Wild Griffon Vultures (Gyps fulvus) as a Source of Salmonella and Campylobacter in Eastern Spain

Clara Marin1*, Maria-Dolores Palomeque1, Francisco Marco-Jiménez2, Santiago Vega1

1 Instituto de Ciencias Biomédicas, Departamento de Producción Animal, Sanidad Animal, Salud Pública Veterinaria y Ciencia y Tecnología de los Alimentos, Facultad de Veterinaria, Universidad CEU-Cardenal Herrera, Alfara del Patriarca, Valencia, Spain, 2 Instituto de Ciencia y Tecnología Animal, Universidad Politécnica de Valencia, Valencia, Spain

Abstract

The existence of Campylobacter and Salmonella reservoirs in wildlife is a potential hazard to animal and human health; however, the prevalence of these species is largely unknown. Until now, only a few studies have evaluated the presence of Campylobacter and Salmonella in wild griffon vultures and based on a small number of birds. The aim of this study was to evaluate the presence of Campylobacter and Salmonella in wild griffon vultures (n = 97) during the normal ringing programme at the Cintores Observatory in Eastern Spain. In addition, the effect of ages of individuals (juveniles, subadult and adult) on the presence were compared. Campylobacter was isolated from 1 of 97 (1.0%) griffon vultures and identified as C. jejuni. Salmonella was isolated from 51 of 97 (52.6%) griffon vultures. No significant differences were found between the ages of individuals for the presence of Salmonella. Serotyping revealed 6 different serovars among two Salmonella enterica subspecies; S. enterica subsp. enterica (n = 49, 96.1%) and S. enterica subsp. salamae (n = 2, 3.9%). No more than one serovar was isolated per individual. The serovars isolated were S. Typhimurium (n = 42, 82.3%), S. Rissen (n = 4, 7.8%), S. Senftenberg (n = 3, 5.9%) and S. 4,12b:– (n = 2, 3.9%). Our results imply that wild griffon vultures are a risk factor for Salmonella transmission, but do not seem to be a reservoir for Campylobacter. We therefore rule out vultures as a risk factor for human campylobacteriosis. Nevertheless, further studies should be undertaken in other countries to confirm these results.

Introduction

Campylobacteriosis and salmonellosis are the two most prevalent zoonoses worldwide [1]. These zoonoses represent an important public health problem and controlling the disease has become a vital challenge in most countries [1–7]. Campylobacteriosis and salmonellosis were responsible respectively for 212,064 and 99,020 cases of illnesses in the EU [1]. Moreover, campylobacteriosis is the most common cause of acute bacterial gastroenteritis in the EU [1,8,9]. Apart from acute gastroenteritis, campylobacteriosis may lead to more severe, occasionally long-term sequel such as Guillain-Barré syndrome, reactive arthritis and irritable bowel syndrome [10,11]. The high and rapidly increasing incidence and the capacity of Campylobacter to cause considerable morbidity make campylobacteriosis a public health problem of considerable magnitude [2]. However, compared to Salmonella, few outbreaks are reported, and most campylobacteriosis cases are considered to be “sporadic” rather than a part of recognised outbreaks, with a seasonal peak in summer [12].

The existence of Campylobacter and Salmonella reservoirs in wildlife has been considered a potential hazard to animal and human health; however, the number of wildlife species acting as reservoirs is unknown [13]. Salmonella and Campylobacter species have been isolated from a wide variety of wild birds, although there is great variation between taxa [14–24]. Nevertheless, several studies have suggested that wild birds are important in the epidemiology of human and livestock salmonellosis [25–30]. In contrast, other studies suggest that they do not present a major public health hazard, given the low numbers and short duration of salmonella excretion [31], emphasising the controversial nature of the subject matter.

