A SURVEY OF THE PREVALENCE OF SELECTED BACTERIA IN WILD BIRDS

Authors: Brittingham, Margaret Clark, Temple, Stanley A., and Duncan, Ruth M.

Source: Journal of Wildlife Diseases, 24(2) : 299-307

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-24.2.299

Journal of Wildlife Diseases, 24(2), 1988, pp. 299–307

A SURVEY OF THE PREVALENCE OF SELECTED BACTERIA IN WILD BIRDS

Margaret Clark Brittingham,[1,3] Stanley A. Temple,[1] and Ruth M. Duncan[2]

[1] Department of Wildlife Ecology, 226 Russell Laboratories, University of Wisconsin, Madison, Wisconsin 53706, USA

[2] National Wildlife Health Research Center, U.S. Fish and Wildlife Service, 6006 Schroeder Road, Madison, Wisconsin 53711, USA

[3] Present address: School of Forest Resources, 111 Ferguson Building, The Pennsylvania State University, University Park, Pennsylvania 16802, USA

ABSTRACT: We determined the prevalence of six genera of bacteria from a sample of 387 cloacal swabs from 364 passerines and woodpeckers. The prevalence of bacteria were as follows: *Escherichia coli* (1%), *Pseudomonas* spp. (22%), *Salmonella* spp. (0%), *Staphylococcus* spp. (15%), *Streptococcus* spp. (18%), and *Yersinia* spp. (1%). The prevalence of *Streptococcus* spp. was higher in omnivorous species than in granivorous species (20% versus 8%). Individuals captured at feeders had a lower prevalence of both *Streptococcus* spp. (15% versus 33%) and *Escherichia coli* (0.5% versus 4%) than birds that did not have access to feeders. These differences are probably not due to the feeder per se, but instead to other site related differences. The prevalence of bacteria did not differ between male and female black-capped chickadees, *Parus atricapillus*. For 279 color marked black-capped chickadees, we calculated the cumulative mortality rate during 12 wk following swabbing. Although the cumulative mortality rates of infected birds were consistently higher than the rates of non-infected birds, none of these differences were significant. Infections may cause slight reductions in survival rates, but we were not able to confirm this with our data.

Key words: Bacteriology, *Escherichia coli*, mortality, *Pseudomonas* spp., *Salmonella* spp., *Staphylococcus* spp., *Streptococcus* spp., survey, wild birds, *Yersinia* spp.

INTRODUCTION

The normal intestinal flora of wild birds is not well documented; particularly for passerines and woodpeckers. Fiennes (1959) presented data on the intestinal flora of urban birds. In addition, there have been a few surveys to determine the prevalence of specific types of bacteria that may present a potential threat to either human health or the health of domestic animals (McClure et al., 1957; Goodchild and Tucker, 1968; Mair, 1973). However, in the majority of cases, information on the prevalence of bacteria in wild birds comes from diagnostic laboratories; dead birds are examined, and the pathogens causing the deaths are reported (Jennings and Soulsby, 1957; Keymer, 1958; Faddoul and Fellows, 1966; Faddoul et al., 1966). The results give an indication of how frequently different kinds of bacteria kill birds, but provide little information on their actual prevalence.

In this study, we sampled 364 apparently healthy wild birds to determine the prevalence of six types of bacteria (*Escherichia coli*, *Pseudomonas* spp., *Salmonella* spp., *Staphylococcus* spp., *Streptococcus* spp., and *Yersinia* spp.) that are potential pathogens. We chose these six genera of bacteria for a number of reasons. We were interested in determining what effect, if any, winter bird-feeding had on the prevalence of bacteria in a population, so we chose genera of bacteria that have been associated with feeders and genera that are commonly associated with fecal contamination (Locke et al., 1973; Olivieri, 1982; Mitscherlich and Marth, 1984). In addition, we selected bacteria for which isolation procedures were available at the National Wildlife Health Research Center.

We tested whether the prevalence of bacteria differed among avian species or was related to the diet (granivorous versus omnivorous) of the species sampled. For black-capped chickadees (*Parus atricapillus*), we tested whether the prevalence of bacteria differed between the sexes, among study sites, and between individuals that

congregated to feed at bird-feeders and those that fed exclusively on the more dispersed natural food supply. We provide information on the probable sources of these potential pathogens and on the effects that they had on the survival of individuals.

