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Evidence of the role of free-living birds as disseminators of *Salmonella* spp.

Evidências das aves de vida livre como transmissoras de Salmonella spp.

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ABSTRACT: This study aimed to review aspects of *Salmonella* spp. in free-living birds and their potential as disseminators for domestic animals, man, and the environment. Isolation of *Salmonella* spp. have been reported in several species of wild birds from Passeridae and Fringillidae, among other avian families, captured in countries of North America and Europe, where *Salmonella* ser. Typhimurium is the most frequently reported serotype. The presence of pathogens, including *Salmonella,* may be influenced by several factors, such as diet, environment, exposure to antibiotics, infection by pathogenic organisms and migration patterns. Researches with wild birds that live in urbanized environment are important, considering that birds may participate in the transmission of zoonotic pathogens, which are more prevalent in cities due to the human activity. Based on the information collected, this article concludes that wild birds are still important disseminators of pathogens in several geographic regions and may affect man, domestic animals, and other birds.

KEYWORDS: salmonellosis; wild birds; zoonosis.

RESUMO: O objetivo deste estudo foi realizar uma revisão acerca da *Salmonella* spp. em aves de vida livre e o potencial delas como disseminadores para animais domésticos, homem e meio ambiente. Casos na literatura relatando *Salmonella* spp. têm sido descritos em diversas espécies de aves silvestres da família Passeridae e Fringilidae em países da América do Norte e Europa, sendo *Salmonella* ser. Typhimurium o sorotipo relatado mais frequentemente. A presença de patógenos como *Salmonella* spp. pode ser influenciada por fatores como dieta, ambiente onde vive, contaminação por antibióticos, infecção por organismos patogênicos e padrões de migração. Pesquisas envolvendo as aves silvestres que vivem em ambiente urbanizado são importantes, pois as aves podem possibilitar a transmissão de patógenos zoonóticos que têm maior prevalência em áreas urbanas devido a mecanismos de ação humana. Com base nas informações coletadas, conclui-se que as aves silvestres continuam sendo importantes na disseminação de patógenos em diversas regiões geográficas, podendo afetar o homem, animais domésticos e outras aves silvestres.

PALAVRAS-CHAVE: salmonelose; aves selvagens; zoonose.

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INTRODUCTION

Infectious diseases, including emerging infectious diseases, are a great threat to wildlife, animal production and human population (DASZAK et al., 2000). However, episodes of populational decrease as a consequence of these diseases in wild birds often lack proper documentation due to the scarce knowledge on emerging pathogens. In addition, screening and diagnosing wild bird populations are challenging tasks, considering the difficulty in capturing individuals for examination (BRITTINGHAM et al. 1988; LADEAU et al., 2007). Bacteria from the genus *Salmonella* are among the most important pathogens of interest in human and veterinary medicine due to the zoonotic potential they hold. Hence, this study aimed to review information on *Salmonella* spp. in free-living birds and their potential in disseminating these pathogens to domestic animals, man, and the environment.

Many species of wild birds coexist with humans and have anthropogenic sources of habitat and nutrition (BRADLEY; ALTIZER, 2007; PALOMO et al., 2013). Birds adapted to the urban life are exposed to infection and may act as disseminators of enteric zoonotic pathogens due to several factors, such as intake of contaminated food and water, polluted environments, microclimates with elevated temperature and reduced seasonality, which promote proliferation of vectors and persistence of some parasites, in addition to contact with other stressing agents causing immunosuppression, and aggregation of great number of birds in small areas, which increases the odds of contact with possible hosts (BRADLEY; ALTIZER, 2007; PALOMO et al., 2013). An inadequate habit that contributes to the presence of microorganisms in urbanized environments is bird feeding (JONES; REYNOLDS, 2008), which is related to the increased prevalence of some bacteria in these animals (BRITTINGHAM et al., 1988). This practice may favor emerging diseases due to the stimulation of reproduction in urban environments, resulting in elevated density of birds and increased concentration of feces and stress due to the interactions between individuals (DAOUST; PRESCOTT, 2007).