The transmission pathway of Campylobacter included direct and indirect contact with infected animals, people and environment [2,25–28]. In this context, the shedding of wild birds faeces into the environment has been identified as a significant reservoir of Campylobacter spp. [32]. For example, exposure to contaminated wild bird faeces in playgrounds has been recognised as a potential environmental source of campylobacteriosis, particularly for children [33]. Avian faecal matter found in children’s playgrounds was positive for C. jejuni in both dried and fresh samples [34]. Recently, Waldenström et al. [32] reported that to better understand Campylobacter biology in wild birds, a number of fundamental questions need to be addressed to elucidate the role of wild birds as reservoirs for Campylobacter, to identify host-specific strains, how long wild birds are colonised for and whether the duration and intensity of bacterial shedding vary depending on strain origin. Furthermore, does colonisation of C. jejuni have any measurable effects on body condition, or are wild birds asymptomatic carriers similar to chickens?
Specifically, in wild griffon vultures both Molina-Lopez et al. [13] and Millan et al. [15] evaluate the presence of Salmonella and, to our best knowledge, only Molina-Lopez et al. [13] evaluate the presence of Campylobacter. In this context, Spain holds the most important Griffon vulture population in Europe [35–37]. Protection of breeding colonies, limited direct persecution (shooting) and a reduction in the use of poisons have assisted the species’ recovery [37]. This would not have been possible without the availability of an important Griffon vulture population in Europe [35–37]. Protec-tion of breeding colonies, limited direct persecution (shooting) and a reduction in the use of poisons have assisted the species’ recovery [37]. This would not have been possible without the availability of an important Griffon vulture population in Europe [35–37].

The aim of this study was to investigate occurrence of Campylobacter and Salmonella in wild griffon vultures and identify the isolates to species.

Materials and Methods

The Ethics and Animal Welfare Committee of the Universidad CEU Cardenal Herrera approved this study. All animals were handled according to the principles of animal care published by Spanish Royal Decree 1201/2005 (BOE, 2005; BOE = Official Spanish State Gazette). The Department of Infrastructure, Planning and Environment of the Valencian Regional Government (Generalitat Valenciana) granted permission to take samples. This study was conducted within the conservation project for endangered species in the Valencia Region.

The study population is located in eastern Spain within the province of Castellón. Wild griffon vultures were captured in September and October 2013 at the Cinctorres Observatory (40°33′N, 0°13′W, Castellón province, Eastern Spain), during the observatory’s normal ringing programme. A total of 97 griffon vultures were captured using a remotely activated purpose-built cage (Figure 1). The age of the animals was determined according to the plumage characteristics and the colour of the bill and eye, classified as juvenile (less than 2 years), subadult (between 2 to 5 years) and adult (more than 5 years). From each chick, two cloacal samples were taken using sterile cotton swabs (Cary Blair sterile transport swabs, DELTALAB). We inserted sterile cotton swabs 1 to 2 cm into the cloaca to collect a suitable sample. Each sample was analysed for Campylobacter and for Salmonella isolation. Additionally, blood samples were collected from the brachial vein (about 5 mL) and transferred to 200 μl pre-refrigerated saline test tubes and stored at 0–4 °C. Hematocrit concentration was measured using heparinised micro-hematocrit capillary tubes centrifuged for 5 min at 10,000 rpm and read in a micro hematocrit tube reader.

Detection of Campylobacter spp.

Bacteriological culture was performed in accordance with ISO 10272-1:2006 for the detection of Campylobacter spp. (Anonymous, 2006). Moreover, all samples were tested by direct culture. Pre-enriched samples were cultured only if direct culture was negative. Cloacal swabs were directly streaked onto the two selective agar plates (mCCDA and Preston, AES laboratories, Bruz Cedex, France) and incubated at 41.5±1 °C for 44±4 hours as reported above. Moreover, cloacal swabs were pre-enriched in 1:10 vol/vol Bolton Broth (OXOID, Dardilly, France) and then pre-incubated at 37±1 °C for 5±1 hours. Then, the pre-enriched broth was incubated at 41.5±1 °C for 43±1 hours. Afterwards, 10 μl of the sample was cultured on the two selective agar plates (mCCDA and Preston agar) and incubated as described above. Campylobacter-like colonies were purified on blood agar and identified to species level on the basis of standard procedures comprising tests for hippurate and indoxyl acetate hydrolysis, catalase production, and susceptibility to cephalothin and nalidixic acid.

Detection of Salmonella spp.

The procedure was based on ISO 6579: 2002 recommendations (Annex D). Samples were pre-enriched in 1:10 vol/vol Buffered Peptone Water 2.5% (BPW, Scharlab, Barcelona, Spain) and then incubated at 37±1 °C for 18±2 hours. The pre-enriched samples were transferred onto Semi-Solid Modification Rappaport Vassiliadis agar plate (MSRV, Dilco, Valencia, Spain) and incubated at 41.5±1 °C for 24–48 hours. The culture obtained in MSRV was inoculated onto Xylose–Lysine–Desoxycholate (XLD, Liofilchem, Valencia, Spain) and Xylose–Lysine–Tergitol-4 (XLT4, Biokar Diagnostics, Pantin Cedex, France) and incubated at 37±1 °C for 24–48 hours. After incubation, 5 typical colonies were streaked onto the surface of pre-dried nutrient agar plates (Scharlab, Barcelona, Spain) 37±1 °C for 24±3 hours. Then, a biochemical test using API (API-20, bioMerieux, Madrid, Spain) was performed to confirm Salmonella spp. Moreover, Salmonella strains isolated were serotyped by the Ministry of Agriculture, Fisheries and Food Reference Laboratory (Algete, Madrid, Spain) in accordance with Kauffman-White-Le Minor technique.