MATERIALS AND METHODS

Study area

We collected cloacal swabs during three winters 1982–1983, 1983–1984 and 1984–1985 in conjunction with a 3-yr study on the impacts of bird-feeding on wild birds (Brittingham and Temple, 1988). We conducted this research on five separate study sites in Sauk and Dane counties, Wisconsin (Devil's Lake North, 43°26'N, 89°44'W; Devil's Lake South, 43°24'N, 89°44'W; Klondike, 43°23'N, 89°48'W; Potter, 43°27'N, 89°38'W; and Temples, 43°13'N, 89°50'W). Each study site consisted of approximately 1500–2000 ha. All study sites were in comparable rural areas dominated by deciduous woods with intermittent openings. Horses were present on one of the sites (Klondike) and absent from the other four. After the fall deer hunting season, deer remains were present on all five sites and were consumed by many avian species.

Bird-feeders were available on three of the sites (Devil's Lake North, Potter and Temples). One feeding station (a bird feeder) was centrally located at each of these sites; there were no other feeders present. We provided sunflower seeds (Madison Audubon Society, 111 King Street, Madison, Wisconsin 53703, USA) but no other supplemental food. The sunflower seeds were placed inside either tubular Droll Yankee feeders (Duncraft, Penacook, New Hampshire 03303, USA) or homemade 5-gallon-hopper feeders. To obtain seeds from both types of feeders, birds stand on a perch and reach inside a small opening to remove a seed. The seeds inside the feeder are completely protected from rain, snow and other inclement weather, and fecal contamination. Our other two sites were control sites with no sources of supplemental food.

Collection of samples

We captured birds with mist nets (Manomet Bird Observatory, P.O. Box 936, Manomet, Massachusetts 02345, USA). On the sites where bird-feeders were available, we captured birds near the feeder. On sites without bird-feeders, we placed nets where birds congregated naturally and used tape recordings of bird vocalizations (Laboratory of Ornithology, Sapsucker Woods, Ithaca, New York 14850, USA) to attract them. Each bird was removed from the mist net and held individually inside a clean paper bag until we were ready to band it. On average, individuals were held for <15 min.

We banded all individuals captured with a numbered aluminum band (Bird Banding Laboratory, U.S. Fish and Wildlife Service, Laurel, Maryland 20811, USA). We also banded black-capped chickadees with a unique combination of plastic color-bands (A. C. Hughes, 1 High Street, Hampton Hill, Middlesex, England TW1Z-1NA) so that individuals could be recognized by reobservation in the field. The sex of each chickadee, when it could be determined, was recorded (Brittingham and Temple, 1988).

If the bird defecated in the paper bag, we swabbed the feces with a sterile calcium alginate swab (Calgiswab, Biomedical Operations, Inolex Division, American Can Company, 3 Science Road, Glenwood, Illinois 60425, USA) without touching the bag itself with the swab. Swabs were placed in pre-packaged Amies charcoal transport-media (DIFCO Laboratories, P.O. Box 1058, Detroit, Michigan 48232, USA), and they were taken to the National Wildlife Health Research Center (U.S. Fish and Wildlife Service, 6006 Schroeder Road, Madison, Wisconsin 53711, USA) within 3 days of collection and stored at −70 C until they were cultured.

We collected 387 cloacal swabs from 364 individuals on our five study sites. Twenty-three birds were swabbed more than once during a winter, but not more than once in a month. We collected 310 swabs from the three feeder sites (Devil's Lake North, n = 124; Potter, n = 67; Temple's, n = 119) and 77 swabs from the two control sites (Devil's Lake South, n = 29; Klondike, n = 48). Our sample included 11 species of passerines and woodpeckers (red-bellied woodpecker, *Melanerpes carolinus*, n = 1; downy woodpecker, *Picoides pubescens*, n = 2; black-capped chickadee, *Parus atricapillus*, n = 290; tufted titmouse, *Parus bicolor*, n = 1; white-breasted nuthatch, *Sitta carolinensis*, n = 19; red-breasted nuthatch, *Sitta canadensis*, n = 2; cardinal, *Cardinalis cardinalis*, n = 2; purple finch, *Carpodacus purpureus*, n = 2; pine siskin, *Carduelis pinus*, n = 3; American goldfinch, *Carduelis tristis*, n = 25; dark-eyed junco, *Junco hyemalis*, n = 40).

Analysis of samples

Each swab was tested for the following organisms: *Escherichia coli*, *Pseudomonas* spp., *Salmonella* spp., *Staphylococcus* spp., *Streptococcus* spp., and *Yersinia* spp. We initially planned to identify bacteria only to genus level. However, in the process of analyzing the samples, many were identified also to species level. These are recorded also in the results.

