Zoonoses in Pet birds: review and perspectives

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Abstract

Pet birds are a not-so-well known veterinarian's clientship fraction. Bought individually or in couples, as families often do (which is a lucrative business for pet shops or local breeders) or traded (sometimes illegaly) for their very high genetic or exotic value, these birds, commonly canaries, parakeets or parrots, are regularly sold at high prices. These animals however are potential carriers and/or transmitters of zoonotic diseases. Some of them could have an important impact on human health, like chlamydophilosis, salmonellosis or even highly pathogenic avian influenza A H5N1. This review paper although non exhausive aims at enlightening, by the description of several cases of birds-humans transmission, the risks encountered by birds owners, including children. Public health consequences will be discussed and emphasis will be made on some vector-borne diseases, known to be emergent or which are underestimated, like those transmitted by the red mite *Dermanyssus gallinae*. Finally, biosecurity and hygiene, as well as prevention guidelines will be developed and perspectives proposed.

Keywords: zoonoses, petbirds, public health, trade, biosecurity, infectious diseases, veterinary medicine, canaries, psittacines, passeriforms.

1. Introduction

The term « Pet bird » designates birds housed and breeded for an exclusively ornamental use. This category includes and will refer later in this paper to mainly Passeriformes (e.g. canaries, finches, sparrows: see table 1), also called songbirds, and Psittaciformes (parrots, parakeets, budgerigars, love birds: see table 1) [1-3], and is a rather unknown vet's clientship fraction. A statistical study made by the American Veterinary Medicine Association (AVMA) repertoried 11 to 16 millions companion and exotic birds in the United States in 2007 [4]. In 2010, following a study made by the FACCO (chambre syndicale des Fabricants d'Aliments préparés pour Chiens, Chats, Oiseaux et autres animaux familiers), 6 millions of pet birds are owned by French people[5]. In Belgium, every bred bird has to be identified by a ring sharing a number directly connected to the breeding's owner (Arrêté du Gouvernement wallon fixant des dérogations aux mesures de protection des oiseaux, AM 2003-11-27). In 2011, the Association Ornithologique de Belgique (AOB) recensed 249 ornithologic societies authorized to identify their birds by an official ring.

Many families own their « kitchen petbird », which represent a lucrative business for pet shops or local breeders , as a single canary male is sold around 30 euros in Belgium and a female around 20 euros. Prices are about the same for zebra finches or budgerigars, and 50% to 100% higher for « special » finches like Gould diamonds. Bird fairs and live birds markets also gathered a lot of people. Besides, some species are bred for their very high value; for example, in the case of canaries, male and female breeding stock reproductors with recognized genetic potential are presented in national and international contests for their posture (the Bossu Belge), their colour (red mosaic) or for their song (Harzer). As a consequence, their offsprings could be sold at high for rising prices. Finally, exotic birds like greater psittaciforms (parrots, e.g. ara, cockatoo), legally or illegaly traded from for example Asia or South America, remain high in the classement of popular pets and are also profusely represented in zoos and parks.

Notwithstanding these socio-economic facts, these animals are potential carriers and/or transmitters of zoonotic diseases. Some of these pathologies could have an important impact on human health, like chlamydophilosis, salmonellosis or even highly pathogenic avian influenza A H5N1, but also have an economic impact if some of these pathogens are spread via carriers or vectors like wild birds, human beings, insects or mites to poultry breeding units or cattle facilities [6], entering then the food chain. The aim of this review is to enlighten and discuss the risks encountered by birds handlers (including children), professional workers (e.g. veterinarians, traders, shop owners) in particular and human population in general, and to assess the eventual health and economic consequences, and propose some guidelines to prevent transmission from such birds to humans.

2. Main transmission routes

2.1 Direct contact :

2.1.1 Households

Passeriforms and psittacines are housed under different conditions, due to their respective behavior. Indeed, psittacines, especially parrots, are more aggressive than passerines and would then rather be kept in pairs than groups [2, 3]. However, relatively high numbers of budgerigars can be gathered temporarily in the same cage for example in petshops facilities or markets.

Besides the “kitchen-housing”, usually a single cage containing typically a couple of canaries or budgerigars for example, passeriform species are preferently kept in captivity in two different types of aviaries [2]: mixed ornamental aviaries and breeding facilities. The first type is usually a big wire-netting space (up to 10 m^3)

located outside and sometimes with different species kept together, mostly for ornamental purposes [2]. In the second type, relatively large numbers of the same species, depending on the breeding size and the breeding purpose (petshops versus competitions) are maintained in pairs, mostly indoors (but sometimes with a partial access to the outside). In both types, new individuals are regularly introduced, in the first case in a purpose of ornamental diversification and in the second, to bring new blood in the genetic diversity of birds. These movements are supposed to be preceded by a quarantine of the new incomers.

Several times a year, performant birds are brought to shows and competitions, where exchange or selling could occur, and by the same way, transmission of pathogens, as this was well illustrated by several authors ([7, 8]). In the case of the “kitchen-canary”, this could be interesting to mention that in the summer, the cages could be moved outside, in order to allow the bird to sunbath. This could be a favorisating condition for contacts between wild and captive passerines (Boseret, pers. obs.). This is also not a rare event to have canaries escaped from their cage, with a potential risk to disseminate pathogens into a wild avian population, pathogens which they could have contracted in their original breeding facility or from humans (for example, chlamydophilosis [8]). Predators, like cats, could also be infected. The question whether birds’ predators could become eventually sentinels has to be raised and needs to be further investigated. Finally, one should not forget other potential zoonotic pathogens shedders, like arthropods or rodents which could also find an easily reachable source of food in cages (Boseret, pers. obs.) or directly on birds themselves, as this could be the case for haematophagous insects. [9, 10].

2.1.2 Petshops, bird fairs and markets

In direct relationship with local breeders, housing of birds in petshop facilities enhances the risk of transfer of several zoonoses, like for example chlamydophilosis [8]. Cages are indeed often overcrowded, filled with birds from mixed origin [8]. The overcrowding also induces intense stress to the birds due to the fight for females, territory (which is extremely limited in this case) or food. This will cause quick debilitation of weakest individues and higher sensitivity to infections [11]. This situation is particularly true in live animals markets as represented in numerous studies performed in Asian countries [12, 13]. Unfortunately, no data are available for European countries. But this is a quite frequent observation that petbirds are sharing the same space than poultry, making easier transmission of pathogens and parasites (e.g. *Dermanyssus gallinae*).

