: *Choanotaenia passerina* (Fuhrmann, 1907) Fuhrmann, 1932; Nematoda: *Dispharynx nasuta* (Rudolphi, 1819) Stiles & Hassall, 1920 and *Cardiofilaria pavlovskyi* Strom, 1937). Overall, there was no difference in prevalence and intensity of infection of any parasite species, parasite richness and community diversity between adult males and females and adults and juveniles. The number of infected sparrows among seasons, the richness of helminths and the abundance of species were also similar between rural and urban landscapes. Only the prevalence of *C. passerina* varied seasonally (p=0.0007). A decrease in the number of parasite species from the original range of *P. domesticus* (13) to its port of entrance in Brazil, the city of Rio de Janeiro (nine), to Porto Alegre (five) is compatible with the hypothesis that host population age is a good predictor of parasite richness.

KEYWORDS. Aves, Passeridae, urbanization, host sex, host age.

RESUMO. Helmintos de pardais (*Passer domesticus*) introduzidos no Brasil: a idade da população afeta a riqueza de parasitos? A introdução de espécies tem alterado a diversidade dos parasitos e seus hospedeiros em todo o mundo. No caso dos hospedeiros introduzidos, a idade da população parece ser um bom preditor da riqueza parasitária. A alteração do habitat é outra variável que pode ter impacto sobre as interações parasito-hospedeiro, pois afeta a disponibilidade de hospedeiros intermediários. O pardal (*Passer domesticus* (Linnaeus, 1758)) é um bom modelo para testar essas predições. Ele foi introduzido em várias partes do mundo e pode ser encontrado ao longo do gradiente urbano-rural. Um total de 160 pardais, provenientes de Porto Alegre, Rio Grande do Sul, Brasil, foram necropsiados, dos quais 19 % (30) estavam parasitados com pelo menos uma das cinco espécies de helmintos encontradas (Digenea: *Tamerlania inopina* Freitas, 1951 and *Eumegacetes* sp.; Eucestoda: *Choanotaenia passerina* (Fuhrmann, 1907) Fuhrmann, 1932; Nematoda: *Dispharynx nasuta* (Rudolphi, 1819) Stiles & Hassall, 1920 and *Cardiofilaria pavlovskyi* Strom, 1937). Não houve diferença entre machos adultos e fêmeas adultas e entre adultos e juvenis na prevalência e intensidade de infecção das espécies, na riqueza de parasitos e na diversidade das comunidades de helmintos. Também não houve diferença significativa no número de pardais infectados em cada estação e na riqueza de helmintos e abundância das espécies entre as paisagens rural e urbana. Somente a prevalência de *C. passerina* variou sazonalmente (p=0,0007). Uma redução no número de espécies de parasitos de *P. domesticus* desde a sua distribuição original (13) ao seu ponto de entrada no Brasil, a cidade do Rio de Janeiro (nove), até Porto Alegre (cinco), é compatível com a hipótese de que a idade da população hospedeira é um bom preditor da riqueza de parasitos.

PALAVRAS-CHAVE. Aves, Passeridae, urbanização, sexo do hospedeiro, idade do hospedeiro.

A large number of species has been displaced from their original ranges as a consequence of striking man-made environmental changes, especially during the last two centuries. The intentional and accidental introduction and the expansion of the distribution of species after the break-down of biogeographic barriers by humans have altered host and parasite diversity throughout the world (Poulin & Morand, 2004; Taraschewski, 2006). Although introduced host species may acquire new parasites in their new ranges, their parasitic fauna is often reduced, and may contain only about half the richness found in native species (Hair & Forrester, 1970; Torchin *et al.*, 2003; Poulin & Morand, 2004). This reduction may favour the population growth of invasive species (Torchin *et al.*, 2003) and give them a competitive advantage against native species (Prenter *et al.*, 2004). The time since the introduction also plays an important role in the composition of parasite communities. Ebert *et al.* (2001), for example, observed that the age of *Daphnia magna* Straus, 1820 populations is the best predictor of their parasite richness.