Each swab was placed in tryptic soy broth (DIFCO, Difco Laboratories, Detroit, Michigan 48201, USA) and incubated at 37 C for 4–6 hr.

Using disposable pipettes, two drops of fluid were placed on each of three plates: a 5% sheep blood agar plate (DIFCO), eosin methylene-blue agar plate (DIFCO), and a Columbia CNA agar plate (DIFCO), and also placed in Dulcitol Selinite broth (Formula from Enteric Laboratory, Wisconsin State Laboratory of Hygiene, University of Wisconsin, 465 Henry Mall, Madison, Wisconsin 53706, USA). The plates were incubated overnight at 37 C. The API 20E identification kit (Analytab Products, Division of Sherwood Medical, 200 Express Street, Plainview, New York 11803, USA) were used to identify isolates of gram-negative bacteria. *Staphylococcus* spp. and *Streptococcus* spp. were identified by colony morphology, gram stain and catalase test. The coagulase test using rabbit coagulase plasma (DIFCO) was used to identify *Staphylococcus aureus*. *Streptococcus* spp. were further tested for growth in 6.5% NaCl broth (broth base from DIFCO) and by the bile-esculin test (GIBCO Laboratories, 2801 Industrial Drive, Madison, Wisconsin, 53706, USA). Additional tests to identify *Streptococcus* spp. included growth on eosin methylene-blue agar plate, sorbitol fermentation and arabinose fermentation (DIFCO). Sugar fermentation tests were run in CTA media (DIFCO) using sugar differentiation discs (DIFCO).

To test for *Salmonella* spp., fluid from the tryptic soy broth was placed in dulcital selenite broth. The dulcital selenite broth was streaked on xylose-lysine-deoxycholate agar plate (DIFCO), Hecktoen agar plate (DIFCO), and brilliant green agar plate (DIFCO) and incubated at 37 C. Since bacterial growth was not observed, we did not proceed past this point. To test for *Yersinia* spp., the cold enrichment technique (Greenwood et al., 1975) substituting *Yersinia* sp. selective media with antimicrobic supplement CN (DIFCO) was used. Colonies were identified using the API 20E identification kit (DIFCO).

Chi-square tests with Yates correction for continuity and the log-likelihood ratio were used to compare the prevalence of bacteria between groups of birds.

Calculating maximum mortality rates

Of the 290 chickadees that were swabbed, 279 were color-marked and released. As part of our study on the impact of winter bird-feeding, each study site was visited at least 1 day/wk from October to April and at least 1 day/mo during the summer. During these visits we recorded observations of previously marked birds (Brittingham and Temple, 1988). In order to estimate whether the presence of a particular pathogen increased mortality rates, we calculated and plotted the cumulative percentage of individuals that died or disappeared during the 12-wk period following swabbing. Individuals reported as disappearing were birds that were never seen again during the 3-yr study. These values represent the maximum mortality rate that could have occurred. Chickadees are year-round residents in Wisconsin. They maintain winter home-ranges and in spring they breed near their winter home-range (Weise and Meyer, 1979). Therefore, we assume that losses of birds were almost exclusively the result of mortality and not emigration. We extended our analysis for only 12 wk after swabbing, because we assumed that, if detrimental effects from the bacteria were going to occur, they would probably occur within this period. In addition, the status of an individual (positive or negative for a particular type of bacteria) probably changes with time, thus confounding the data as the time after swabbing increases.

We plotted a mortality curve for the group of chickadees that were negative for all six types of bacteria ("clean birds") and a separate curve for individuals that were positive for each type of bacteria. In many instances, an individual was carrying more than one kind of bacteria and was represented in more than one group.

TABLE 1. Prevalence of bacteria in a sample of 387 cloacal swabs from 364 birds on five study sites in Wisconsin.

Bacteria	Positive swabs	
	n	Percent
Escherichia coli	5	1
Pseudomonas spp.	85	22
Pseudomonas spp.	12	3
P. fluorescens	34	9
P. maltophilia	26	7
P. aeruginosa	6	2
P. paucimobilis	3	<1
P. stuzeri	2	<1
P. cepacia	1	<1
Pseudomonas sp. CDC group VE2	1	<1
Salmonella spp.	0	0
Staphyloccus spp.	59	15
Staphyloccus spp.	58	15
S. aureus	1	<1
Streptococcus spp.	68	18
Streptococcus spp.	15	4
S. avium	16	4
Streptococcus sp. group D (non-enterocci)	23	6
S. fecalis	11	3
S. durhans	2	<1
S. viridans	1	<1
Yersinia spp.	5	1
Y. enterocolitica	4	1
Y. intermedia	1	<1

TABLE 2. Log-likelihood ratio analysis of differences in prevalence of bacteria among four common avian species from five study sites in Wisconsin.