Finally, bird fairs constitute a last example of contamination possibility. In these regional, national or international gatherings, breeders meet each other and present their production, in a context of championships. Cases of transmission of *Chlamydophila psittaci* from birds-to-human in such conditions have been recently related in France and the Netherlands by respectively Belchior, and Berk and collaborators [7, 14]. In both cases, clinical symptoms were developed by patients and led in several cases to hospitalization.

2.1.3 International trade

As illustrated by several authors, controlled as well as non-controlled movements of birds could enhance the introduction of zoonotic pathogens (like chlamydophilosis or highly pathogenic avian influenza A) and their vectors (like *D. gallinae*) in non-endemic countries [15-18]. Indeed this remains still problematic to obtain accurate estimation of wildlife trade as most of the time it is conducted through non-official and non-legal routes ([19-21]). It must be pointed out that illegal wildlife trade for e.a. companion or ornamental pets ranks in terms of economic activities second to the illegal narcotic trade ([22]). In addition to this huge financial impact, this situation reflects also a non-negligeable threat for human health since it facilitates multiplication and circulation of zoonotic pathogens and should facilitate adaptation of these pathogens to new hosts ([16] [22]). On another hand, controlling movements is not the absolute way to prevent pathogens transmission. Roy and Burnonfosse have illustrated this fact through their study on nuclear and sequence data analysis of pest species [18] wherein authors showed that commercial exchanges could have an impact on international gene flows in populations of *D. gallinae*, even in a highly controlled context (for example, quarantine measures in industrial layer farms).

2.2 Vector borne transmission

2.2.1 Mites

Vector-borne diseases represent a major problem for public health. Bird ectoparasites, especially mesostigmatic mites belonging to Dermanyssidae and Macronyssidae, are well known for their heavy potential to transmit diseases to poultry. *Dermanyssus gallinae* in particular, even if exhaustively described in poultry breedings, is also a petbird pathogen rather underestimated. This mite is often found in both petbirds family household and intensive breedings. *D. gallinae* is a nocturnal haematophagous ectoparasite and has been described to cause an important debilitation by exsanguination, involving high mortality rate in new borns, and sometimes in hens, *D. gallinae* has been also proved to transmit zoonotic pathogens[23-25], such as *C. psittaci* [26], *Coxiella burnetii* [24, 25], *Salmonella spp.*

[27-29], *Erysipelothrix rhusiopathiae* [30, 31], *Listeria monocytogenes* [24, 25] and viruses like Fowl pox virus [24]. Moreover, evidence of transmission to humans has been described, with subsequent apparition of skin lesions and a dermatological pruritic syndrome. [32-38] *D. gallinae* is characterized by a specific thigmotactic behavior and spends most of its life in the bird's environment rather than on the host itself, especially in narrow interstices like perches, feeding bowls and sandtrays anfractuosities; it acts more like a mosquito or a bed bug than like other parasites, as it only occasionally bites its hosts to take a bloodmeal [39]. In addition to complicate early detection of the mite (contrary to other parasites spending most of their life on the bird, like e.g. the blood-sucking mite *Ornithonyssus silviarum*-see also below), this particular life trait makes the parasite hard to eliminate by antiparasitic spray treatment (e.g. organo-phosphorus, pyrethrinoids) [40]. A topic treatment, with application of a long-term remanent antiparasitic spot-on product (e.g. 0,1% ivermectine) directly on the birds' skin, has been suggested by Dorrestein [41]; this alternative however might not be easily applicable in large breedings and big facilities.

D. gallinae could be considered as an invasive species presenting a host spectrum especially wide, of more than 40 birds families (including Passeriforms [39, 40]). Hypothesis has been formulated that these parasites could be easily transmitted horizontally, from one infested bird nest to another close one [42]or in the case of mixt colonies [43]) or from wild birds (e.g. passerines) feeding in open air together with domestic species [40]. This could also represent a way of transmission to humans. Indeed it has been well described that pigeons do nest in the vicinity of humans (such as city buildings, including hospitals [44]) and several case studies have presented the evidence of *D. gallinae* populations close to abandoned pigeons perches or nests, near windows or aeration circuitry [2, 35]. Such infestation has been putted in direct relationship with dermatologic clinical syndromes in humans ("pseudo-scabies"), associated with pruritic syndrome [32-38]. As *D. gallinae* has been proved to be shedding zoonotic pathogens [28, 37] and as birds like pigeons are found to be perching alongside hospital walls [35], one could point out the eventual risks encountered by immunocompromised humans, as hospitalized people, if they experienced such situation.

Ornithonyssus sylviarum (Macronissidae), also named Northern Fowl mite or white poultry mite is another blood-sucking arthropod identified in petbirds. Clinical symptoms are similar to those developed by a *D. gallinae* infestation: depression, anemia, newborns mortality[41]. However, *O. sylviarum* behavior is notably different from *D. gallinae's*, as it spent its entire life on the host's body, making pest detection in some way easier [41, 45]. *O. sylviarum* has been isolated in wild avifauna and petbirds; it showed the ability to quit its host and reach birds even housed in other cages. However, its capacity to resist from starvation (i.e. living in absence of any host) in the environment is significantly shorter than the red mite's (resp. 3 weeks and 24 weeks [45]). Only a few case of zoonotic transmission to humans have been reported, with clinical signs restricted to dermatologic symptoms associated with prurit [46]. Nonetheless, *O. sylviarum* is considered to be emergent in Europe and to present an increasingly problem in aviaries [41] and should then be not neglected.

2.2.2 Mosquitoes

Different species of mosquitoes (*Diptera*, especially *Culex* species) are responsible for horizontal and reciprocid transmission of arboviruses like West Nile fever Virus

(WNV; [47, 48]) or Usutu virus ([49]). These diseases will be discussed further in the next section.

Dipterae act as bridging vectors between two hosts categories: amplificators (e.g. birds) and incidental/dead-end (e.a. humans). Following Turell, Sardelis et collaborators ([50] [51], cited in [47]), an infected vertebrate must present a viremia of 10^5 pfu/ ml (pfu : plate forming unit) to be efficient as an amplification host. Studies have shown that house sparrows develop WNV viremia superior to 10^{10} pfu/ml after experimental infection, and maintain it above 10^5 pfu/ml for five days [47, 52, 53] and are indeed good amplificators hosts and, moreover overwintering hosts [48] for at least one arbovirus, the WNV. Beside these effects of amplification and seasonal resistance, international exchanges, trade and migration are factors enhancing these viral diseases emergence, as shown by the increasing number of diagnosed infections acquired during stays in tropical countries. Interestingly, Pfeffer and Dobler [53] pointed out the fact that no attention is actually paid on accompanying pet animals and parasites that these pets could be carrying. Pet birds are also concerned as a large amount of companion birds are obtained by sellers from trade with exotic countries [15, 53].