Some species of birds migrate thousands of kilometers through different continents and carry certain pathogens in this process (HUBÁLEK, 2004; BRUGMAN et al., 2013). Approximately 60.3% of all the emerging infectious diseases in humans are zoonoses and 71.8% originated from wild animals (JONES; REYNOLDS, 2008). According to TIZARD (2004), among these infections, salmonellosis is an emerging disease in wild birds and its prevalence have been documented since the 1960s.

Modification of the natural environment by human action may cause a superposition of the natural habitat of birds with urban, agricultural or fishing areas, which may increase the transmission of zoonotic pathogens, such as *Salmonella* spp. (LILLEHAUG et al., 2005). This bacterium may resist for months in humid soil, feces and water, and may cause new infections in birds (MURRAY, 1991; BÖHM, 1993; WINFIELD; GROISMAN, 2003). Its prevalence in free-living birds is influenced by factors such as diet, environment, exposure to antibiotics, infection by pathogenic microorganisms and migration patterns (PALMGREN et al., 1997; LU et al., 2003; GABRIEL et al., 2005; SKOV et al., 2008). Salmonellosis in birds occurs as a result of temporary colonization of the digestive tract by environmental strains. In addition, infections caused by strains that are adapted to the host may occur, which may or may not be pathogenic (TIZARD, 2004). Hence, depending on the strain, the bird may present an asymptomatic condition or die.

Asymptomatic cases of infection by *Salmonella* spp. present great relevance. Carriers may shed bacteria without clinical evidence (CONNOLLY et al., 2006). KLAASSEN et al. (2012) suggest that some stressful conditions may act as a trigger for the bird to develop and disseminate *Salmonella* in the environment, such as cold weather, behavioral alterations, and the prereproduction cycle (MORENO et al., 2003).

Some *Salmonella* strains were identified as specific pathogens of birds in 1889, when Klein isolated *Salmonella* ser. Gallinarum (BARROW, 1993) and Rettger identified *S.* ser. Gallinarum biovar Pullorum in 1899 (RETTGER, 1909). These pathogens cause fowl typhoid and pullorum disease, respectively, which have been more frequently reported in Galliformes reared in domestic environment (GAST, 2008). In free-living birds, both serotypes were rarely reported. *Salmonella* ser. Gallinarum biovar Pullorum was isolated from buff-necked ibis (*Theristicus caudatus*) that lived near a poultry production in Brazil (SOUSA et al., 2010a). In the United Kingdom, *S.* ser. Gallinarum have been isolated from rooks (*Corvus frugilegus*) and common wood pigeons (*Columba palumbus*) that lived in regions where fowl typhoid was occurred frequently (HARBOURNE, 1955). In 2012, *S.* ser. Gallinarum was isolated from a red-winged blackbird (*Agelaius phoeniceus*) in the United States (HAMER et al., 2012).

In the scientific literature, a predominance of *Salmonella* ser. Typhimurium (ST) as a cause of mortality in free-living birds occurs, affecting especially birds from Passeridae and Fringillidae families, which are mostly granivorous species (MIKAELIAN et al., 1997; HUDSON et al., 2000; UNE et al., 2008; GIOVANNINI et al., 2013; VELARDE et al., 2012). Epizooties in free-living birds by *S.* ser. Typhimurium were described for the first time in Switzerland during the 1950s (BOUVIER et al., 1955). Since then, several other reports were published. In 1999, an outbreak of gastroenteritis caused by *S.* ser. Typhimurium DT40 in humans and cats in the center of Sweden was associated with infections and mortality in wild birds, especially in common redpolls (*Carduelis flammea*) and Eurasian siskins (*Carduelis spinus*) (TAUNI; ÖSTERLUND, 2000). *Salmonella* ser. Typhimurium was pointed as the cause of mortality in wild birds from winter 1997 to summer 1998 in the eastern North America. Most affected species in these areas were pine siskin (*Spinus pinus*), purple finches (*Carpodacus purpureus*), evening grosbeaks (*Coccothraustes vespertinus*) and American goldfinches (*Carduelis tristis*) (DAOUST et al., 2000). REFSUM et al. (2003) reported an outbreak caused by *S.* ser. Typhimurium in 64.8% of wild Passeriformes found dead in a bird feeding station, and the following species were most affected: Eurasian siskins (*C. spinus*), purple finches (*C. purpureus*), common redpolls (*C. flammea*) and European greenfinches (*Carduelis chloris*).

