DOI : 10.4267/2042/62332

# *RISK FACTORS FOR THE TRANSMISSION OF INFECTIOUS DISEASES AGENTS AT THE WILD BIRDS -COMMERCIAL BIRDS INTERFACE. A PILOT STUDY IN THE REGION OF THE ALTOS DE JALISCO, MEXICO*

# FACTEURS DE RISQUE POUR LA TRANSMISSION D'AGENTS DE MALADIES INFECTIEUSES DANS L'INTERFACE OISEAUX SAUVAGES - OISEAUX COMMERCIAUX. ÉTUDE PRÉLIMINAIRE DANS LA RÉGION DES ALTOS DE JALISCO, MEXIQUE

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*(Communication présentée par Jeanne Brugère-Picoux le 8 Juin 2017*
*Manuscrit accepté le 12 Mai 2017)*

## ABSTRACT

*The Altos de Jalisco region in west central Mexico is the location of the largest concentration of poultry farms. This district has witnessed the emergence of Low Pathogenic H5N2 and the Highly Pathogenic H7N3 Influenza viruses. Eighty counting stations along a 50 km corridor were designated in five ecological environments from water bodies to poultry production facilities. The survey, implemented from fall 2014 to winter 2015, identified 82 species of wild birds where the family Icteridae comprised the most abundant group. A network-theory model provided a value of interaction among the wild bird species in these five environments. The highest ranked species corresponded to the Mexican Great-tailed Grackle and the Barn Swallow; making those potential hosts for disease transmission of pathogens in the wild bird-poultry interface in the region of Jalisco. These interactions are likely to positively correlate with increased risk factors.*

***Key-Words: wild birds, abundance, environments, interactions, net theory.***

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DOI : 10.4267/2042/62332

## RÉSUMÉ

La région des Altos de Jalisco au Mexique qui se trouve dans la zone centre-occidentale du pays, correspond à la plus grande concentration des fermes avicoles. Ce secteur a été le témoin de l'émergence des virus influenza faiblement pathogène H5N2 et hautement pathogène H7N3. Quatre-vingts points d'évaluation le long d'un couloir de 50 kilomètres ont été réalisés dans cinq environnements écologiques des corps d'eau voisins  aux installations productives de volaille. L'enquête, mise en application de l'automne 2014 à l'hiver 2015, a identifié 82 espèces d'oiseaux sauvages où la famille Icteridae a constitué le groupe le plus abondant. Un modèle de théorie des réseaux a fourni une valeur d'interaction parmi les espèces sauvages d'oiseaux dans ces cinq environnements. Les espèces avec les valeurs d'interaction plus hautes ont correspondu au Quiscale à longue queue et à l´Hirondelle rustique permettant de suspecter ces deux espèces en tant que responsables potentiels dans la transmission des agents pathogènes infectieux dans l'interface oiseau sauvages-oiseaux commerciaux dans cette région de Jalisco. Ces interactions permettent de suspecter une corrélation positive avec les facteurs de risque.