The qualitative reduction of parasites seen in introduced hosts takes place because several parasite species are lost when (a) individuals in the founding population, a sample of the original population, are not infected (this is particularly relevant for less prevalent species), (b) some parasites do not find their intermediate hosts or the interaction between intermediate and definitive hosts is compromised or missing in the new area, (c) native parasite species are unable to adapt to exotic hosts due to their high host specificity and (d) the environmental conditions required for completing their cycles are lacking (Hair & Forrester, 1970; Torchin *et al.*, 2003).

Habitat alteration is particularly strong in urban landscapes, where vegetation structure and the diversity and abundance of animals are changed radically compared to natural landscapes (MARZLUFF, 2001; MCKINNEY, 2002; MILLER & HOBBS, 2002). The high level of pollution of some urban environments may also promote changes in parasite communities by decreasing the efficiency of the immune system of hosts (COMBES, 2001). Albeit several native host or parasite species cope well with urban landscapes, most of them do not adapt to the new environmental conditions and go locally extinct (MCKINNEY, 2002). Therefore, despite the high resource availability capable of sustaining high animal densities in towns, local diversity tends to decrease with increasing urbanization (MCDONNELL & PICKETT, 1990).

The house sparrow *Passer domesticus* (Linnaeus, 1758) is a good model for testing the influence of introduction latency and urbanization on a species parasite richness. It is native to Eurasia and northern Africa, but currently is found well established in the Americas (LEVER, 1987). It is also highly adaptable to urban landscapes. Whereas SICK (1997) states house sparrows arrived in Brazil in 1906 through the city of Rio de Janeiro, EFE *et al*. (2001) believe the species was already introduced in the country in the 18th century. Irrespective of the actual date of introduction of house sparrows in Brazil, their high degree of adaptation to urban environments allowed them to spread throughout the Brazilian territory during the last century (EFE *et al*., 2001). *Passer domesticus* is host to 13 helminth species (eight cestodes, four digeneans and one nematode) in its original range (MEGGITT, 1916; JOSZT, 1962; BAUGH & SAXENA, 1975, 1976; MARTINEZ *et al*., 1977; ILLESCAS-GOMEZ & LOPEZ-ROMAN, 1980). In Brazil, nine helminth species (five digeneans, two nematodes, one cestode and one acanthocephalan) have been identified at the species port of entrance, the city of Rio de Janeiro (AMATO & BRASIL, 1990; BRASIL & AMATO, 1992).

In this paper we describe the helminth fauna of *P. domesticus* in the metropolitan region of Porto Alegre, southern Brazil, where it was first recorded around 1920 (FONTANA, 2005), and test the prediction that the richness of its helminth community is lower than that observed in populations living in its original distribution and in the city of Rio de Janeiro. In addition, we estimate the structure of its helminth community and test whether host sex and age, season and landscape (rural *vs*. urban) affect helminth richness and composition.

MATERIAL AND METHODS

A total of 160 house sparrows were collected using mist nets in 10 sites in the metropolitan region of Porto Alegre, state of Rio Grande do Sul, Brazil, between March 2003 and March 2006. The technique for euthanasia involved an overdose with gaseous anesthetic (GAUNT & ORING, 1999). All procedures fulfilled Brazilian laws (federal and municipal licenses, respectively, Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) #051/2002/RS, 005/2004/RS and 004/2005/RS, and Secretaria Municipal do Meio Ambiente (SMAM) #176/04 and 049/05). Sparrow necropsy and helminth processing followed AMATO *et al.* (1991). Host carcasses were deposited at the Museu de Ciências e Tecnologia of the Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre.

Because habitat heterogeneity varied widely among sites, five environmental types were quantified in an area with a radius of 564 m around each trapping location (=1 km^2): buildings, wood, grassland, bare soil and water. This quantification involved orbital image processing and treatment routines using the software Idrisi Andes 15.0 for Windows. Collection sites were classified into urban and rural landscapes based on their degree of urbanization, that is, their area covered by buildings. Sites <50 % urbanized were treated as rural, whereas sites >63 % urbanized were treated as urban. About half house sparrows were collected in each landscape type.