Statistical analyses

We use a generalised linear model (GLM) to compare the body mass and hematocrit against the ages of individuals (Juveniles, subadult and adult). As previously, a GLM which assumed a binomial distribution for Salmonella shedding was fitted to the data to determine whether there is a main effect of the ages of individual griffon vultures. A P value of less than 0.05 was considered to indicate a statistically significant difference. Data are presented as least squares means ± standard error of the least squares means. All statistical analyses were carried out using a commercially available software program (SPSS 16.0 software package; SPSS Inc., Chicago, Illinois, USA, 2002).

Results

All the griffon vultures tested in this study were healthy, according to the hematocrit level and body mass (Table 1). No significant differences were found between ages of individuals for body mass and hematocrit value.

Campylobacter was isolated from 1 of 97 (1.0%) griffon vultures and identified as C. jejuni. Salmonella was isolated from 51 of 97 (52.6%) griffon vultures. No significant differences were found between the ages of individuals for the presence of Salmonella (Table 2).

Serootyping revealed 6 different serovars among two Salmonella enterica subspecies (Table 3); S. enterica subsp. enterica (n = 49, 96.1%) and S. enterica subsp. salmonae (n = 2, 3.9%). No more than one serovar was isolated per individual. The serovars isolated were S. Typhimurium (n = 42, 82.3%), S. Rissen (n = 4, 7.8%), S. Senftenberg (n = 3, 5.9%) and S. 4,12b[−] (n = 2, 3.9%).

Discussion

Our experiment was carried out to examine colonisation of Salmonella and Campylobacter in wild griffon vultures. To our knowledge, this is the only study in the scientific literature to evaluate a considerable sample size from a healthy population of wild griffon vultures. Hematocrit values are a useful indicator of the general state of health in raptors [38,39]. The mean hematocrit values obtained were similar to those described previously in the literature for griffon vultures [40]. The shedding of wild bird faeces into the environment has been identified as a significant reservoir of Campylobacter spp. [32] and we tested the hypothesis that wild griffon vultures could also be a
potential reservoir for Campylobacter. Wild birds may factor into both Campylobacter and Salmonella epidemiology by coming into contact with farm and food production animals and moving great distances throughout the landscape [41,42]. Wild birds can function as animal vectors, spreading diseases along migration routes and transferring zoonotic bacteria throughout large parts of the world in faecal droppings [43]. In our study, C. jejuni was identified in griffon vulture, in agreement with Molina-Lopez et al. [13] and consistent with observations in other species of wild birds [41,44]. Recently, Griekspoo et al. [45] demonstrated that C. jejuni isolated from wild birds are in general distinct from those isolated from human campylobacteriosis and food animals. Thus, our results suggest that wild griffon vultures are relatively poorly colonised by Campylobacter and are likely of little importance in human campylobacteriosis. To verify this, future studies will need to evaluate the genotypes of Campylobacter isolates from wild griffon vultures and their relationship to those isolated from human campylobacteriosis.

Nevertheless, the positive percentage of Salmonella detected in this study among wild griffon vultures was high (52.6%) and these results are inconsistent with those of other studies, in which the detection was lower than 10% [13,17,23,46,47]. The most plausible explanation for the high detection rates of Salmonella could be associated with the feed. In our study, 82.3% of Salmonella isolates belong to S. Typhimurium, a serovar of particular public health significance. This is, together with S. Enteritidis, one of the most frequently reported serovars involved in human salmonellosis [1,48]. Salmonella Typhimurium has previously been described in griffon vulture [13,15] and is considered the most common serotype found in wild birds [49–51]. In Spain, after the appearance of the first cases of Bovine Spongiform Encephalopathy, griffon vultures almost exclusively fed on swine carcasses [52,53]. According to the latest studies, S. Typhimurium is the most prevalent serotype isolated in swine production [54–56]. Although it has previously been posited that raptors may have acquired the bacteria by ingesting small passerines, mice or pigeons [15,57], our findings suggest the possibility that vultures may be contaminated by ingesting pig carcasses. In raptors, it has been reported that Salmonella may indicate infection in other animal populations (e.g. small mammals and passerine birds) [58,59]. Millán et al. [15] suggest that wild griffon vultures could acquire the bacteria from sources such as livestock carcasses or human residues. However, further studies are necessary to determine the origin of the Salmonella reported here and the exact role, if any, of the pig in transmitting the infection to griffon vultures. Nevertheless, our results underline the need to consider the griffon vultures as a potential infection source of this bacterial pathogen, and the zoonotic risk for the general population.