Bacteria	% Positive swabs from each species*				Significance of differences	
	BCC	WBN	AGF	DEJ	*G*	*P*
Escherichia coli	1	0	0	0	2.0	>0.5
Pseudomonas spp.	24	16	8	15	6.3	<0.1
Salmonella spp.	0	0	0	0	0.0	>0.5
Staphylococcus spp.	15	21	12	15	0.7	>0.5
Streptococcus spp.	19	32	4	10	8.7	<0.05
Yersinia spp.	2	5	0	0	3.0	>0.2

* BCC = black-capped chickadee, n = 290; WBN = white-breasted nuthatch, n = 19; AGF = American goldfinch, n = 25; DEJ = dark-eyed junco, n = 40.

We used a Kolmogorov-Smirnov test to test for differences between the mortality curve of "clean" birds and curves for birds that were positive for each type of bacteria (Gibbons, 1985).

RESULTS

A summary of the bacteria isolated in our samples is presented in Table 1. Two hundred seventeen swabs were negative for all types of bacteria for which we specifically tested. In addition to these organisms, others that were incidentally isolated from the swabs included *Bacillus* spp., *Klebisella pneumoneae*, *Serratia* spp., yeasts and a fungus (*Penicillium* spp.).

TABLE 3. Chi-square analysis of prevalence of bacteria in granivorous versus omnivorous avian species from five study sites in Wisconsin.

Bacteria	Prevalence (%)			
	Granivores[a]	Omnivores[b]	χ^2	*P*
Escherichia coli	1	1	0.0	>0.5
Pseudomonas spp.	15	23	1.8	>0.1
Salmonella spp.	0	0	0.0	>0.5
Staphylococcus spp.	14	15	0.03	>0.5
Streptococcus spp.	8	20	4.4	<0.05
Yersinia spp.	1	1	0.0	>0.5

[a] Species with a granivorous diet in winter: American goldfinch, dark-eyed junco, pine siskin, purple finch, northern cardinal (n = 72).

[b] Species with an omnivorous diet in winter: red-bellied woodpecker, downy woodpecker, black-capped chickadee, tufted titmouse, white-breasted nuthatch, red-breasted nuthatch (n = 315).

Prevalence of bacteria by species and diet

The prevalence of *Streptococcus* spp. differed significantly among host species and differed with the winter diet of the bird species. It was highest in white-breasted nuthatches and lowest in American goldfinches (Table 2). Birds that have an omnivorous diet during the winter had a significantly higher prevalence of *Streptococcus* spp. than individuals that were primarily granivorous during the winter (Table 3). We did not find differences in prevalence among bird species or between omnivorous and granivorous species for any of the other bacteria tested (Tables 2, 3).

Sexual differences in prevalence of bacteria

We did not find a difference in the prevalence of bacteria between male (n = 83) and female (n = 63) chickadees for *Escherichia coli* (χ^2 = 0.0, df = 1, P > 0.5), *Pseudomonas* spp. (χ^2 = 0.2, df = 1, P > 0.5), *Salmonella* spp. (χ^2 = 0.0, df = 1, P > 0.5), *Staphylococcus* spp. (χ^2 = 0.0, df = 1, P > 0.5) *Streptococcus* spp. (χ^2 = 0.0, df = 1, P > 0.5) or *Yersinia* spp. (χ^2 = 0.3, df = 1, P > 0.5).

Site differences in prevalence of bacteria

For black-capped chickadees, the prevalence of *Escherichia coli* and *Streptococcus* spp. differed among the five study sites (Table 4). Both were highest at the Klondike study site. Horses were present at this site, and chickadees were often observed

TABLE 4. Log-likelihood ratio analysis of differences in prevalence of bacteria in black-capped chickadees on five study sites in Wisconsin.