Prevalence, mean intensity of infection, mean abundance and range of intensity of infection were calculated following BUSH *et al*. (1997). In addition, each helminth species was classified based on its importance value (I) as suggested by THUL *et al.* (1985) as dominant ($I \geq 1.0$), co-dominant ($0.01 \leq I < 1$), subordinate ($0 < I < 0.01$) and unsuccessful pioneer ($I = 0$). Helminth species richness was evaluated using a sampling sufficiency curve (SANTOS, 2003). Shannon's diversity index ($\log_e$) of the host species helminth community, as well as of adult male and female sparrows, was also calculated (BROWER & ZAR, 1984).

The qualitative similarity of the parasite communities of adult males and females was estimated based on Jaccard similarity index, whereas the quantitative similarity was evaluated by the Morisita-Horn similarity index (MAGURRAN, 1988). The prevalence of each helminth species in the parasite communities of adult and juvenile sparrows (identified based on the presence or absence of the bursa of Fabricius, respectively; PROCTOR & LYNCH, 1993), and of adult male and female individuals were compared with a *G*-test with Yates' correction, while parasite intensity of infection were compared with a Mann-Whitney test. In the absence of differences between classes, data were pooled for further analyses.

The climate of the study region is subtropical humid, CFA type in Koeppen's classification, with the four seasons well defined (LIVI, 1998). Fourty house sparrows were collected in each season, evenly distributed between urban and rural landscapes and years. The prevalence and intensity of infection for each helminth species were compared among seasons, respectively, with the *G*-test and the Kruskal-Wallis analysis of variance. The Student-Newman-Keuls *post-hoc* test was used to determine which pairs of seasons differed statistically when appropriate. Parasite richness and abundance of hosts living in urban and rural landscapes were compared with a Kruskal-Wallis analysis of variance.

Variables with sample sizes ≥20 were tested for normality with a D'Agostino Pearson test, whereas those variables whose sample sizes fell between 10 and 19 were tested with a D'Agostino test (AYRES *et al*., 2005). Variables with a normal distribution were tested with the parametric Student *t* test when variances were similar, and with a Z test when variances differed. In the absence of a normal distribution, and when data could not be normalized with transformation, non-parametric tests were used. Unless otherwise stated a significance level of 5 % was used for all tests. When multiple tests were performed on the same variable, the significance level was adjusted following Leigh & Jungers (1994). Tests were performed using BioEstat 4.0 (Ayres *et al*., 2005) and Systat 5.0 (Wilkinson, 1990).

RESULTS

Twenty nine house sparrows (18.1 %) were parasitized with a single helminth species and one (0.6 %) was parasitized with two species out of 160 necropsied birds (mean richness = 0.19 helminth species per host). A total of 143 helminth individuals belonging to five species (digeneans *Tamerlania inopina* (Freitas, 1951) and *Eumegacetes* sp.; nematodes *Dispharynx nasuta* (Rudolphi, 1819) Stiles & Hassall, 1920 and *Cardiofilaria pavlovskyi* Strom, 1937; cestode *Choanotaenia passerina* (Fuhrmann, 1907) Fuhrmann, 1932) were collected (mean intensity of infection = 0.90 helminths per host). *Choanotaenia passerina* showed the highest prevalence, range of intensity of infection and mean abundance (Tab. I). On the other hand, *Eumegacetes* sp. was found in a single juvenile individual, whereas *D. nasuta* was found in a single adult male. The sufficiency curve stabilized after the 87th necropsy when the fifth helminth species of this low diversity community (Shannon's H'=1.235) was found. Four species were classified as dominant (*C. passerina*, I=78.95; *C. pavlovskyi*, I=12.43; *T. inopina*, I=7.37; and *D. nasuta*, I=1.18) and one as co-dominant (*Eumegacetes* sp., I=0.07).

Parasite richness of adult males (mean ± sd=0.2 ± 0.4, n=73) and adult females (mean ± sd=0.2 ± 0.4, n=77) were similar (Student's *t*=-0.2778, df=144, p=0.7817), as were the diversities of their helminth communities (Shannon's $H'_{\text{adult males}}=1.113$; $H'_{\text{adult females}}=0.995$). In addition, their helminth faunas were both qualitatively (Jaccard similarity index=75.0 %) and quantitatively (Morisita-Horn similarity index=93.2 %) very similar, and no difference was found in the prevalence of species (*T. inopina*, G=0.2076, df=1, p=0.6486; *C. passerina*, G=0.0230, df=1, p=0.8794; *D. nasuta*, G=0.0007, df=1, p=0.9787; *C. pavlovskyi*, G=0.0052, df=1, p=0.9424) and their intensity of infection (*C. passerina*, U=28.0, p=0.674; *C. pavlovskyi*, U=4.0, p=0.479; *T. inopina*, sample size too small to run the test).