**Mots-clés : oiseaux sauvages, abondance, environnements, interactions, théorie de réseaux.**

## INTRODUCTION

The need to elucidate the role of the ecological factors that are involved in the interactions between wild and commercial poultry birds as well as the identification of epidemiological risks of diseases transmitted by wild birds has become a serious concern of the modern poultry industry worldwide (Webster *et al.* 1992; Potter, 2001). In the risk assessment (RA) studies used for diminishing the probability of and infectious agent entering a population, serious methodological difficulties are presented when the infectious agent is difficult to visualize, like the Avian Influenza Viruses [AIV], especially if it is located in a wild reservoir (Vandegrift *et al.* 2011). Therefore, in the risk evaluation [RE] process, one must identify the key bird species through observation, and with that, the management of the hazard outside the source (Artois *et al.* 2007). Furthermore, the evaluation and risk management [RM] for the prevention of viral diseases from spreading inside commercial poultry farms, requires not only the identification of the species capable of functioning as vectors for the virus, but one must also recognize and assess the eco-epidemiologic risk factors [RF] that result in the wild – commercial bird interface (Dimitrov *et al.* 2016). It is considered that the RF for the spreading or emergence of avian influenza virus (AIV) includes the change in the susceptibility of the host to the infection, among others (Taylor *et al.* 2001; Donatelli *et al.* 2016). With that said, the RA and RE take part in the correct management of zoosanitary emergencies. (Honhold *et al.* 2001). The Altos de Jalisco is the most important region for the poultry industry in Mexico, there is also an abundance of water bodies which serve as a crucial habitat for wintering populations of aquatic birds which include Anseriformes (ducks, geese) and Charadriiformes (shorebirds), associated to the Central Flyway of North America (Arellano, 1956; Lafón & Reyna, 2014). The region also has been the scenario of outbreaks of AIV H5N2 low pathogenic [LP] in 1993 (Villarreal, 2009) and AIV H7N3 highly pathogenic [HP] in 2012 (Wainwright, 2012; Kapczynski *et al.* 2013; OIE, 2016) causing a major impact on the national poultry industry. During the outbreak of the H7N3 HP positive outcomes of this agent were found in wild resident birds, such is the case of a Great-tailed Grackle (*Quiscalus mexicanus*) (Navarro-López *et al.* 2014) and a Barn Swallow (*Hirundo rustica*) (Soto *et al.* 2014). For the prevention and control of the AIV H5N2 LP and H7N3 HP, various zoosanitary procedures were followed, for instance, the application of vaccines and the assurance of biosecurity measurements near poultry farms, such measures were managed by the official sector (SAGARPA, 2011; SENASICA, 2011). It is unknown just how exactly the AIV H5N2 LP managed to enter Mexico however, it is considered that the AIV H7N3 HP is the result of the reassortment of two or more strings of different origin that came with the migration of wild birds from USA and Canada through the Central and Pacific Flyways (Maurer-Stroh *et al.* 2013; Lu *et al.* 2014). It is also not known just how the AIV H7N3 HP propagated from a wild environment to the isolated commercial poultry farms this could be due to the participation of resident birds that come into contact with migratory waterfowl. Therefore, in RM one must consider that in order to manage an adequate level of protection against the AIV, it is imperative to assure the maximum protection of domestic poultry against the direct and indirect contact with wild birds as an essential part of the biosecurity measures (Artois *et al.*  2007; Zepeda, 2007). The present study was designed to quantify the abundance of both resident and migratory wild birds and their relationships with poultry farms. By implementing point-count stations along a gradient that spans from the nearby wetlands to the production stalls, highlighting the importance of the vegetation structure in this processes.

## MATERIAL & METHODS

In Altos de Jalisco region, over a 50 km corridor, five sites were selected associated to the nearby localities: Presa Calderón, Acatic, Tepatitlán, Santa Bárbara – Pegueros and Valle de Guadalupe. Using satellite imagery, various key landscape elements were identified, such as commercial poultry farms, fragments of native and introduced vegetation, plains, crops and water bodies, including Tepatitlán city as an urban landscape. During the Fall of 2014 and the Winter of 2015, point-count methodology were established on roads, trails and neighboring poultry farms, with the goal of determining and counting bird species present within a 100 meter

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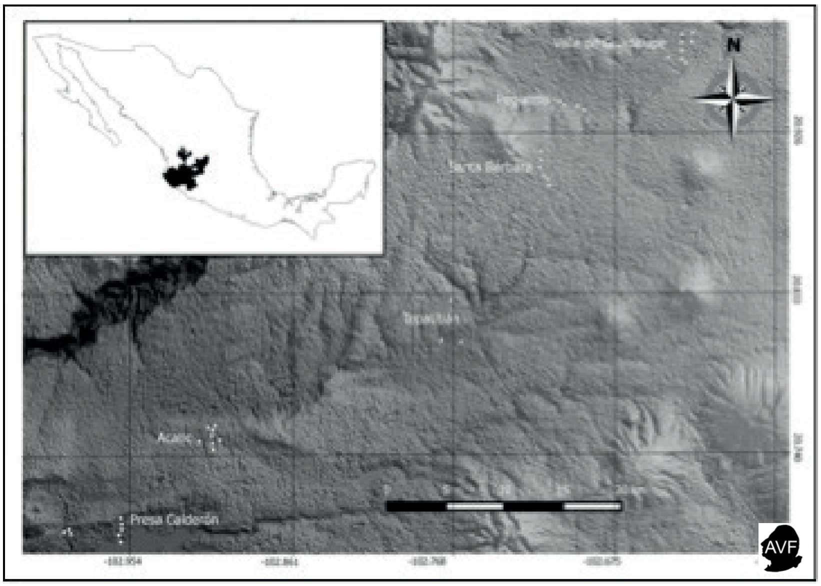