Outbreaks related to free-living birds and humans have also been reported. In Great Britain, the access of sparrows to a kitchen resulted in fecal contamination of food, which originated two outbreaks of gastroenteritis (caused by *S.* ser. Typhimurium DT40 and DT160) in hospitalized patients (PENFOLD et al., 1979). ALLEY et al. (2002) reported an outbreak of *S.* ser. Typhimurium DT160 causing enteric disease in humans and mortality in sparrows (*Passer domesticus*), European greenfinches (*C. chloris*), European goldfinches (*Carduelis carduelis*) and common blackbirds (*Turdus merula*) that lived in rural areas of New Zealand. More recently, the occurrence of identical genotypes of *S.* ser. Typhimurium were isolated from wild bird populations and humans in Germany (HAUSER et al., 2009).

In addition to the mentioned above, many other serotypes of *Salmonella* have also been isolated from free-living bird in numerous parts of the world, especially in North America and Europe (Table 1).

A group of birds that deserve special attention are predators, considering that they may identify weakened birds and attack (GRANT et al., 2007). However, they may harbor *Salmonella* in greater proportion than nonpredatory birds (RECHE et al., 2003; MILLÁN et al., 2004; MOLINA-LOPEZ et al., 2011). A variety of serotypes have been isolated from cloacal swabs or organ samples collected from different species of birds of prey, such as *S.* ser. Typhimurium, *S.* ser. Tuindorp, *S.* ser. Enteritidis, *S.* ser. Newport and *S.* ser. Pajala (Table 1). Some species, such as the peregrine falcon (*Falco peregrinus*), are possible disseminators of these pathogens. HERNANDEZ et al. (2012) explain that the diet of this species consists mostly of birds from the Charadridae and Laridae families. Hence, peregrine falcons are migratory birds that reach great distances and may disseminate this pathogen through several areas, including those unoccupied by man.

Migratory birds are epidemiologically relevant for the possibility of acting as long-distance disseminators of pathogens that may affect man and animals (TAUNI; ÖSTERLUND, 2000). FENLON (1981) found that 72% of the serotypes isolated from human cases in Grampian, Scotland, were found in seagulls, and suggested that this was the result of them feeding on untreated sewage disposal. The European herring gull (*Larus argentatus*) species was reported as a probable source of *S.* ser. Montivideo for sheep and cattle (COULSON et al., 1983).

Table 1. Occurrence of *Salmonella* serotypes in wild birds.

Reference	Location	Bird species	*Salmonella* serotypes
NEEL et al. (1953)	Iran	*Corvus corax*	*S.* ser. Hessarek
HARBOURNE (1955)	United Kingdom	*Corvus frugilegus, Columba palumbus, Perdix perdix*	*S.* ser. Thompson, *S.* ser. Gallinarum
RADWAN; LAMPKY (1972)	United States	*Molothrus ater*	*S.* ser. Typhimurium, *S.* ser. Paratyphi A e B, *S.* ser. Albany
SPECKMANN (1975)	England	*Cygnus olor*	*S.* ser. Typhimurium
FREITAS et al. (1977)	Brazil	*Ardea alba*	*S.* ser. Typhimurium
PLANT (1978)	England	*Prunella modularis*	*S.* ser. Anatum
FENLON (1981)	United Kingdom	*Larus* spp.	*S.* ser. Typhimurium, *S.* ser. Derby, S. ser. Give, *S.* ser. Panama, *S.* ser. Agona, *S.* ser. Chester, *S.* ser. Virchow +more than ten serotypes
COULSON et al. (1983)	Scotland & England	*Larus argentatus*	*S.* ser. Montivideo, *S.* ser. Heidelberg, *S.* ser. Hadar, *S.* ser. Agona, (more than ten serotypes)
FENLON (1983)	Scotland	*Larus* spp.	*S.* ser. Stanley, *S.* ser. Typhimurium (DT 40 and DT110), *S.* ser. Virchow, *S.* ser. Binza, *S.* ser. Newport, *S.* ser. Ohio, *S.* ser. Schwarzengrund
FRICKER (1984)	United Kingdom	*Larus ridibundus*	*S.* ser. Agona, *S.* ser. Anatum, *S.* ser. Bredeney, *S.* ser. Derby, *S.* ser. Infantis, *S.* ser. Panama, *S.* ser. Saintpaul, *S.* ser. Stanley, *S.* ser. Tokaradi, *S.* ser. Typhimurium, *S.* ser. Virchow