Helminth richness of immature females ranged from 0 to 1 species (mean ± sd=0.3 ± 0.5, n=9), while the only juvenile male trapped was negative for helminths. There was no difference in helminth richness between adults and juveniles (*t*=-0.8414, df=158, p=0.4017). Although only *C. pavlovskyi* was found in both adult and juvenile house sparrows, prevalence of parasite species did not differ between adults and juveniles (*T. inopina*, G=0.2171, df=1, p=0.6413; *Eumegacetes* sp., G=1.4717, df=1, p=0.2251; *C. passerina*, G=0.3525, df=1, p=0.5527; *D. nasuta*, G=1.4717, df=1, p=0.2251; *C. pavlovskyi*, G=1.2783, df=1, p=0.2582).

The number of infected sparrows did not differ among seasons and only the prevalence of *C. passerina* varied seasonally (Tab. II). This cestode was more prevalent in the spring (25 %) than in the other seasons, but its intensity of infection in the spring (6.50 ± 11.37, n=10) did not differ from that observed in the winter (1.75 ± 0.96, n=4; H=0.7726, df=1, p=0.3794). The landscape did not influence helminth richness (rural sparrows: mean ± sd=0.21 ± 0.41, median=0, n=82; urban sparrows: mean ± sd=0.18 ± 0.42, median=0, n=78; H=0.1731, df=1, p=0.6774) and species abundances.

Table I. Helminth prevalence, range of intensity, mean intensity of infection and mean abundance in house sparrows *Passer domesticus* (Linnaeus, 1758) introduced in the metropolitan region of Porto Alegre, Rio Grande do Sul, Brazil (n=160 necropsied birds).

Helminth taxa	Prevalence (%)	Intensity		Mean abundance (X ± sd)
		Range	Mean (X ± sd)	
Digenea				
Tamerlania inopina	2.50	1–17	7.00 ± 7.35	0.18 ± 1.49
Eumegacetes sp.	0.63	1	1.00	0.01 ± 0.08
Eucestoda				
Choanotaenia passerina	10.00	1–38	4.69 ± 9.14	0.47 ± 3.14
Nematoda				
Dispharynx nasuta	0.63	18	18.00	0.11 ± 1.42
Cardiofilaria pavlovskyi	5.63	1–8	2.33 ± 2.24	0.13 ± 0.74

Table II. House sparrows' (*Passer domesticus* (Linnaeus, 1758)) helminth prevalence per season (n=40 each). The *G* test (G; df=3) result of a seasonal comparison and its associated significance level (p) are also shown (significant seasonal differences in bold).

Helminth taxa	Prevalence (%)				*G* test
	Fall	Winter	Spring	Summer	
Tamerlania inopina	5.0	2.5	2.5	0	G=2.823, p=0.4196
Eumegacetes sp.	0	0	2.5	0	G=2.791, p=0.4249
Choanotaenia passerina	0	10.0	25.0	5.0	G=17.151, p=0.0007
Dispharynx nasuta	2.5	0	0	0	G=2.791, p=0.4249
Cardiofilaria pavlovskyi	7.5	7.5	2.5	5.0	G=1.431, p=0.6981
Total	15.0	20.0	32.5	10.0	G=5.700, p=0.1271

Table III. List of parasite helminth species of *Passer domesticus* (Linnaeus, 1758) found in its original range, in the city of Rio de Janeiro, state of Rio de Janeiro, and in the metropolitan region of Porto Alegre, state of Rio Grande do Sul, Brazil.