**Figure 1 :** *Study area. The white dots represent the locations of point-counts implemented.*

(m) radius for a period of 8 minute intervals (Ralph & Scott, 1981; Bibby *et al.* 2000). Bird counts started 15 minutes before sunrise, considering a minimum distance of 380 m between point-counts as criteria to avoid the duplication of individuals ***(figure 1)***. The distance to the observer was recorded as a parameter to estimate bird densities (Buckland *et al.* 2001). The regional status of birds according Howell & Webb (1995), considered four categories: Resident breeder [RES], Winter resident [WIN] (reproduce on northern latitudes of Mexico or higher and their presence spans from October to March); Transient migrants [TRN] (brief stays or flyover); and Summer residents [SRS] (breeder). As a parameter for quantifying the quality of the compiled inventory, the number of sampled units and the resulting sample-based curve outlined by the program ©*EstimateS* (Collwell, 2006), were exported to the ©*Statistica 8.0* (Stat Soft Inc. 2007) software, in which the non-linear Clench's algorithm (Jiménez-Valverde & Hortal, 2003), as well as *Chao-1* model (Chao, 1987), were computed to calculate the efficiency of the survey based on those species potentially present but not detected. In order to interpret the wild bird – domestic Poultry interface, five environments were proposed, considering those spaces where wild birds were registered, these include: *i.-* Interior of poultry stalls (IN); *ii.-* Commercial poultry farm infrastructure (PI), such as yards, sheds, feeding hoppers, electricity posts, cabling, etc. without including any element of the vegetation; *iii.-* Suburban vegetation (SV), composed mostly of elements of secondary vegetation and three stratum of vertical cover such as grasses, shrubs, and trees (Melles *et al.* 2003); *iv.-* Plains and Crops (PC); and *v.-* Water bodies (WB) either natural or artificial. The interaction between environments was performed under the Net Theory Model, calculated by the ©*Node-XL* (Microsoft-PL, 2015) extension. This algorithm, designed to interpret similarities among nodal joints reveals centrality parameter, which allows the identification of the most influential vertices in a graph. The vertices with the highest probability of occurrence were defined by the highest Betweenness Centrality. It assigns scores relative to all the nodes of the network, according to their degree of connectivity. Nodes with the largest number of extensions contribute to a higher score (Van Mieghem, 2011; Girvan & Newman, 2012). To determine significant differences between the numbers of registered species by site, the G – test of independence was applied (Gotelli & Ellison, 2004). The taxonomic criteria for this study were based on the Checklist of North American Birds, 7th Edition, Supplement 55th (Chesser *et al.* 2015).

## RESULTS

Spanning from October 06 of 2014 to February 03 of 2015, 80 point-counts were implemented, at a mean distance (km) of $(\bar{x} \pm SD)$ 12.4 ± 2.7; where 8,786 wild birds, grouped in 82 species, 31 families and 14 orders were registered. Their regional status of birds corresponded to 55 resident breeders species, 25 wintering migrants, one transient migrant and one summer resident. Clench's equation computed a correlation coefficient of $R^2 = 0.991$; while the value of the obtained slope was 0.19. From this data, the *Chao-1* estimator performed suggested that the curve species-area may reach its asymptote when the inventory registers between 99 and 108 species of birds. Thus, our inventory achieved the 82.6% of species potentially present. Among the most abundant species, Icterids (*Molothrus ater*, *Xanthocephalus xanthocephalus*, *Quiscalus mexicanus* and *Molothrus aeneus*) compose the 61% of the total number of birds counted, followed by sparrows (*Passer domesticus*), herons (*Bubulcus ibis*), swallows (*Hirundo rustica*), ibis (*Plegadis chii*) and the Yellow-rumped Warbler (*Setophaga coronata*). The previous species along with the Groove-billed Ani (*Crotophaga sulcirostris*), were found in the interior of the poultry stall ***(table 1)***. The sites where this study was carried out presented a range of 41 to 50 species registered, Tepatitlán being an exception with only 23

***Table 1:*** *Species observed inside poultry stalls, Degree of interaction, Betweenness centrality, Abundance and Calculated Density (individuals per hectare).*

| ID | Species | Number of interactions | Betweenness Centrality | Abundance (Ind / ha) |
|---|---|---|---|---|
| 1 | Plegadis chihi | 4 | 176.3 | 342 (1.9) |
| 2 | Molothrus aeneus | 4 | 20.9 | 1072 (8.0) |
| 3 | Quiscalus mexicanus | 5 | 298.7 | 1113 (11.9) |
| 4 | Hirundo rustica | 5 | 298.7 | 1071 (6.4) |
| 5 | Setophaga coronata | 4 | 20.9 | 120 (1.7) |
| 6 | Bubulcus ibis | 4 | 20.9 | 645 (5.7) |
| 7 | Xanthocephalus xanthocephalus | 4 | 20.9 | 716 (5.7) |
| 8 | Molothrus ater | 4 | 20.9 | 2108 (17.0) |
| 9 | Crotophaga sulcirostris | 2 | 2.5 | 24 (0.5) |
| 10 | Passer domesticus | 3 | 4.6 | 531 (4.7) |