Bacteria	% Positive swabs at each site					Significance of differences	
	Klondike (41)[a]	Devil's Lake South (26)	Devil's Lake North (91)	Temples (88)	Potter (44)	*G*	*P*
Escherichia coli	7[b]	0	1	0	0	9.7	<0.05
Pseudomonas spp.	22	31	21	26	27	1.6	>0.5
Salmonella spp.	0	0	0	0	0	0.0	>0.5
Staphylococcus spp.	15	23	17	16	16	2.6	>0.5
Streptococcus spp.	37	27	16	13	16	11.2	<0.05
Yersinia spp.	5	0	1	0	0	6.4	>0.1

[a] See text for details of study sites; number of swabs collected in parentheses.
[b] Percentage values.

picking seeds out of the horse manure. In six chickadees captured while feeding at a manure pile, we isolated *Escherichia coli* (one bird), *Streptococcus fecalis* (one bird), *Yersinia enterocolitica* (two birds) and *Pseudomonas maltophilia* (two birds). Birds feeding on manure are exposed to many kinds of bacteria, some of which becomes established in their intestinal tracts.

Prevalence of bacteria and bird-feeders

For black-capped chickadees the prevalence of both *Escherichia coli* and *Streptococcus* spp. was significantly less in individuals that congregated to feed at bird-feeders than among individuals that fed solely on the natural food supply (Table 5). The prevalence of all other bacteria we tested was lower also, although differences were not significant (Table 5).

Prevalence of bacteria and mortality rate

There was not a significant difference between the mortality curve of "clean" birds and the mortality curves of birds infected with *Escherichia coli* ($D = 0.14$, $P > 0.2$), *Pseudomonas* spp. ($D = 0.08$, $P > 0.2$), *Staphylococcus* spp. ($D = 0.05$, $P > 0.2$), *Streptococcus* spp. ($D = 0.12$, $P > 0.1$), or *Yersinia* spp. ($D = 0.51$, $P > 0.1$) (Fig. 1).

DISCUSSION

For 217 of 387 swabs none of the six types of bacteria for which we tested was detected. Some of these negative results may have resulted from storage of the swabs in transport media prior to freezing. The storage of samples in transport media reduces the total bacterial population. More fastidious bacteria often decrease in num-

TABLE 5. Chi-square analysis of prevalence of bacteria isolated from black-capped chickadees on three feeder and two no-feeder sites in Wisconsin.

Bacteria	% Positive swabs		Significance of differences	
	No feeder (67)[a]	Feeder (223)	χ^2	*P*
Escherichia coli	4[b]	0.4	3.5	=0.06
Pseudomonas spp.	25	24	0.0	>0.5
Salmonella spp.	0	0	0.0	>0.5
Staphylococcus spp.	18	15	0.2	>0.5
Streptococcus spp.	33	15	9.8	<0.05
Yersinia spp.	3	<1	1.2	>0.2

[a] Number of birds examined.
[b] Percentage values.