Helminth taxa	Original range	Rio de Janeiro	Porto Alegre
TREMATODA			
Athesmia rudecta (Braun, 1901) Travassos, 1941		X	
Echinostoma revolutum (Froelich, 1802) Looss, 1899		X	
Eumegacetes medioximus Braun, 1901		X	
Eumegacetes sp.			X
Leucochloridium macrostomum Rudolphi, 1803	X		
Leucochloridium parcum Travassos, 1922		X	
Plagiorchis elegans Rudolphi, 1802	X		
P. maculosus (Rudolphi, 1802)	X		
Prosthogonimus ovatus (Rudolphi, 1803) Lühe, 1899	X		
Tamerlania inopina (Freitas, 1951)		X	X
EUCESTODA			
Anonchotaenia globata (Linstow, 1879)	X		
Anonchotaenia sp.	X		
Choanotaenia musculosa (Fuhrmann, 1896)	X		
C. passerina (Fuhrmann, 1907) Fuhrmann, 1932	X	X	X
Hymenolepis interruptus Clerc, 1906	X		
Proparuterina lali Baugh & Saxena, 1976	X		
Raillietina galeritae (Skrjabin 1915)	X		
R. sartica (Skrjabin, 1914) Fuhrmann, 1932	X		
ACANTHOCEPHALA			
Mediorhynchus papillosus van Cleave, 1916		X	
NEMATODA			
Acuaria subula (Dujardin, 1845)	X		
Cardiofilaria pavlovskyi Strom, 1937			X
Dispharynx nasuta (Rudolphi, 1819) Stiles & Hassall, 1920		X	X
Tetrameres minima (Travassos, 1914) Travassos, 1915		X	

DISCUSSION

The helminth parasite fauna of *P. domesticus* living in the metropolitan region of Porto Alegre reached sampling sufficiency when the fifth species was found after about half the necropsies had been completed. Although rarer species would likely be found with increasing sample size, this richness represents a reliable estimate of the local helminth fauna of *P. domesticus*. Therefore, there is a parasite species richness reduction from its original distribution (13 species; MEGGITT, 1916; JOSZT, 1962; BAUGH & SAXENA, 1975, 1976; MARTINEZ *et al.*, 1977; ILLESCAS-GOMEZ & LOPEZ-ROMAN, 1980) to Rio de Janeiro (9 species; AMATO & BRASIL, 1990; BRASIL & AMATO, 1992) to Porto Alegre (5 species; this study) that is compatible with the hypothesis that host population age is a good predictor of parasite richness (EBERT *et al.*, 2001). The percentage of infected house sparrows showed the same pattern: 47 % in the original range (JOSZT, 1962), 34 % in Rio de Janeiro (AMATO & BRASIL, 1990; BRASIL & AMATO, 1992), and 19 % in Porto Alegre (this study). Three helminth species found in the Porto Alegre population were present in Rio de Janeiro (*T. inopina*, *C. passerina*, and *D. nasuta*), but only *C. passerina* was also found in the original distribution of house sparrows (Tab. III).

Most parasites of *P. domesticus* present a heteroxen cycle. Therefore, house sparrows get infected by eating invertebrate intermediate hosts such as snails, isopodes and flies. Consequently, at least three hypotheses may help explain the overall low prevalence observed in this study: intermediate hosts present a naturally low infection rate with these parasites, there is a low availability of intermediate hosts, and the consumption of intermediate prey hosts by house sparrows is low. The available data do not allow to test these non-mutually exclusive hypotheses. On the other hand, the filariid nematode *C. pavlovskyi* shows a different cycle, does not present a high host specificity, and is transmitted by vectors directly to several bird species (ANDERSON, 1992).

The relationship between the diet of a species and its parasite fauna is well exemplified by house sparrows infection with *C. passerina*, the most characteristic species of *P. domesticus* helminth community both in Rio de Janeiro (BRASIL & AMATO, 1992) and Porto Alegre (this study). House sparrows use of domestic garbage as a food source is likely to be directly linked to their infection with this cestode species, whose intermediate hosts are domestic flies (*Musca domestica* Linnaeus, 1758) that feed on the decomposing organic matter found in human waste (YAMAGUTI, 1958). Therefore, the high association of both house sparrows and domestic flies with humans helps explain why *C. passerina* is the only species found in all regions where the parasite fauna of *P. domesticus* has been studied. Because *C. passerina* presents a high especificity to *P. domesticus* as definitive host, its geographic distribution probably matches the range of house sparrows from Europe, northern Africa and part of Asia to North America, South America, and Australia (BRASIL & AMATO, 1992).