Table 1. Measurements of body mass and hematocrit in the Spanish wild griffon vultures (Gyps fulvus) according to age.

| Age     | n  | Body mass (g) | Hematocrit (%) |
|---------|----|---------------|----------------|
| Juveniles | 5  | 8508±76       | 45.2±0.4       |
| Subadult | 11 | 8250±200      | 45.8±1.0       |
| Adult   | 81 | 7498±297      | 46.8±1.5       |
| All     | 97 | 8447±70       | 45.4±0.4       |

The age of the animals was determined according to the plumage characteristics and the colour of the bill and eye (juvenile, less than 2 years; subadult, between 2 to 5 years; adult, more than 5 years). Data are presented as least squares means ± standard error of the least squares means.

n: number of birds analysed.

doi:10.1371/journal.pone.0094191.t001
population should be considered. As an example, Davies and Wales [42] recently illustrated the potential of domestic cereal crops to pose a risk of Salmonella exposure for livestock via compound feedstuffs.

All serovars identified have previously been associated with human salmonellosis. Although the other serovars may be considered types rarely associated with human disease, they have also been involved in human salmonellosis. For example, S. Rissen, which has previously been described in griffon vulture [13], is commonly isolated from pigs and pork products, whereas it is rarely reported worldwide from human sources, except for Thailand, where in recent years a remarkable rise in infection cases has been emerging [60–63]. S. Senftenberg has been isolated from wild birds in northern England [16]. Although S. Senftenberg is not listed among the top 20 serotypes implicated in human illness [64], the organism is routinely detected in humans and has been recognised in clinical non-human cases of disease (ranked #10 in 2006) and in non-clinical non-human cases (ranked #4), supporting the potential for the emergence of this strain type in human disease [65]. In 2007, the Health Protection Agency Laboratory of Enteric Pathogens reported 51 human isolates of Salmonella Senftenberg in England and Wales [66]. In addition, to our best knowledge, Salmonella subsp. salamae has not been described in wild birds. It has been documented in reptiles and red fox [17,67] and one case of S. salamae infection associated with consumption of reptile meat in humans has been reported [60].

This study showed wild griffon vultures as a risk factor for Salmonella infection, but indicates that wild griffon vultures are poor bacterial reservoirs for Campylobacter and likely of minimal importance in human campylobacteriosis.

Acknowledgments

We wish to thank the technical support of Martin Surroca, Xema Gil and all the members of the research group “Improvement of the Food Safety related with the Production System and Final Products” (Veterinary Faculty, University CEU-Cardenal Herrera).

Author Contributions

Conceived and designed the experiments: CMFJ SV. Performed the experiments: CM MDP. Analyzed the data: CM FJ. Contributed reagents/materials/analysis tools: CM MDP FJ SV. Wrote the paper: CM FJ.

Table 2. Percentage of Salmonella-positive wild griffon vultures from different ages.

| Age       | n   | Salmonella (%) |
|-----------|-----|----------------|
| Juveniles | 5   | 80.0           |
| Subadult  | 11  | 54.5           |
| Adult     | 81  | 50.6           |
| All       | 97  | 52.6           |

The age of the animals was determined according to the plumage characteristics and the colour of the bill and eye (juvenile, less than 2 years; subadult, between 2 to 5 years; adult, more than 5 years).

n: number of birds analysed.

doi:10.1371/journal.pone.0094191.t002

References

1. EFSA (2012) European Food Safety Authority. The European Union Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Food-borne Outbreaks in 2010. EFSA Journal 10: 2597.

2. Kapperud G, Espeland G, Wahl E, Walde A, Herikstad H, et al. (2003) Factors associated with increased and decreased risk of Campylobacter infection: a prospective case-control study in Norway. Am J Epidemiol 158: 234–242.

3. Mermin J, Hutwagner L, Vugia D, Shallow S, Daily P, et al. (2004) Reptiles, amphibians, and human Salmonella infection: a population-based, case-control study. Clin Infect Dis 39: 253–261.