2.2.3 Ticks

Ticks from the genus *Ixodes* (e.g. *I. ricinus*, *I. scapularis*), are carried by birds and then have the ability to transmit pathogens like *Borrelia burgdoferi*, causative agent of the Lyme disease, and the flavivirus louping ill virus. Migrating birds also could be carriers of infected ticks and then contribute to long distance dispersal of both vectors and spirochetes [54]. Mathers et collaborators have recently published a interesting study on the potential role of wild birds and the ticks that feed on them in the introduction of the agent of Lyme disease to emergent areas [55]. No evidence however has been reported of transmission from wild to domestic petbirds even housed in open air aviaries.

3. Most important diseases

Note : table 5 summarizes the main diseases described below in term of clinical signs and necroptic lesions presented by birds, recommended diagnostic tools and treatment, and symptomatology reported in humans.

3.1 Bacterial diseases

3.1.1 Chlamydophilosis

One of the most threatening zoonotic diseases transmitted by birds to humans is chlamydophilosis (also known as chlamydiosis, ornithosis, psittacosis or parrot fever), caused by the intracellular bacterium *Chlamydophila psittaci*. Psittacine species are highly sensitive to this pathogen, but passerines are not excluded [26, 41, 56]. Human symptoms come from mild respiratory signs to severe pneumonia, with localization in several organs leading to diarrhoea, cunjunctivitis, arthritis and genital organs infection. The first people susceptible to be infected appear to be, as expected, veterinarians and birds breeders; this has been e.g. enlightened by the two following studies. The first reported an accidental contamination of a vet by infected turkeys [57] ; the second, an epidemiological study made by Ghent university, pointed out a high percentage of human infection in owners and vets working in breeding psittacine facilities [8]. On 39 breedings facilities, which represent 308 birds (most of them psittacines like cockatoos, parrots, parakeets and lories) and 46 humans, 19.2% of birds were tested positive for *C. psittaci* by nested PCR/EIA, 13%

of pet owners (and the vet student in charge of the study) were also positive after swap pharyngeal sampling. A total of 66% of the positive people presented mild respiratory symptoms, in association with viable *C. psittaci* isolation. Van Rompay and collaborators concluded their investigation with an important observation: on 18 breedings facilities, despite a broad spectrum-antibiotherapy, 60.6% were still positive for *C. psittaci* through culture and PCR (16.6 % and 44 % respectively) [8]. This raises the point of antibiotic resistance and development of drug-resistant strains in some facilities.

Another interesting case was described in a Liège hospital (Belgium), where a 10-year old child was admitted for persistant fever, acute abdomen, pneumonia and neurologic symptoms [58]. The pathogen, further identified as *C. psittaci*, was cefotaxime-resistant. Two budgerigars (the second most popular petbird) were housed in the child's living place; the elder brother of this child presented a high level of anti-*C. psittaci* IgA, which suggested a non-symptomatic chlamydophilosis.

Direct transmission of *C. psittaci* from birds to humans has been putted in evidence in a compendium of security measures about avian chlamydophilosis edited by the Centre of Diseases Control and Prevention in 1998, and warned birds owners (43% of infected people in USA between 1987 and 1996) but also professionals working with birds like e.g. veterinarians, breeders, zoo workers to be aware of a real risk of zoonotic transmission [59]. Bird fairs are a good illustration of the occupational risk presented by a high concentration of people and birds in the the same space for a relatively long period of time. Belchior and Berk reported recently two similar events in respectively France and the Netherlands, where chlamydophilosis outbreaks occurred during bird fairs. In Belchior study, 68% of exhibitors were tested positive for *C. psittaci* infection [7, 14].

Finally, one has to mention a case of illegaly imported *chlamydophila psittaci*-positive psittacine occurred in the Antwerp custom, which led to custom officer hospitalization after handling infected parakeets [15, 17].

This point out the real threat petbirds could represent when little information on biosecurity is provided to the people breeding and/or handling them. *D. gallinae* could moreover transfer this pathogen [24-26]. This reinforces the urgent need to apply hygienic measures on place at risk, e. a. birds fairs, petshops facilities and small familial breeding units. The CDC compendium of measures to control *Chlamydophila*

3.1.2 *psittaci* infection would be in this sight of a great help [59].Salmonellosis

Salmonella species were isolated from several captive passerine or psittacine birds, in relation or not (asymptomatic carriage) with clinical symptoms : diarrhea, multisystem disease, septicaemia, osteomyelitis, depression, crop stasis, dehydration, anorexia [60, 61],[62, 63] [56]. The serovar Typhimurium, a well-known zoonotic agent, was described in passerine birds in such clinical manifestations as granulomas (liver, ceca, spleen), multisystemic symptoms, ocular lesions and osteomyelitis [61], [64]. Transmission to humans was reported in different cases [63] [65, 66]. Smith et collaborators also reported two cases of *Salmonella typhimurium* outbreaks in elementary schools related to owl pellets dissection [67]. Even if these cases are more anecdotical than quite frequent, men should be careful (and at least respect elementary hygienic rules) when manipulating birds'products such as wild bird pellets, which could be in a somehow comprehensive way undertaken as a didactive manner to teach nature to kids.

Another point of view is the problematic of wild reservoirs. Indeed, wild songbirds have been repeatedly documented as *Salmonella spp.* carriers [68, 69] and implicated in the transmission of these pathogens to humans and mammals. In particular, starlings were shown to be potential spread agents of salmonellosis in cattle feeding operations [6]. Linked to that fact, bovine herds have been demonstrated to be reservoirs of many gastro-intestinal pathogens being of concern to humans, especially professionals like livestock producers or veterinarians [70], as well as consumers [71].

Finally, as discussed in chapters above, *D. gallinae* seems to play a significant role in *Salmonella spp*. Transmission in layer farms, as developed by Moro and collaborators [23, 27-29].