The highest prevalence of *C. passerina* in the spring may be related to seasonal differences in the availability of domestic flies, their degree of infection or their importance in the diet of house sparrows. Considering the cysticercoid of *C. passerina* takes about seven weeks to develop into an adult helminth, as observed in *Choanotaenia infundibulum* Linnaeus, 1758 (Reid & Ackert, 1937), it is possible to estimate the infection of house sparrows is higher at the end of the winter and the beginning of the spring. Although domestic flies mature throughout the year in Porto Alegre, there are seasonal differences in their ontogenetic development, such as an increase in the duration of prepupa and pupa stages during the coldest months (Torres *et al.*, 2002), which are likely to result in a lower availability of domestic flies at the time of higher *C. passerina* prevalence. Therefore, differences in domestic fly availability are unlikely to explain seasonal differences in the prevalence of *C. passerina*. It is possible, then, that domestic flies are a more important food item for house sparrows at coldest times of the year when the availability of other prey is lower, or that they are more easily captured under lower ambient temperatures.

The overall low helminth prevalence in house sparrows is compatible with their highly granivorous diet complemented with human food remains and prey (Sick, 1997). The likely lower importance of prey in the host habitual diet helps explain, for example, the low prevalence of *D. nasuta* in the Brazilian populations. Whereas Brasil & Amato (1992) observed only six out of 142 house sparrows from Rio de Janeiro infected with this acuariid nematode, only one individual was infected in the Porto Alegre population. Isopodes, orthopterans, coleopterans, and diplopods serve as intermediate hosts to *D. nasuta*, a parasite found in both aquatic and terrestrial birds (Anderson, 1992).

An understanding of the intermediate hosts involved in the life cycle of a parasite also sheds light into the niche overlap and partitioning between- and within-species. In this sense, the high similarity of the helminth communities of adult male and female house sparrows supports the contention that there is no difference in the animal portion of their diets.

Knowledge on the behaviour, ecology, and environmental requirements of hosts and parasites are also important for evaluating the role that the landscape plays in determining the helminth fauna of a species. Despite the fact that the urbanization changes drastically the environment and may have profound influences for both hosts and parasites, such as population density declines particularly for species with complex life cycles (Lafferty & Kuris, 2005), no differences in parasite richness and species abundances were found in the present study between house sparrows living in rural and urban landscapes. The previously mentioned granivorous-omnivorous diet and the high association of house sparrows with human settlements may account for this lack of difference. Therefore, it is likely that host diet is similar in rural and urban landscapes. The fact that no house sparrow was captured in trapping sites containing <40 % urbanization (seven sites ranging from <1 to 34 % urbanization) and the general low parasite prevalence support the idea that grains and human food remains are responsible for the bulk of the diet of *P. domesticus* in both landscapes.

Future studies on the parasite fauna of *P. domesticus* in areas where it was introduced more recently are needed to confirm the hypothesis that the age of a population is a good predictor of its parasite richness. In addition, as stated by Combes (2001), studies on the parasite-environment relationship offer a challenge to parasitological research and the landscape influence on parasite community structure needs to be enlightened for hosts belonging to different guilds. Finally, a more thoroughly comprehension of this multi-species ecological interaction will require research focusing on both definitive and intermediate hosts, their relationships, densities, and interactions with parasite species.

In this research was found a decrease in parasite species richness from its original distribution to Rio de Janeiro to Porto Alegre that is compatible with the contention host population age is a good predictor of parasite richness. The percentage of infected house sparrows showed the same pattern. No differences in parasite richness and species abundances were found between house sparrows living in rural and urban landscapes, despite the fact that the urbanization changes drastically the environment and may have profound influences for both hosts and parasites. The previously mentioned granivorous-omnivorous diet and the high association of house sparrows with human settlements may account for this lack of difference. Therefore, it is likely that the host diet is similar in rural and urban landscapes. The high similarity of the helminth communities of adult male and female house sparrows supports the contention that there is no difference in the animal portion of their diets.

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