Continue...

Table 1. Continuation.

Reference	Location	Bird species	*Salmonella* serotypes
GIRDWOOD et al. (1985)	Scotland	*Larus fuscus, Larus ridibundus*	*S.* ser. Virchow, *S.* ser. Typhimurium, *S.* ser. Bredeney, *S.* ser. Hadar, *S.* ser. Infantis, (more than ten serotypes)
KIRKPATRICK; COLVIN (1986)	United States	*Tyto furcata*	*S.* ser. Typhimurium, *S.* ser. Tuindorp, *S.* ser. Thompson
KIRKPATRICK; TREXLER-MYREN (1986)	United States	*Buteo jamaicensis*	*S.* ser. Enteritidis, *S.* ser. Newport
LITERÁK et al. (1992)	Czech Republic	*Larus ridibundus*	*S.* ser. Typhimurium, *S.* ser. Derby, *S.* ser. Enteriditis, *S.* ser. Hadar, *S.* ser. Agona, *S.* ser. Infantis, *S.* ser. Montivideo, *S.* ser. Abony
QUESSY; MESSIER (1992)	Canada	*Larus delawarensis*	*S.* ser. Hadar, *S.* ser. Montivideo, *S.* ser. Heidelberg, *S.* ser. Infantis, *S.* ser. Berta, *S.* ser. Kentucky, *S.* ser. Thompson, *S.* ser. Mamilla, *S.* ser. Typhimurium
LÉVESQUE et al. (1993)	Canada	*Larus delawarensis*	*S.* ser. Brandenburg, *S.* ser. Agona, *S.* ser. Hadar, *S.* ser. Stanley, *S.* ser. Anatum, *S.* ser. Typhimurium
ĈÍẐEK et al. (1994)	Czech Republic	*Larus ridibundus, Passer domesticus, Parus major, Columba livia, Parus montanus,* (more than ten species)	*S.* ser. Typhimurium, *S.* ser. Enteritidis, *S.* ser. Agona, *S.* ser. Hadar (more than ten serotypes)
OLSEN et al. (1996)	Iceland	*Pygoscelis papua*	*S.* ser. Enteritidis
MIKAELIAN et al. (1997)	Canada	*Passer domesticus, Bubo virginianus, Rissa tridactyla, Larus delawarensis*	*S.* ser. Typhimurium (*)
PALMGREN et al. (1997)	Sweden	*Larus ridibundus*	*S.* ser. Typhimurium (DT 22)
PALMGREN et al. (2000)	Georgia	*Pygoscelis papua, Diomedea melanophris*	*S.* ser. Typhimurium (DT150), *S.* ser. Havana (PT4, PT4-Like, PT35), *S.* ser. Enteritidis, *S.* ser. Newport
FRERE et al. (2000)	Argentina	*Larus dominicanus*	*S.* ser. Typhimurium
HUDSON et al. (2000)	United States	*Molothrus* sp., *Carduelis* sp. and *Passer* sp.	*S.* ser. Typhimurium (*)
SMITH et al. (2002)	United States	*Circus cyaneus, Larus occidentalis*	*S.* ser. Montevideo, *S.* ser. Typhimurium 4,5,12:1 monophasic, *S.* ser. Ohio, *S.* ser. Johannesberg
ALLEY et al. (2002)	New Zealand	*Passer domesticus, Carduelis chloris, Carduelis carduelis, Turdus merula*	*S.* ser. Typhimurium DT160 (*)
DUARTE et al. (2002)	Portugal	*Larus fuscus, Larus cachinnans*	*S.* ser. Typhimurium, *S.* ser. Hadar, *S.* ser. Bardo, *S.* ser. Newport, *S.* ser. Derby, *S.* ser. Enteritidis, *S.* ser. Infantis (more than ten serotypes)
KIRK et al. (2002)	United States	*Passer domesticus, Molothrus ater, Euphagus cyanocephalus, Carpodacus mexicanus, Sturnus vulgaris, Agelaius phoeniceus*	*S.* ser. Montevideo, *S.* ser. Meleagridis, *S.* ser. Muenster, *S.* ser. Typhimurium
REFSUM et al. (2002)	Norway	*Pyrrhula pyrrhula, Carduelis chloris, Carduelis spinus, Carduelis flammea, Passer domesticus* (more than ten species)	*S.* ser. Typhimurium O:4,12 (DT 40, U277, DT 99 and DT 110) (*)