3.1.3 Tuberculosis

Isolation of zoonotic agents from the *Mycobacterium* species is not so rare in pet birds, especially in psittacines. The most commonly isolated species are respectively *Mycobacterium genavense* and *Mycobacterium avium* [72] [56]. The main species causing tuberculosis in humans, i.e. *M. tuberculosis*, has been rarely reported in birds, and essentially in parrots. In this particular birds' family, a interesting observation should to be pointed out, as it seems that the main route of infection was of human origin. Well documented examples are these green-winged macaws (*Ara chloroptera*) diagnosed positive for *Mycobacterium tuberculosis,* the first in New York City [73] and the second in Switzerland [74]. Both birds developed a panel of clinicals signs associated with tuberculosis: lethargy, osteomyelitis, multifocal granulomatous panniculitis and granulomatous hepatitis. Bird owners in both cases had a history of culture-confirmed pulmonary tuberculosis and confessed a real close contact with their birds (mouth-to-beak feeding). Moreover, in the swiss case, two veterinarians in charge of the case showed a positive reaction to tuberculin skin test after handling the sick bird[74]. One observation made by the authors is that these parrots have lived a sufficiently long time incubating the diseases to become themselves a potential source of infection for others humans. Data lack about susceptibility of nonpsittacine petbirds to *M. tuberculosis*, as authors found only one study reporting such infection in a canary, was diagnosed with a lung knot positive for *M. tuberculosis* [75].

This is however a fact that infection with zoonotic *Mycobacterium spp* in petbirds are rare. Regarding the susceptibility of birds to *Mycobacterium bovis*, to date, only experimental infections have been reported as responsible for clinical signs. A recent study focusing on the experimental infection of budgerigars by several species of *Mycobacterium* reported that the only clinical signs were seen 70 days after inoculation with *M. bovis*, while no clinical signs were observed following the challenge with the other species [76]. *M. bovis* is also a zoonotic agent, considered to be responsible for 1 to 2% of human cases of tuberculosis in industrialized countries, while this proportion is susceptible to be much more important in developing countries (until 8% of human cases, depending on the region) [77, 78].

Nevertheless, infected/carrying/untreated birds could become a potential reservoir for humans, and then have consequences on public health. In an ideal situation, surveillance and early diagnosis of zoonotic mycobacteria should be performed in every imported birds' bunch [79, 80] including animals captured from the wild [81]. Mycobacterial culture or PCR analyses would be the most sensitive and specific laboratory tests for a definitive diagnosis [82]. However, the long-term onset of the disease, the pathogen's intracellular localisation and the difficulty to dispose of not expensive highly sensitive diagnostic tests makes systematic and/or regular check-ups difficult to perform in routine conditions.

3.1.4 Campylobacter jejuni

Campylobacter spp., and in particular *Campylobacter jejuni* are responsible for food-borne diseases in many countries, responsible in humans for debilitating symptoms such as gastro-enteritidis (diarrhea, vomiting), headaches, and depression , leading sometimes to death. Campylobacteriosis was the most frequent zoonotic disease reported in 2009 in the European Union [71]. But *Campylobacter spp.* is not exclusively a food-borne disease. Even if little information is available on the role of other avian species (like petbirds) in the epidemiology of the disease, this pathogen is shed by an important birds variety, among which are « hobby birds » including estrildidae, canaries and psittacines [41, 83, 84]. Moreover, an Italian study showed a high occurrence of *C. jejuni* in migrating passeriforms [85], and concluded that these birds constitute a reservoir and a possible transmission route from birds to humans and domesticated animals, including cattle. This observation was also made by Adhikari and collaborators in 2004 [86], in a study dealing with dairy cows and sparrows faeces in New Zealand. However, other reports and experimental protocols tend to demonstrate that *C. jejuni* infection is highly host-specific and that the transmission from birds to humans, *a fortiori* from petbirds, although not impossible, is likely to play a minor role [87] [88]. Nevertheless, one still has to consider the potential role of petbirds in *C. jejuni* shedding and consequently apply elementary hygienic precautions while manipulating birds and/or faeces.

3.1.5 Lyme disease

Different strains of *Borrelia burgdorferi sensu lato* were isolated from ticks collected on songbirds in different areas of the world, including Europe [54]. Olsen and collaborators [89] showed that canaries presented relatively quickly a mild spirochaetemia after experimental infection with *B. burgdorferi,* but without or few clinical symptoms. This suggests that passerines may be of little importance as long-term amplifying reservoirs for Borreliosis. Moreover, ticks are usually quickly detected in the feathers of bred birds, as well as in kitchen-canaries, diminishing then the risk of wild-to-captive birds transmission and a fortiori to humans.

Concerning psittacines, no evidence of Lyme disease seems to have been putted in evidence.

3.1.6 Others

There are numerous other potential zoonotic bacteria also identified in pet birds, including multiple gram-negative bacteria such as *Pasteurella* spp, *Klebsiella* spp, *Yersinia* spp, *Pseudomonas spp.,* and *Escherichia coli* [41, 56, 90, 91]. Indeed, *Escherichia coli* O157:H7 strains transmitted from wild passerines (European starlings mostly) to cattle and then introduced into the food chain has been reported in several studies [92-94]. Lack of hygiene and the absence of quarantine (especially concerning imported birds), and dirty food and water sources seem to be the most probable origin of infection with these zoonotic pathogens. Besides, the potential transmission from wild birds to open-air aviaries hosted petbirds (via faecal drops) should be considered (Boseret, pers. obs.). However, reports of transmission of these bacteria from pet birds to humans still lack in the literature.

3.2 Viral diseases

3.2.1 Avian influenza

Highly pathogenic avian influenza A H5N1 has been in the world health focus since the years 2000's outbreaks. Perkins et collaborators [95], demonstrated in 2003 that the avian influenza A virus H5N1 after intranasal administration was able to induce clinical symptoms leading to death in petbirds species like zebra finches and common budgerigars, which are very common hosts of domestic ornamental aviaries, as well as in wild species like house sparrows and european starlings, usually living close to human habitations [95]. Several studies demonstrated the important role of migrating birds as pathogens vehicles all over the world [21, 96, 97], being putatively able to infect wild indigenous birds (house sparrows, european starlings), these latter possibly contaminating petbirds living in open air aviaries [2]. This virus could also spread from endemic countries [12, 16] to other locations through international trade of exotic birds [15, 16, 22]. In relation with this fact, markets where live birds are sold appear to represent a great risk for zoonotic transmission as demonstrated by several authors [12, 13]. This is indeed noticeable that Asian owners seemed to be, even at the peak of the H5N1 outbreak, unaware of the zoonotic risks this kind of business could cause [12, 13] and this was also the case in Western countries as hybrids between canaries and different wild passerines were and are still sold on public markets (Boseret, pers. inform.). Illegal bird importation can also induce a risk as suggested by Van Borm and collaborators [16].