4. de Jong B, Anderson Y, Ekdahl K (2005) Effect of regulation and education on reptile-associated salmonellosis. Emerg Infect Dis 11: 398–403.

5. Nakada I, Kuroki T, Kato Y, Suzuki R, Yami S, et al. (2005) Prevalence of Salmonella spp. in pet reptiles in Japan. J Vet Med Sci 67: 97–101.

6. FAO/WHO (2009) Technical Meeting on reptile-associated salmonellosis. Emerg Infect Dis 11: 398–403.

7. Lafuente S, Bellido JB, Moraga FA, Herrera S, Yague A, et al. (2013) Salmonella enterica subsp. enterica Typhimurium 4,5,12:i:- in France. J Med Microbiol 62: 1291–5.

8. van Pelt W, de Wit M, Wannet W, Ligtvoet E, Widdowson MA, et al. (2003) Outbreaks in 2010. EFSA Journal 10: 2597.

9. Havelaar AH, Haagsma JA, Siersema PD, De Wit NJ, Havelaar AH (2010) Disease burden of post-infectious irritable bowel syndrome in The Netherlands. Epidemiol Infect 138: 1650–1656.

10. Thompson SA, Blaser MJ (2000) Pathogenesis of Campylobacter fetus infections. In: Nachamkin I, Blaser MJ, editors. Campylobacter. 2nd Edn. American Society for Microbiology, Washington, D.C. pp. 321–347.

11. Haagsma JA, Siersema PD, De Wit NJ, Havelaar AH (2010) Disease burden of post-infectious irritable bowel syndrome in The Netherlands. Epidemiol Infect 138: 1650–1656.

12. Thompsoon SA, Blaser MJ (2000) Pathogenesis of Campylobacter fetus infections. In: Nachamkin I, Blaser MJ, editors. Campylobacter. 2nd Edn. American Society for Microbiology, Washington, D.C. pp. 321–347.

13. Molina-Lopez RA, Valverd N, Martin M, Mateu E, Ohen E, et al. (2011) Wild raptors as carriers of antimicrobial-resistant Salmonella and Campylobacter strains. Vet Res 40: 565.

14. Wilson JE, MacDonald JW (1967) Salmonella infection in wild birds. Br Vet J 123:212–8.

15. Milla´n J, Aduriz G, Moreno B, Juste RA, Barral M (2004) Salmonella isolates from wild birds and mammals in the Basque Country (Spain). Rev sci tech Off int Epiz 23:903–911.

16. Hughes LA, Shopland S, Wigley P, Bradon H, Leatherbarrow A, et al. (2008) Characterisation of Salmonella enterica serotype Typhimurium isolates from wild birds in northern England from 2005–2006. BMC Vet Res 4:14–13.

17. Botti V, Navillod PV, Domienis L, Orasa K, Pepe E, et al. (2013) Salmonella spp. and antibiotic-resistant strains in wild mammals and birds in north-western Italy from 2002 to 2010. Vet Ital 49:195–202.

18. Chuma T, Hashimoto S, Okamoto K (2000) Detection of thermophilic Campylobacter from sparrows by multiplex PCR: the role of sparrows as a source of contamination of broilers with Campylobacter. J Vet Med Sci 62:1291–5.

19. Petersen L, Nielsen EM, Engeb J, On SL, Dietz HH (2001) Comparison of genotypes and serotypes of Campylobacter jejuni isolated from Danish wild mammals and birds and from broiler flocks and humans. Appl Environ Microbiol 67:3115–21.

20. Bromann T, Palmgren H, Bergstrøm S, Sellin M, Waldenstrom J, et al. (2002) Campylobacter jejuni in black-headed gulls (Larus ridibundus): prevalence, genotyping, and antibiotic susceptibility. J Clin Microbiol 40:1562–1567.

Table 3. Salmonella serovars isolated from wild griffon vultures (Gyps fulvus).

| Subspecies Serovar | n   |
|---------------------|-----|
| enterica Monophasic Typhimurium 4,12:i:- | 1 |
| enterica Monophasic Typhimurium 4,12:i:- | 40 |
| salamae 4,12:i:- | 2 |
| enterica Senftenberg 1,3,19: g3,a1,- | 3 |
| enterica Rissen 6,7: f,g: - | 4 |
| enterica Typhimurium 4,12:i: 1,2 | 1 |

n: number of strains isolated.

doi:10.1371/journal.pone.0094191.t003