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Table 1. Continuation.

Reference	Location	Bird species	*Salmonella* serotypes
RECHE et al. (2003)	Spain	*Falco naumanni, Aquila heliaca, Athene noctua, Tyto furcata, Buteo buteo, Asio otus, Gyps fulvus*	*S.* ser. Enteritidis (PT6a, PNR), *S.* ser. Adelaide, *S.* ser. Brandemburgo, *S.* ser. Newport, *S.* ser. Typhimurium, *S.* ser. Hadar, *S.* ser. Saintpaul, *S.* ser. Virchow
REFSUM et al. (2003)	Norway	*Pyrrhula pyrrhula, Carduelis spinus, Carduelis flammea, Carduelis chloris,* (more than ten species)	*S.* ser. Typhimurium 4,12:i:1,2 (*)
VLAHOVIĆ et al. (2004)	Croatia	*Columba livia, Corvus frugilegus, Buteo buteo, Larus ridibundus, Strix aluco*	*S.* ser. Typhimurium, *S.* ser. Enteritidis
TANAKA et al. (2005)	Japan	*Columba livia*	*Salmonella* spp.
DOBBIN et al. (2005)	Canada	*Phalacrocorax auritus*	*S.* ser. Typhimurium
FERRAZZI et al. (2005)	Italy	*Corvus cornix*	*S.* ser. Typhimurium
LILLEHAUG et al. (2005)	Norway	*Anser anser*	*S.* ser. Diarizona
EPSTEIN et al. (2006)	Australia	*Threskiornis molucca*	*Salmonella* spp.
PENNYCOTT et al. (2006)	Great Britain	*Carduelis chloris, Passer domesticus, Fringilla coelebs, Carduelis carduelis, Passer montanus, Carduelis spinus, Parus major, Accipiter nisus, Strix aluco, Corvus frugilegus, Columba livia, Larus ridibundus, Larus canus, Larus marinus, Larus argentatus, Larus fuscus*	*S.* ser. Typhimurium (DT2, DT99, DT41, DT104, DT195, DT56) (*)
PALMGREN et al. (2005)	Sweden	*Larus ridibundus*	*S.* ser. Typhimurium (DT115, DT41, DT120)
KOCABIYIK et al. (2006)	Turkey	*Bubo bubo*	*S.* ser. Enteritidis (PT21b) (*)
ĈÍẐEK et al. (2007)	Czech Republic	*Larus ridibundus*	*S.* ser. Typhimurium (DT104), *S.* Enteritidis, *S.* ser. Panama, *S.* ser. Kentucky (more than ten serotypes)
LITERÁK et al. (2007)	Czech Republic	*Corvus frugilegus*	*S.* ser. Enteritidis (PT8, PT23)
GRANT et al. (2007)	United Kingdom	*Carduelis chloris, Passer domesticus, Sturnus vulgaris, Fringilla coelebs, Turdus merula*	*S.* ser. Typhimurium (DT56, DT40)
JIJÓN et al. (2007)	United States	*Parabuteo unicinctus, Otus asio*	*S.* ser. Saintpaul, *S. enterica houtenae*
ALBARNAZ et al. (2007)	Brazil	*Larus dominicanus*	*S.* ser. Typhimurium
UNE et al. (2008)	Japan	*Passer montanus*	*S.* ser. Typhimurium (DT40) (*)
ALLGAYER et al. (2009)	Brazil	*Anodorhynchus hyacinthinus*	*S.* ser. Braenderup
IVESON et al. (2009)	Australia	*Eudyptula minor, Anous stolidus, Anous tenuirostris, Onychoprion fuscatus*	*S.* ser. Bovismorbificons, *S.* ser. Derby, *S.* ser. Panama, *S.* ser. Saintpaul, *S.* ser. Muenchen, *S.* Typhimurium, *S.* ser. Adelaide, *S.* ser. Havana, *S.* ser. Infantis
DIMITROV et al. (2009)	Antarctica	*Pygoscelis papua*	*S.* ser. Typhimurium, *S.* ser. Enteritidis
KITADAI et al. (2010)	China	*Grus monacha, Grus vipio, Grus grus*	*S.* ser. Typhimurium, *S.* ser. Hvittingfoss, *S.* ser. Abaetetuba, *S.* ser. Enteritidis, *S.* ser. Konstanz, *S.* ser. Pakiston