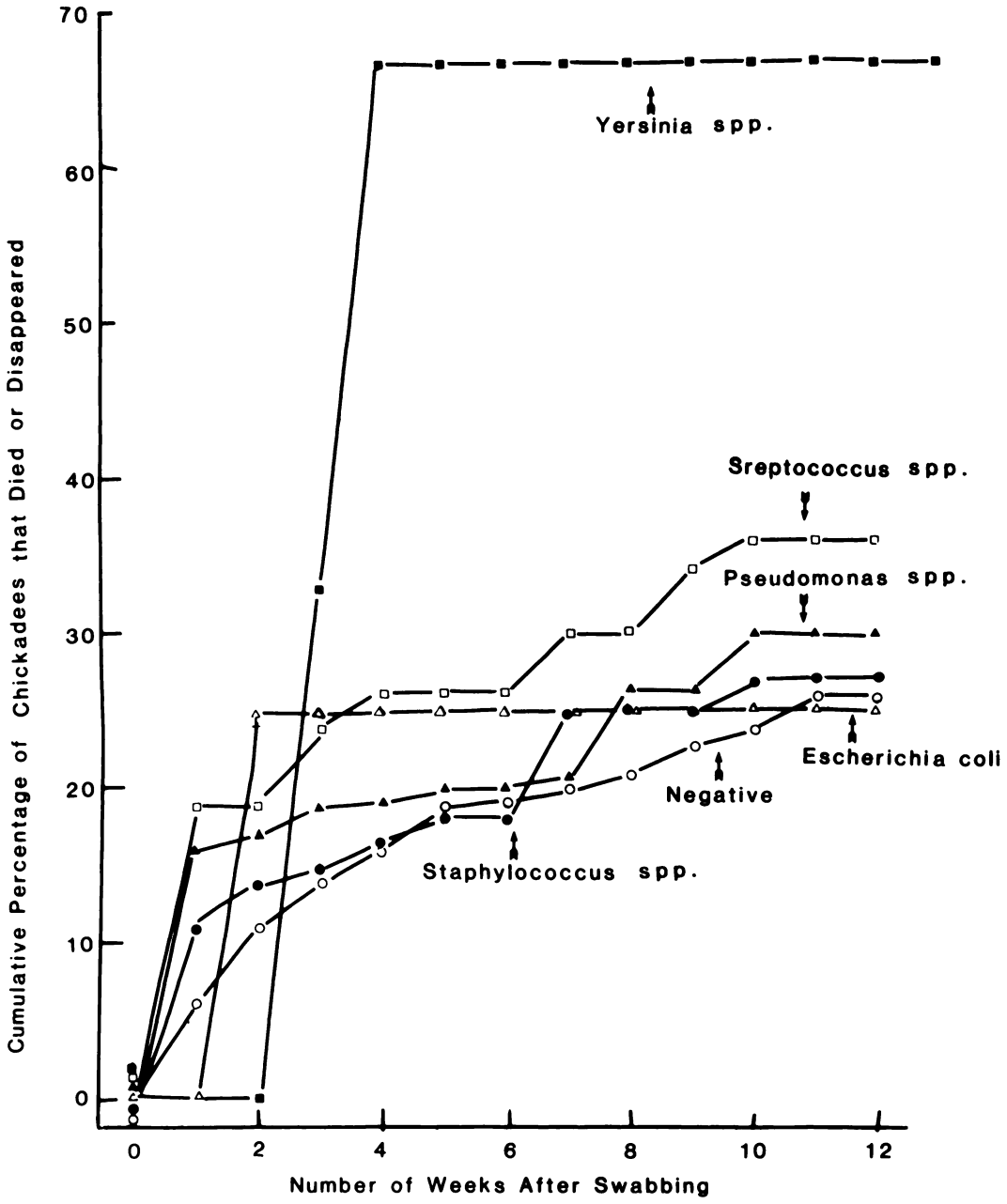

FIGURE 1. Cumulative mortality rates for black-capped chickadees negative for all bacteria tested (n = 148) and for chickadees positive for *Escherichia coli* (n = 4), *Pseudomonas* spp. (n = 69), *Staphylococcus* spp. (n = 44), *Streptococcus* spp. (n = 53) or *Yersinia* spp. (n = 3).

ber while coliform bacteria may increase in number. Our samples were frozen within 3 days of collection, so we suspect that, in most cases, representatives of all types of bacteria originally present still remained.

Escherichia coli

The low prevalence of *Escherichia coli* (1%) isolated from our sample of wild birds was similar to that reported for other populations of passerines. Glunder (1981) iso-

lated *E. coli* from 5% of 98 apparently healthy passerines he examined. Fiennes (1982) reported that *E. coli* was rarely found in the gut flora of granivorous birds. Our results are in agreement with this, but we also found the prevalence of *E. coli* to be low for omnivorous passerines. McClure et al. (1957) isolated *E. coli* from 15% of the birds they tested, but their sample included gulls (Laridae), herons (Ardeidae), and other carnivorous non-passerines.

The prevalence of *E. coli* differed among the five study sites and was highest at the Klondike site. Horses were present on this study site, and birds were often observed picking seeds out of the horse manure. Individuals on this site may have acquired *E. coli* from the horse manure. The bacteria is often associated with fecal material (Olivieri, 1982), and we isolated *E. coli* from one of six individuals captured while feeding on manure.

Pseudomonas spp.

We isolated *Pseudomonas* spp. from 22% of the birds we tested. Bowman and Jacobson (1980) isolated it from 5% of the psittacines they tested. We found no data on its prevalence in passerines, except the comment that it is not a normal member of the intestinal flora of granivorous birds (Fiennes, 1982). We isolated *Pseudomonas* spp. from 15% of the granivorous birds we tested and found no difference in the prevalence of this bacteria with diet. Pseudomonads are ubiquitous in the environment, found in animal matter, soil, and water (Mitscherlich and Marth, 1984). Our results suggest that they are not uncommon in the gut flora of either omnivorous or granivorous birds.

Salmonella spp.

Salmonella spp. was not isolated from any of the birds we tested. The prevalence of *Salmonella* spp. in healthy wild birds is often low (Bigland et al., 1962; Goodchild and Tucker, 1968). *Salmonella* spp. often causes acute illness in passerines, killing the birds within a short period (Keymer, 1959; Fiennes, 1982). Therefore, although it has been associated with epizootics of passerines, particularly at bird-feeders (Locke et al., 1973), its occurrence in samples from a population of healthy birds remains low.

Staphylococcus spp.