DOI : 10.4267/2042/62332

($G_{(0.05),\,4} = 12.00$; $P = 0.017$). More precisely, within the poultry stall interiors (IN) between 2 and 6 species were observed ($\bar{x} \pm SD$): 4.4 ± 1.5; meanwhile, 7.6 ± 1.9 species were found in the surrounding of commercial poultry infrastructure (PI); suburban vegetation (SV) 14.2 ± 0.8; plains and crops (PC) 8.2 ± 4.4; and water bodies (WB) 6.4 ± 3.9 ***(figure 2)***. Based on 80 point counts implemented within five environments, the wild bird-commercial bird interface demonstrated 105 interactions: five in water bodies, 35 in plains and crops, 37 in suburban vegetation, 19 in areas surrounding poultry production facilities and 10 inside the poultry stalls ***(figure 3)***. Out of all species registered, only *Quiscalus mexicanus* and *Hirundo rustica* were present throughout every single environment, which in turn resulted in maximum values of Betweenness Centrality ***(table 1)***. Particularly, in the sub-urban environment, seven species were found to be associated with grasses, 29 to shrubs and 35 to trees. Following the applied point-count methodology, it was possible to document 4 waterfowl species and 3 shorebirds ***(table 2)***. Water bodies, a recurrent element found in the region of Altos de Jalisco (Tepatitlán being an exception), were present in a proportion of 4.6 for every site. By considering the average distance (meters) between the proximal wetland's shore and the nearest poultry stall ($\bar{x} \pm SE$; *N*), it was obtained (77 ± 16.7; 23).

Risk factors. Our observation in the production stalls detected either absence or deterioration of poultry netting, open doors or lack of these ones, as well as openings in walls or ceilings. However, still in farms with a good biosecurity management practices, Great-tailed Grackle (*Quiscalus mexicanus*) and Cowbirds (*Molothrus* spp., *Xanthocephalus x.*) were identified, that in an insistent way managed to go into the stalls through crannies and peepholes. In the particular case of the Barn Swallow and the Yellow-Rumped Warbler (*Setophaga coronata*), they only entered in absence of poultry netting or when this one had big openings ***(figure 4)***.

## DISCUSSION

The commercial poultry farms located in the region of Los Altos de Jalisco, may possess the eco-epidemiological and social determinants that facilitate the emergence of new outbreaks of avian influenza and the maintenance of the prevalent strains H5N2 LP and H7N3 HP. It is considered that the most important determinants are the inadequate RM and the permanent programs of vaccination that makes it possible to maintain the AIV in the environment (Webster, *et al.* 1992; Bublot, 2004; Webster & Hulse, 2004; Swayne, 2006; Zepeda, 2007; Webster *et al.* 2007).