3.2.2 Arboviruses

West Nile Fever is an emergent vector-borne zoonosis in which birds, e.a. house sparrows, play a key role as main and amplifying reservoir hosts [48]. The virus responsible for this disease is a flavivirus (*Flaviviridae*) known under the name of West Nile Fever Virus (WNV) which was isolated from numerous passeriform species, including canaries [48], as well as psittacines [98]. Birds, most of the time are subclinically affected , but can however develop a clinical form of the disease with ocular and neurologic symptoms [56]. Usutu virus (USUV) is another mosquito-borne flavivirus of African origin. This avian virus is transmitted by arthropod vectors (mainly mosquitoes of the *Culex pipiens* complex). Since 2001, death of birds especially passerines have been associated with infection by USUV [99, 100] . It is well known that free-living birds, including migratory species, have the potential to disperse certain pathogenic microorganisms [53]. Usutu virus has recently been detected in Europe and is spreading through Austria, Hungary, Italy, Spain and Switzerland, causing disease in birds and humans [49]. Following the same pattern than the West Nile Fever virus, USUV is a candidate as emerging pathogen in Europe and the consequences for human health safety have to be considered [49, 53]. Open air aviaries are common in our countries and could be an important feeding source for mosquitoes, which could then inoculate the virus to humans

3.2.3 Others

Proventricular dilation disease (PDD) is a disease in petbirds and, as it could be frequently lethal, PDD is considered as a major threat to aviculture [101]. This syndrome is associated with inflammation of the nervous system and gastrointestinal dysfunction as well as neurologic changes like seizures. Recently, the cause of this disease has been attributed to a novel bornavirus, the Avian Borna Virus (ABV) [102]. However, there is no evidence of ABV cross-species transmission and the zoonotic potential of this family of viruses remains unclear [103].

Newcastle disease, caused by avian paramyxovirus (APMV) was also described in petbirds [56, 91, 104]. Transmission to humans could also be possible, with conjunctivitis [56] but the most important consequence would be spreading of the infection among poultry breeding by the intermediary of human, wildbirds (especially pigeons) or maybe insects mechanical vectors like the house fly (*Musca domestica*) [105]

3.3 Parasitic/fungal diseases

3.3.1 Toxoplasmosis

Toxoplasmosis is a well-known human disease, responsible for abortion or congenital malformations in human. Although less documented than through the cat-cycle transmission, *Toxoplasma gondii* has also been described as an important pathogen for canaries, finches and budgerigars [106, 107], inducing blindness among other symptoms. However, transmission to humans appears to be mostly unlikely, as the birds don't excrete *T. gondii* in faeces (implying no risk of contamination by lack of hygiene or fecal matter manipulation). Indeed, *Toxoplasma gondii* should be found in internal organs and muscles, butas these birds are usually not bred in an alimentary purpose, this eliminates then the possibility of a contamination by raw or undercooked flesh eating (Losson, pers. comm).

3.3.2 Cryptococcosis

Pigeons are known to be reservoirs of pathogenic yeasts, like *Cryptococcus neoformans*, which is described to cause opportunistic infections in humans [108]. However less is known on the role that might play petbirds in such zoonotic transmission. Several studies have demonstrated the presence of *C. neoformans* in parrots, little petbirds like canaries, budgerigars or lovebirds and cockatiels [109, 110]. As it has been discussed above, petbirds, moreover housed in outdoor aviaries and then in contact with wild pigeons' droppings, could be a potential health hazard for humans as *Cryptococcus neoformans* reservoirs.

3.3.3 Others

Despite a relatively poor documentation on petbirds parasitic diseases, giardiosis, aspergillosis and cryptosporidiosis have been reported in these avian populations, both in chronic and in acute infections. Favorisating conditions could be high-density populations, stress, adaptation to new environment or prolonged periods in confined housings.[111] Transmission to human often results from faeces manipulation or lack of hygiene [41, 56, 90].

Avian giardiasis is caused by two different *Giardia* species: *G. ardeae* and *G. psittaci*. *G. psittaci* has been demonstrated to be responsible for fatal infections in budgerigars [112], but is not transmissible to humans. The species responsible for zoonotic infections is *Giardia duodenalis*, causing generally a self-limited illness, sometimes asymptomatic, characterized by diarrhoea, abdominal pain and weight loss. [112] *G. duodenalis* is divided into eight genotypes or "Assemblages", among whose Assemblages A and B appear to be responsible for human infections [113]. Interestingly, these genotypes have been isolated in faeces of different avian species, without leading to the development of clinical symptoms. Birds seem then more likely to serve as mechanical vectors of cysts and oocysts.[111]

In birds, *Cryptosporidium* infection leads to intestinal, respiratory or nephrotic symptoms and could be caused by three distinct species: *C. galli*, *C. meleagridis* and *C. baylei*. The two latter have been described as possible zoonotic agents, though in a low frequency in comparison with other species such as *C. hominis* or *C. parvum* [114]. The main human population at risk are very young children (first exposure, lack of hygiene) and immunocompromised individues such as HIV-positive patients, who will develop gastro-intestinal lesions but also infections of other organs such as pancreas, liver and sometimes respiratory tract [115]. *Cryptosporidium parvum* has been isolated in faeces of various avian species, conforting the possibility of zoonotic parasites shedding and transmission by birds. [116]

Aspergillosis has been frequently isolated from pet birds [56] [117], in both acute (severe respiratory condition with lethargy and changes in vocalization) and chronic forms (more often fatal because of its long-term development). However, human infection would rather come from environmental origin, and therefore be considered as a minor zoonotic threat, apart eventually from human immunocompromised patients [117].

4. Guidelines to prevent transmission from birds to humans

One interesting document to start with is the "Compendium of Measures To Control Chlamydia psittaci Infection Among Humans (Psittacosis) and Pet Birds (Avian Chlamydiosis), 1998" edited by the Centre for Diseases Control in 1998 [59].

4.1 Household hygiene

The transmission of zoonotic pathogens from animals to humans could be easily decreased by applying some elementary hygiene principles. A few recommandations could be delivered to the owner by the bird seller like the following ones:

- Clean clothing and shoes after any contact with other birds (bird club meeting, bird fair, live poultry).
- Wash hands before and after handling birds (including cages cleaning).
- Look out every day to cages, food and water; to be sure they are clean (including perches, feeding cups, etc.).