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Table 1. Continuation.

Reference	Location	Bird species	*Salmonella* serotypes
SOUSA et al. (2010a)	Brazil	*Theristicus caudatus, Zenaida auriculata, Cariama cristata*	*S.* ser. Muenchen, *S.* ser. Enteritidis, *S.* ser. Saintpaul, *S.* ser. Pullorum
PHALEN et al. (2010)	United States	*Bubulcus ibis*	*S.* ser. Bredeney, *S.* ser. Anatum, *S.* ser. Ibadon, *S.* ser. Mississipi, *S.* ser. Oranienburg, *S.* ser. Braenderup, *S.* ser. Typhimurium (more than ten serotypes)
BRUNTHALER et al. (2010)	Australia	*Pyrrhula pyrrhula, Carduelis spinus, Carduelis chloris*	*S.* ser. Typhimurium (*)
SOUSA et al. (2010b)	Brazil	*Columba livia*	*S.* ser. Typhimurium
KHIDHIR (2010)	Iraq	*Streptopelia decaocto, Columba livia*	*S.* ser. Typhimurium
PENNYCOTT et al. (2010)	Scotland	*Carduelis carduelis, Carduelis spinus, Parus major, Passer montanus, Passer modularis, Fringilla montifringilla*	*S.* ser. Typhimurium (DT40, DT85, DT41, DT56) (*)
HUGHES et al. (2010)	United Kingdom	*Passer domesticus, Carduelis chloris, Carduelis spinus, Streptopelia decaocto, Columba palumbus*	*S.* ser. Typhimurium (DT56, DT40, DT56, DT41, PT U277) (*)
MIRZAIE et al. (2010)	Iran	*Passer domesticus*	*S.* ser. Typhimurium, *S.* ser. Enteritidis, *S.* ser. Montevideo
VIGO et al. (2011)	Argentina	*Pygoscelis adeliae, Larus dominicanus*	*S.* ser. Enteritidis
LÓPEZ-MARTÍN et al. (2011)	Chile	*Larus dominicanus, Leucophaeus pipixcan*	*S.* ser. Enteritidis, *S.* ser. Anatum *S.* ser. Senfteberg, *S.* ser. Infantis
MOLINA-LOPEZ et al. (2011)	Spain	*Buteo buteo, Gyps fulvus, Athene noctua, Bubo bubo*	*S.* ser. Bredeney, *S.* ser. Scheissheim, *S.* ser. Rissen, *S.* ser. Diarizonae, *S.* ser. Derby, *S.* ser. Schwarzengrund, *S.* ser. Muenster
FOTI et al. (2011)	Italy	*Sylvia atricapilla*	*S.* ser. bangori 48:z35
VICO; MAINAR-JAIME (2011)	Spain	*Passer domesticus, Sturnus vulgaris, Sylvia atricapilla, Turdus merula, Erithacus rubecula, Luscinia megarhynchos, Sylvia melanocephala*	*S.* ser. Typhimurium, *S.* ser. Braendenburg, *S.* ser. Anatum, *S.* ser. Arizonae, *S.* ser. Mikawasima, *S.* ser. Bredeney, *S.* ser. Reading, *S.* ser. Houtenae, *S.* ser. Kapemba
VELARDE et al. (2012)	Spain	*Turdus philomelos*	*S.* ser. Hessarek (*)
HERNANDEZ et al. (2012)	United States	*Spinus spinus*	*S.* ser. Typhimurium (*)
HERNANDEZ et al. (2012)	Sweden	*Falco peregrinus*	*S.* ser. Pajala
HAMER et al. (2012)	United States	*Agelaius phoeniceus*	*S.* ser. Dublin, *S.* ser. Typhi, *S.* ser. Enteritidis, *S.* ser. Paratyphi, *S.* ser. Gallinarium
LA SALA et al. (2013)	Argentina	*Larus atlanticus, Larus dominicanus*	*S.* ser. Typhimurium, *S.* ser. Gallinarum
BOTTI et al. (2013)	Italy	*Columba livia, Passer domesticus, Garrulus glandarius, Buteo buteo, Asio otus, Tyto furcata, Strix aluco, Larus* spp.	*S.* ser. Typhimurium (DT104, DT12, DT193, DT302), *S.* ser. Enteritidis (PT4) (more than ten serotypes)