We isolated *Staphylococcus* spp. from 15% of the birds we tested and did not find the prevalence to differ with the diet of the bird. Gram-positive bacteria are commonly isolated from passerines (Fiennes, 1982). *Staphylococci* are ubiquitous in the environment, found on the skin of most warm-blooded animals (Mitschlerlich and Marth, 1984).

Streptococcus

The prevalence of *Streptococcus* spp. differed significantly among the four avian species, with the winter diet, and among the study sites. It was highest in omnivorous birds at the Klondike study site. We suspect that these differences result from omnivores being exposed to many species of *Streptococcus* that individuals with a granivorous diet rarely come in contact with and to the presence of horse manure at the Klondike site.

Many species of *Streptococcus* spp. that we isolated are associated primarily with animal by-products such as manure or carcass remains. For example, *S. fecalis*, *S. bovis* and *S. equinus* are all associated with fecal material (Mitscherlich and Marth, 1984). After the fall deer hunting season, we observed many avian species feeding on deer carcass remains. In addition, individuals at the Klondike site were observed picking seeds out of horse manure. These foods are both potential sources of many kinds of bacteria.

Yersinia spp.

We isolated *Yersinia* spp. from 1% of the individuals we tested. Kapperud and Olsvik (1982) isolated *Yersinia* spp. from

5% of 76 Norwegian birds, most of which were non-passerines.

Prevalence of bacteria and bird-feeders

The prevalence of *Escherichia coli* and *Streptococcus* spp. were lower for individuals that fed at bird-feeders than for those that did not have access to feeders. Since the effect of the bird-feeder is confounded with the study-site effect, it is difficult to interpret these results. We suspect that the differences are a result of differences in other food supplies associated with each site. For example, there was horse manure at one of the non-feeder sites.

We initially predicted that the prevalence of bacteria would be higher among individuals that congregated to feed at bird-feeders. Salmonellosis and other disease have been associated with high densities of birds at feeders (Locke et al., 1973; Brittingham and Temple, 1986). Although we did not find a higher prevalence of bacteria in birds that used feeders, our results should be interpreted with caution. Our feeders were probably not typical of the type used by many people. The seeds in our feeders were protected from both the elements and fecal contamination. Platform feeders, that allow birds to contaminate the seeds, have been associated with higher levels of disease and mortality (Hurvell et al., 1974; Brittingham and Temple, 1986). In addition, we only provided sunflower seeds. It is possible that suet, bread, table scraps and other items frequently fed to birds are more likely to become contaminated.

All the granivorous species we tested, except the cardinal, are extremely gregarious during the winter. Alternatively, the omnivores are found in pairs or small flocks. If the spread of bacteria was increased by close contact between individuals, we would expect the occurrence of bacteria to be higher in the granivorous species; this was not the case. Apparently, the prevalence of bacteria in healthy birds is influenced more by the birds' food supply than by their social organization.

Prevalence of bacteria and mortality rate

We did not detect a significant increase in mortality rates among individuals that were infected with any of the bacteria we tested. We expected to find an increase in mortality rates among individuals infected with *Yersinia* spp., since yersiniosis is usually fatal within a short period of time (Mair, 1973; Fiennes, 1982). Our failure to detect a difference between the mortality curve of "clean" birds and those infected with *Yersinia* spp. may be due to our small sample size; only three chickadees were positive for *Yersinia* spp. The low prevalence of *Yersinia* spp. may be a result of its high virulence. If *Yersinia* spp. kills quickly, it is difficult to capture birds carrying the organism. Two of the three infected birds that we captured disappeared within 1 mo. In any event, we know that *Yersinia* spp. does not always cause mortality. The third infected bird was still alive 1.5 yr later and bred during the two following breeding seasons.

For all five genera of bacteria, the rate of disappearance of the infected birds was higher than the rate of disappearance of "clean" individuals. However, the differences were not statistically significant. This suggests that infections may cause slight reductions in survival rates that we were unable to confirm with our methods.

ACKNOWLEDGMENTS

We thank Scott Hereford and Sherrie Gruder-Adams for assisting with field collection of the samples; Renee Sandler, Kaye Boehlen, Amy Groteluechen and Mary Walker for assisting in the bacterial analysis; Christie Riebe for compiling the data; Christopher Brand and the staff of the National Wildlife Health Research Center for providing supplies and laboratory space; and Thomas Yuill and Robert Hanson for critical comments on an earlier draft of this manuscript. Brent Haglund and the Wisconsin Chapter of the Nature Conservancy gave us permission to conduct our research at the Klondike campground and Willis Forest Preserve; Ken Lange and Craig Karr gave us permission to conduct our research at Devil's Lake State Park; and Robert Rennebohm, Edwin Young, and the University of Wisconsin Foundation gave us permission to conduct our research at the Howard

I. Potter Preserve. We thank each of the above individuals and organizations. Funding for the research was provided by the University of Wisconsin, College of Agricultural and Life Sciences, Agricultural Experiment Station.