- When giving fruits or vegetables to birds, discard the rotten remainings.
- Change bath pots every day and let them available to birds only one hour/day (to avoid the bathing waste water to become a reservoir for pathogens).
- Wash cages once a week.
- Preserve food in clean and sealed containers.
- Clean and disinfect every aviary items before use.

Usually, birds breeders are correctly aware of these precautions; the risk is however higher in the case of family pets bought for the first time in a decorative purpose or as present for the children, especially when either parents or kids haven't been informed about the cited above elementary advices.

4.2 Birds'origin traceability :

In the case of birds bred in the country wherein they are sold (e.g. little birds like canaries, finches, budgerigars), they are usually provided without any certificate or identification (apart from a legband with the breeding identification number). Sellers are supposed to keep an accurate traceability of their stocks, but there is as far as we know no legal obligation of the seller to give any documents to the buyer.

About exotic pet birds issued from importation, laws differ from countries, but in a general view, a vet certificate, a passport and an importation authorization have to be delivered with the birds. As said before, smuggled birds represent a high risk of zoonoses introduction. In Europe, exotic bird importation from non EU countries is forbidden and animals imported from other EU-members countries should have an international passport, a correct identification and a veterinary certificate of good health (Directive 91/496/CE).

However on the owner point of view, there are some recommandations to be aware of after buying a new pet bird.

- If the birds comes from another country, request certification from the seller that these were legally imported (eventually ask for official documents) and were healthy prior to shipment (certified by an official veterinarian).
- Schedule an appointment with a veterinarian.
- Isolate new birds from other birds for a quarantine time determined by the veterinarian.
- Restrict access to birds from people owning birds too.
- Keep birds away from other birds (e.g. in the gardens).

4.3 Awareness of sickness signs

Breeders usually know the sickness signs of a bird, even if they could be somehow difficult to detect. But for non initiated people, like sellers in animal shops or new owners, this could be difficult to see whether their birds are healthy or ill. Prevention tools and information should then be provided by the breeders to people they are selling/giving their animals. Veterinarians also should better inform owners for example by providing documentation on warning signs of infectious bird diseases. If unusual signs of disease or if unexpected deaths occur in a breeding, the owners should then warn their avian veterinarian.

4.4 Biosecurity and hygiene precautions in big facilities

When of sufficient size, a Hazard Analysis and Critical Control Points (HACCP) plan could be applied in breeding facilities and in selling facilities. To quarantine newly incoming birds is an absolutely necessary precaution. These animals should be kept in clean cages for a duration estimated by the sanitary veterinarian, and pathogens and/or pests absence (including *D. gallinae*) should be carefully checked. CDC recommends at least a quarantine of 30-45 days when *Chlamydophila psittaci* infection is suspected [59]. For example, one should check these different control points:

1. Direct birds' environment :

- Presence/absence of *D. gallinae* in the quarantine cages after at least one week, which is the time needed by the parasite to accomplish a complete reproduction cycle, from egg to egg [40]. For example, the acarids could be easily found on feedballs, perches or on the removable bottom sandtray. An easy test is to push strongly with the thumb on dirty spots pasted on the reverse face of this tray and scratch them from left to right (or vice versa). If a bloody smear does appear, this would be an efficient sign that blood-fed parasites did begin to colonize cages' anfractuosities (Boseret, pers. obs.).
- Color/consistency/quantity of droppings: for example, a yellow stain should suggest campylobacteriosis, a liquid consistency should refer to salmonellosis or other enterobacteriaceae infections [41].
- Transport cages: were they soiled or clean? Presence of dead birds?

2. Birds : general examination

- Presence/absence of other pests' species living most of their time on the host, e.g. at the calamus of the feathers (like *Ornithonyssus sylviarum)*, at the edge of the beak or in the leg's scales (like *Knemidokoptes pilae,* which is a non zoonotic mange agent*)* or in another part of the body (e.g. ticks, lice). Broken feathers or feather-loss could indicate pruritus and discomfort, other indicators of ectoparasites infestation [41]. Ectoparasites are considered by many breeders to be a good indicator of inadequate hygiene and management and their detection therefore could awake attention of the owner on the health status of their infested incoming birds.
- General state of the birds (good/bad)
  - Perching/ lying at the bottom of the cage
  - Normal activity/apathic, rolled in ruffled feathers
  - In social groups/isolated
  - Bright eyes/enophthalmy
  - Good respiratory state/nasal-ocular discharge, open beak
- Plumage aspect: are the birds in molting period? How is the molting: homogenous and bilateral/heterogenous and asymmetric

3. Quarantine facilities hygienic state:

- Frequence and efficiency of cages/walls/floor/shells disinfection
- Food storage (access to mice, rats?)
- Environmental conditions: temperature, humidity, duration of light hours

This list is not exhaustive and a complete list of adequate control points has to be determined in function of the kind and size of breeding, facilities conformation, season, frequence of birds movements, etc. The above recommendations should however constitute a basis of elementary examinations to be performed in every cases.

In case of a high level of risk or when a doubt emerges relatively to the birds' health state, the following laboratory analyses could be performed:

1. Individu level: necropsy of a dead or a sacrificed sick individu, performed along with bacterial analyses of intestinal content or other organs presenting lesions.
2. Group level: Bacterial analyses of cloacal or/and oral swabs of a birds sample bunch (one-to-ten, one-to-fifteen…).
3. Vector level: molecular analyses of vectors found on birds and/or in the cages, to detect specifically zoonotic agents: *Chlamydophila psittaci*, west nile fever, etc…

The first two types of analyses could be an interesting investment and couldn't be too much expensive (less than 100 euros/birds' bunch).

However, molecular analyses are on another financial level. One should recommend them in particular cases, first when birds are about to be handled by owners, like parrots, parakeets or cockatiels, second when the pathogen targeted is of zoonotic non negligeable importance. For example, tuberculosis detection has to be carried out with a critical mind, as false negative do occur. On another hand, as surveillance of zoonoses is a European legal obligation (Directive 2003/99/EC), testing birds could be systematically included in national surveillance programs, a fortiori when human health is estimated to be put at risk, and then could then grant the breeders with a official budget intervention.

Another suggestion to diminish the costs at a local level would be to perform such tests in multiplex series, allowing breeders to share somehow elevated costs. But all these possibilities involves a complete change of mind and implies a broader transparency in these kind of breedings, which still lacks even in our high-controlled countries (Boseret, pers. inform.).