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Table 1. Continuation.

Reference	Location	Bird species	*Salmonella* serotypes
ANDRÉS et al. (2013)	Spain	*Sturnus vulgaris, Motacilla alba, Columba livia, Sylvia atricapilla, Passer domesticus, Hirundo rustica, Cettia cetti*	*S.* ser. Typhimurium 4,12:i:1,2, *S.* ser. Arizona, *S.* ser. Diarizona, *S.* ser. Mikawasima 6:7:y:e,n,z15, *S.* ser. Anatum
BORRELLI et al. (2013)	Italy	*Apus apus*	*S.* ser. Infantis
PEDERSEN et al. (2013)	United States	*Cygnus olor*	*S.* ser. Typhimurium (DT104), *S.* ser. Braenderup
SULZNER et al. (2014)	United States	*Cathartes aura*	*S.* ser. Anatum, *S.* ser. Newport, *S.* ser. Montevideo, *S.* ser. Arizonae, *S.* ser. Enteritidis, *S.* ser. Typhimurium
LAWSON et al. (2014)	England	*Carduelis chloris, Passer domesticus*	*S.* ser. Typhimurium (*)
AFEMA (2014)	Uganda	*Mimus migrans, Ceryle rudis, Egretta garzetta, Ardeola ralloides, Alopochen aegyptiacus, Anas undulata, Ardea goliath, Ardea cinerea, Ardea melanocephala, Mesophoyx intermedia, Burhinus vermiculatus*	*S.* ser. Stanleyville, *S.* ser. Typhimurium, *S.* ser. Newport, *S.* ser. Chandans, *S.* ser. Kentucky (more than ten serotypes)
FUKUI et al. (2014)	Japan	*Passer monatus*	*S.* ser. Typhimurium (DT40) (*)
DIAS et al. (2014)	Brazil	*Chrysomus ruficapillus, Sicalis flaveola*	*Salmonella enterica*
BLANCO (2015)	Spain	*Milvus milvus*	*S.* ser. Typhimurium 4,5,12:i
KRAWIEC et al. (2015)	Poland	*Anas platyrhynchos, Carduelis cabaret, Cyanistes caeruleus, Corvus fringillarius, Sturnus vulgaris, Carduelis spinus, Carduelis chloris*	*S.* ser. Typhimurium 4,12:i:1,2, *S.* ser. Infantis 6,7:v:1,5, *S.* ser. Virchow, *S.* ser. Hadar, *S.* ser. Salamae, *S.* ser. Houtenae
VAN ANDEL et al. (2015)	New Zealand	*Notiomystis cincta, Vanellus miles, Philesturnus carunculatus*	*S.* ser. Saintpaul, *S.* enterica subspecies houatenae (*)
HERNANDEZ et al. (2016)	United States	*Eudocimus albus*	*S.* ser. Anatum, *S.* ser. Baildon, *S.* ser. Newport, *S.* ser. Rubislow, *S.* ser. Typhimurium (more than ten serotypes)
ROUFFAER et al. (2016)	Belgium	*Passer domesticus*	*S.* ser. Typhimurium (DT99, DT195)
HAESENDONCK et al. (2016)	Belgium	*Columba livia*	*S.* ser. Enteritidis (PT4)
LIAKOPOULOS et al. (2016)	Argentina	*Larus dominicanus*	*S.* ser. Heidelberg