LITERATURE CITED

BIGLAND, C. H., G. S. WILTON, H. N. VANCE, AND H. C. CARLSON. 1962. Salmonellosis of animals in Alberta, 1949 to 1960. Journal of the American Veterinary Medical Association 140: 251–253.

BOWMAN, T. A., AND E. R. JACOBSON. 1980. Cloacal flora of clinically normal captive psittacine birds. Journal of Zoo Animal Medicine 11: 81–85.

BRITTINGHAM, M. C., AND S. A. TEMPLE. 1986. A survey of avian mortality at winter feeders. Wildlife Society Bulletin 4: 445–450.

———, AND ———. 1988. Impacts of supplemental feeding on survival rates of black-capped chickadees. Ecology 69: In press.

FADDOUL, G. P., AND G. W. FELLOWS. 1966. A five-year survey of the incidence of *Salmonella* in avian species. Avian Diseases 10: 296–304.

———, ———, AND J. BAIRD. 1966. A survey on the incidence of salmonellae in wild birds. Avian Diseases 10: 89–94.

FIENNES, R. N. 1959. Report of the society's pathologist for the year 1957. Proceedings of the Zoological Society of London 132: 129–146.

———. 1982. Diseases of bacterial origin. *In* Diseases of cage and aviary birds, 2nd ed., M. L. Petrak (ed.). Lea and Febiger, Philadelphia, Pennsylvania, pp. 497–515.

GIBBONS, J. D. 1985. Nonparametric methods for quantitative analysis, 2nd ed. American Sciences Press, Inc., Columbus, Ohio, 481 pp.

GLUNDER, G. 1981. Occurrence of Enterobacteriaceae in feces of granivorous passeriform birds. Avian Diseases 25: 195–198.

GOODCHILD, W. M., AND J. F. TUCKER. 1968. Salmonellae in British wild birds and their transfer to domestic fowl. British Veterinary Journal 124: 95–101.

GREENWOOD, J. R., S. M. FLANIGAN, M. J. PICKETT, AND W. J. MARTIN. 1975. Clinical isolation of *Yersinia enterocolitica*: Cold temperature enrichment. Journal of Clinical Microbiology 2: 559–560.

HURVELL, B., K. BORG, A. GUNNARSSON, AND J. JEVRING. 1974. Studies on *Salmonella typhimurium* infections in passerine birds in Sweden. International Congress of Game Biologists 11: 493–497.

JENNINGS, A. R., AND E. J. L. SOULSBY. 1957. Diseases of wild birds, fourth report. Bird Study 4: 216–220.

KAPPERUD, G., AND O. OLSVIK. 1982. Isolation of enterotoxigenic *Yersinia enterocolitica* from birds in Norway. Journal of Wildlife Diseases 18: 247–248.

KEYMER, I. F. 1958. A survey and review of the causes of mortality in British birds and the significance of wild birds as disseminators of disease. I. A survey of the causes of mortality. Veterinary Record 70: 713–720.

———. 1959. Specific diseases of the canary and other passerine birds. Modern Veterinary Practice 40: September 1, 32–35.

LOCKE, L. N., R. B. SHILLINGER, AND T. JAREED. 1973. Salmonellosis in passerine birds in Maryland and West Virginia. Journal of Wildlife Diseases 9: 144–145.

MAIR, N. S. 1973. Yersiniosis in wildlife and its public health implications. Journal of Wildlife Diseases 9: 64–71.

MCCLURE, H. E., W. C. EVELAND, AND A. KASE. 1957. The occurrence of certain enterobacteriaceae in birds. American Journal of Veterinary Research 18: 207–209.

MITSCHERLICH, E., AND E. H. MARTH. 1984. Microbial survival in the environment. Springer-Verlag, New York, New York, 802 pp.

OLIVIERI, V. P. 1982. Bacterial indicators of pollution. *In* Bacterial indicators of pollution, W. O. Pipes (ed.). CRC Press, Inc., Boca Raton, Florida, pp. 22–41.

WEISE, C. M., AND J. R. MEYER. 1979. Juvenile dispersal and development of site-fidelity in the black-capped chickadee. Auk 96: 40–55.

Received for publication 15 June 1987.