When birds are proved to be healthy, then they could be introduced in their definitive facilities. Outcoming birds should be submitted to similar sanitary systematic checking.

Moreover, the precaution of all-in/all-out replacement system, already applied in poultry exploitations, should be carried out in petbirds breedings too. For example, only birds of the same age should be kept in the same location, and when moved, the facility should be disinfected carefully before welcoming a new flock.

In selling facilities, where birds from different origins could be mixed up, only replace them when the whole flock has been sold and the cages cleaned with ad hoc disinfectants. One interesting initiative would be to create a certificate of « good health » to moving flocks, but as many animals are sold in non-official ways (e.g. private breedings, markets), this couldn't be not so easy to put in place.

Control point should be also implemented on bird's fairs. Sanitary certificates could be an obligatory document to provide to authorities to allow the breeder to attend any fair.

5. Conclusion

This review aimed to present a non-exhaustive panorama of data relative to petbirds-human pathogen transmission. Different situations have been illustrated in this short review: familial households, breeding or selling facilities, bird fairs, international trade and the wildbirds'problematic of reservoirs. Although this represents a minor part of the companion animals' vet clientship, petbirds' diseases with zoonotic potential shouldn't be neglected or underestimated, considering the major health impact on the population, including children. Referring to Pastoret and Vallat zoonoses classification, petbird zoonoses own to the most threadful diseases types: 2 and 2+ (see table 3; [118]). Vets could then play an important role in educating pets (including birds) owners.

On an another point of view, pathogens' shedding by wild passerine birds could be responsible of maintaining infection in domestic birds pools, such as openair aviaries or poultry breedings, and could have important economic impacts. The presence of *Salmonella* species in starling faeces and in cattle feeding operations reported e.a. by Carlson and collaborators is a good example of a under-known reservoir phenomenon. Another example is the role of birds, among which passerines, as amplifying hosts for some vector-borne zoonotic emerging viruses. Open air aviaries are not protected from mosquitoes, and ornamental birds have been showed to be able to act the same way than their wild counterparts. Migrating birds are also a sanitary concern, as these birds could spread a high variety of pathogens by solely defecating above outdoor aviaries wherein petbirds are housed. Thus these birds concentration could become a non negligible reservoir of pathogens, contributing to maintain and spread infection in human population.

Referring on vectors, *D. gallinae* following author's advice is an underestimated concern – probably too many times misdiagnosed - in petbird medicine as well as in small avian breedings, as the parasite could be carried and transferred from one species to another, mostly by inert materials such cages, perches, water or feed bowls, etc. and eventually by the intermediaire of man. Threatening pathogens like *C. psittaci* or *Salmonella ssp.* were reported to be carried by the mite and transmitted to petbirds, which could then infect either their owners or their cagemates. In addition, sanitary state of petbird owning and trade is rather unclear in many countries. HACCP or other quality control plans (ISO, AFNOR…) are applied by the Federal Agency for Food Safety Chain (FAFSC) in Belgian poultry breedings, but not in « backyard poultry flocks » or in local passerine breedings. Legislation does exist e.g. on international trade but despite this, illegal introduction of birds in our countries still remains a threat for human health when considering the highly pathogenic agents that could be brought in our frontiers (e.g. avian influenza A virus H5N1 or chlamydophilosis).

Therefore, investigate the health status of pet birds, facilities, avian exploitations and owners should be an interesting starting point to define human health risks encountered (from family to breeding scale), to propose economic and sanitary prevention measures (e.g. biosecurity, prophylaxy, hygiene) in an interest of health protection and economic improvement. This investigation could be a good picture illustrating the concept of « Animals + Humans = One Health ».

Competing interests

The author(s) declare that they have no competing interests.

Authors' contributions

GB and CS fixed the design of the study; GB has realized the literature research and analysis; BL, ET, JM and CS have been involved in revising the manuscript critically for important intellectual content; CS has given final approval of the version to be published.

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GB is doctor in veterinary medicine and defended a PhD on songbirds'behavior and health status. She is currently studying zoonoses transmitted by birds, especially petbirds, in CS research unit.

BL, ET, JGM and CS are professors and heads of respectively parasitology, virology, bacteriology and epidemiology and risk analysis sections of the department of infectious and parasitic diseases, (Faculty of Veterinary Medicine, University of Liège, Belgium) and therefore provided the author with expert advices on diseases discussed in this manuscript.

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TABLES

Table 1: main pet bird species following International Ornithologic Congress (IOC) classification 3.1 (2012)

Order	Family	Genus	Species	English name	French name
Passeriforms	Fringillidae	*Serinus*	*S. canaria*	Canary	Canari/serin des canaries
		Carduelis	*C. carduelis*	Gold finch	Chardonneret
			C. chloris	Green finch	Verdier
			C. spinus	siskin	Tarin
		Pyrrhula	*P. pyrrhula*	Bullfinch	Bouvreuil
		Fringilla	*F. coelebs*	Chaffinch	Pinson des arbres
	Estrildidae	*Taeniopygia*	*T. guttata*	Zebra finch	Moineau mandarin
		Poephila	*P. acuticauda*	Long-tailed finch	Diamant à longue queue
		Erythrura	*E. gouldiae*	Gouldian Finch	Diamant de Gould
		Lonchura	*L. striata*	Bengalese finch	Bengali/moineau du japon
	Sturnidae	*Gracula*	*G. religiosa*	Mynah	Mainate
		Sturnus	*S. vulgaris*	Starling	Etourneau
Psittaciforms	Psittacidae	*Melopsittacus*	*M. undulatus*	Budgerigar	Perruche ondulée
		Agapornis	*A spp*	Lovebird	Inséparable
		Psittacula	*P. eupatria*	Alexandrine parakeet	Perruche alexandrine
		Lorius	*L. spp*	Lories	Loris
		Psittacus	*P. erithacus*	African or Timneh grey parrot	Gris du Gabon
		Poicephalus	*P.senegalus*	Senegal parrot	Perroquet Youyou
		Ara	*A spp*	Macaw	Ara
		Aratinga	*A spp*	Conure	Conure
		Amazona	*A. aestiva*	Amazon	Amazone
	Cacatuidae	*Cacatua*	*C. alba*	Cockatoo	Cacatoës
		Nymphicus	*N. hollandicus*	Cockatiel	Calopsitte