JURADO-TARIFA et al. (2016)	Spain	*Gyps fulvus, Falco naumanni, Falco tinnunculus, Accipiter nisus, Milvus nigrans, Buteo buteo, Asio otus, Bubo bubo, Athene noctua, Otus scops, Anas platyrhynchos, Anser anser*	*S.* ser. Typhimurium, *S.* ser. Enteritidis, *S.* ser. Mikawasima, *S.* ser. Montevideo, *S.* ser. Bredney, *S.* ser. Anatum
AFEMA; SISCHO (2016)	Uganda	*Mimus migrans, Ceryle rudis, Alopochen aegyptiacus, Ardea cinerea* (more than ten species)	*S.* ser. Chandans, *S.* ser. Heidelberg, *S.* ser. Newport, *S.* ser. Senftemberg, *S.* ser. Stanleyvilte

Continue...

Table 1. Continuation.

Reference	Location	Bird species	*Salmonella* serotypes
CAMACHO et al. (2016)	Iberian Peninsula	*Ciconia ciconia*	*Salmonella* spp.
EBERT et al. (2016)	Brazil	*Larus dominicanus*	*S.* ser. Enteritidis
BROBEY et al. (2017)	United States	*Cyanocitta cristata, Sphyrapicus varius, Melanerpes carolinus, Columbina inca, Spinus tristis, Cardinalis cardinalis, Zenaida macroura*	*Salmonella* spp.

*Studies in which outbreaks or deaths occurred

Other studies reporting *Salmonella* serotypes in asymptomatic migratory birds were reported in United Kingdom (FRICKER, 1984), Czech Republic (LITERÁK et al., 1992), Canada (QUESSY; MESSIER, 1992) Sweden (PALMGREN et al., 2000), Argentina (FRERE et al., 2000; LIAKOPOULOS et al., 2016), Brazil (ALBARNAZ et al., 2007; EBERT et al., 2016) and Chile (LÓPEZ-MARTÍN et al., 2011).

This study presents published scientific evidence suggesting the direct and indirect role of wild birds in the transmission of *Salmonella* to humans. Foremost, there are no real evidence for the direct transmission of free-living birds to humans, in addition to the rare cases that occur under exceptional circumstances. Theoretically, several human infections may be transmitted by these animals. However, the scientific base for most of these associations remains speculative. The review demonstrated that carrier birds are probably important in maintaining active sources of infections, which may implicate in epizooties of salmonellosis. However, most of the findings are related to the presence of the pathogen in an asymptomatic manner and the influence of environmental factors in the epidemiology of extensive epizooties remain unknown.

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