Table 2: main transmission routes of diseases

Transmission route	Contagious diseases				Non contagious diseases	
Direct contact	yes	yes	no	no	no	no
Indirect contact	yes	yes	yes	yes	no	no
Vector-borne	yes	no	yes	no	yes	no
Example in petbirds	Chlamydiosis	Tuberculosis	West Nile Fever	Cryptosporidiosis	Lyme disease	Genetic disorders

Table 3: classification of emerging zoonoses [106]

Transmission	Wild to humans	Humans to humans	Wild to domestic	Domestic to humans	Example in petbirds
1	Yes	No	No	No	None
1+	Yes	Yes	No	No	None
2	Yes	No	Yes	No	West Nile fever Newcastle disease
2+	Yes	Yes	Yes	Yes	Avian Influenza Salmonellosis Chlamydiosis Tuberculosis

Table 4: summary of main petbird zoonotic diseases

Disease	Pathology	Clinical issue	Asymptomatic shedding	Transmission route	OIE listed disease	Risk for human*
Chlamydophilosis	Systemic	Fatal	yes	D/I/V	Yes	high
Salmonellosis	Digestive to systemic	Treatable	yes	D/I/V	No	
Tuberculosis	Respiratory to systemic	Fatal	no	D/I/V	Yes	high
Campylobacteriosis	Digestive to systemic	Treatable	yes	D/I/V	No	moderate
Lyme disease		None	no	V	No	low
Avian Influenza	Systemic	Fatal	no	D/V ?	Yes	high
West Nile fever and other arboviruses	Respiratory to systemic	Fatal	yes	V	Yes (WNF)	moderate
Avian Bornavirus	Digestive/nervous to systemic	Fatal	no	D	No	null
Newcastle disease	Ocular To Systemic	Mild to fatal	yes	D/I/V	Yes	low
Toxoplasmosis	Digestive	Digestive	yes	I	No	Null to low
Giardiosis (G. duodenalis)	Digestive to systemic	Treatable	yes	I	No	moderate
Cryptosporidiosis	Digestive	Treatable	yes	I	No	moderate
Cryptococcosis	Digestive	Treatable	yes	I	No	moderate

**when handling a bird without hygienic precautions*

Legend: D =direct contact; I = Indirect contact ; V = vector-mediated contact

Table 5: summary of clinical data associated to main petbird zoonotic diseases [41]

Disease	Sensitive species	Clinical signs	Necroptic lesions	Diagnostic (sample/analysis)	Remarks and Pitfalls	Treatment	Human symptoms
Blood-sucking mites	All	*Nestlings*: weakness, anemia, death *Adults*: AA, respiratory distress, depression	None	Direct examen	*Dermanyssus gallinae*: hide in cages anfractuosities and could not be found on birds themselves	Ivermectine, permethrins in spray. Total disinfection of cages and facilities (see also chapter 4)	Dermatitis, pruritus
Chlamydo-philosis	Psittacines – canaries - finches	AA, SBS, diarrhoea, nasal discharge, dehydration, Ocular signs	Air sacs lesions, hepato-splenomegaly	CSw, OSw, FE/BC, serology (paired serology 2 weeks apart),IMF, PCR	Asymptomatic carriage (up to 40%), false negative	Tetracyclins (1st of 2d generation)	Flu-like syndrom, genital, articular, skin symptoms
Salmonellosis	All (open-air aviaries)	AA, WL, diarrhoea, mild respiratory symptoms	Congestive gastro-intestinal tract, hepato-splenomegaly	CSw, FE	Mostly in winter and in outdoor aviaries; hard to differentiate from pseudo-tuberculosis	Not recommended (high probability of antibio-resistance)	Gastro-intestinal infection
Tuberculosis	Psittacines (canaries?)	Progressive AA, WL, respiratory symptoms, long bones lesions	Cachexia, osteolysis spots in long bones, lung lesions (non caseous)	RX (bone lesions), OSw/ MO (Ziehl-Nielsen), BC, HP	Chronic development, sometimes during months to years; human origin infection	Not recommended (high probability of antibio-resistance)	Chronic pulmonary symptoms (caseous lung knots), generalized infection
Campylo-bacteriosis	Estrildidae mostly.	Apathy, yellow faeces (solid or liquid)	Cachexia , congestive gastro-intestinal tract, containing a yellow amylum or undigested seeds.	FE/MO (curved rods in stained smears), BC	Canaries and psittacines are asymptomatic carriers	Not recommended (high probability of antibio-resistance)	Gastro-intestinal infection, Gillain-Barré syndrome
Avian Influenza	Passerines	Sudden death, SBS, respiratory and neurological signs	Dehydration, respiratory lesions	OSw, CSw, BS/HP, PCR	Mostly in outdoor aviaries	None	Mild to severe respiratory and systemic infection

West Nile fever	All	Ocular and neurological signs		OSw, CSw/PCR	Mostly asymptomatic carriage	None: prevention based on limitation of exposure to mosquitoes (vectors)	Mild to severe respiratory and systemic infection, encephalitis, septicaemia, death
Newcastle disease	All	SBS, AA, ocular, respiratory and neurological signs	Dehydration, respiratory lesions	OSw, CSw/serology		None ; prevention by vaccination	Cunjunctivitis, mild flu-like symptoms
Toxoplasmosis	Canary, finch, budgerigar minah	SBS, AA, respiratory and neurological signs, blindness	iridocyclitis, panophthalmia, catarrhal pneumonia, hepato-splenomegaly	CSw/MO, serology, HP, PCR	Systemic symptoms sometimes unseen; detection of the disease 3 months later (blindness)	Trimetoprim-sulfamids	Mostly asymptomatic. Abortion, congenital malformation.
Giardiosis **(G. duodenalis)**		None	None				Sometimes asymptomatic. WL, diarrhoea, abdominal pain
Crypto-sporidiosis	All	Rare ; acute diarrhoea	Gastro-enteric lesions	CsW/MO		Ronidazole	Gastro-intestinal symptoms; liver, pancreas, respiratory tract lesions
Cryptococcosis	Parrots, little petbirds	Rare	None	CSw/MO	Possible aerosol-borne contamination		Mostly asymptomatic. Respiratory and nervous symptoms.

Legend : AA : Apathy-Anorexy ; WL : weight loss; FE: faeces examination; BC: bacterial culture; MO: microscopic observation; SBS: sick bird signs (ruffled feathers, standing at the bottom of the cage, depression); HP: histopathology (including immunocytochemistry); BS: blood sample; CSw: cloacal swab; OSw: oral swab; IMF: Immunofluorescence; PCR: polymerase chain reaction.