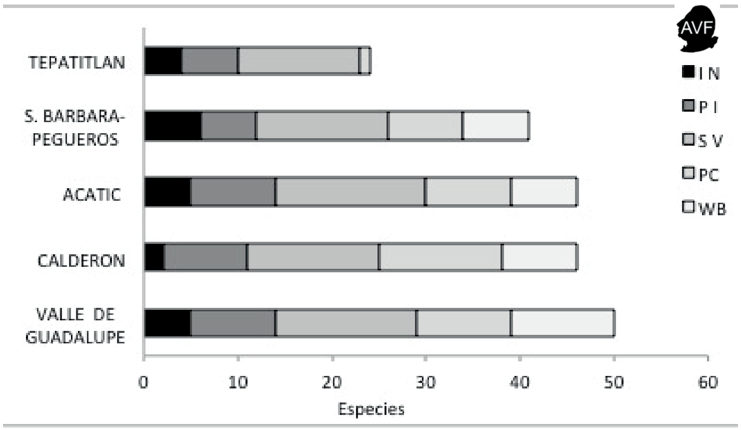

***Figure 2:*** *Species richness per environment for each site.*

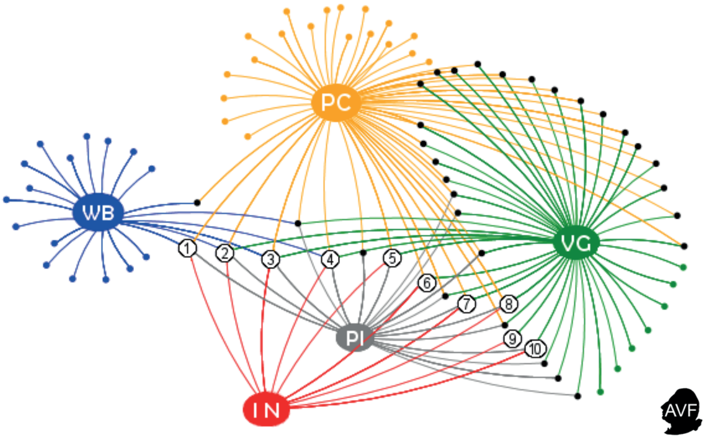

***Figure 3 :*** *Interface Wild birds – Ecosystem – Commercial poultry, depicted by network theory. Discrete objects or discs represent wild bird species associated with five environments: Poultry stall interior (IN / red), Commercial poultry farm infrastructure (PI / gray), Suburban vegetation (SV / green), Plains and crops (PC / orange) and Water bodies (WB / blue). The degree of interaction is defined by the number of links among environments, that ranges from species observed inside Poultry stalls (numbered dots), species playing a secondary role (black dots) or those species highly specialized (colored dots).*

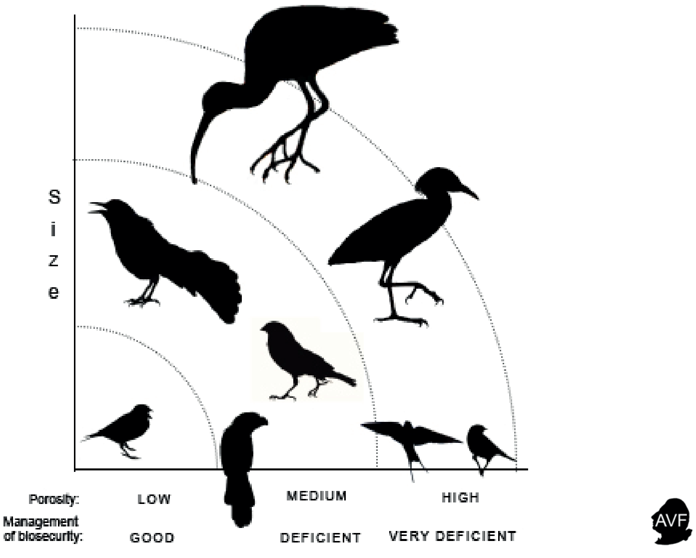

***Figure 4 :*** *Hypothetical correlation of species observed inside poultry stalls, in relation to its size as well as three levels of porosity and management of biosecurity.*

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***Table 2:*** *Checklist of the birds in the region of Altos de Jalisco, ordered alphabetically. Taxonomy based on the American Ornithologist Union 7ª Ed. Sup. 56Th (Chesser* et al. *2014). Status (STAT) proposed by Howell & Webb (1995). Vegetation structure (VEG) for Grass (G), Shrub (S), and Tree (T). The environments proposed correspond to: Interior of stall (IN) Poultry Infrastructure (PI), Suburban Vegetation (SV), Fields and Crops (FC) and Water Bodies (WB).*

| ORDER / Family | Species | Common name | STAT | VEG | IN | PI | SV | FC | WB |
|---|---|---|---|---|---|---|---|---|---|
| **ACCIPITRIFORMES** | | | | | | | | | |
| Accipitridae | *Accipiter striatus* | Sharp-shinned Hawk | RES | | 0 | 0 | 0 | 1 | 0 |
| Accipitridae | *Buteo albicaudatus* | White-tailed Hawk | RES | | 0 | 0 | 0 | 1 | 0 |
| Accipitridae | *Elanus leucurus* | White-tailed Kite | RES | | 0 | 0 | 0 | 1 | 0 |
| Cathartidae | *Cathartes aura* | Turkey Vulture | RES | T | 0 | 0 | 1 | 1 | 0 |
| **ANSERIFORMES** | | | | | | | | | |
| Anatidae | *Anas discors* | Blue-winged Teal | WIN | | 0 | 0 | 0 | 0 | 1 |
| Anatidae | *Anas strepera* | Gadwall | WIN | | 0 | 0 | 0 | 0 | 1 |
| Anatidae | *Aythya affinis* | Lesser Scaup | WIN | | 0 | 0 | 0 | 0 | 1 |
| Anatidae | *Oxyura jamaicensis* | Ruddy Duck | RES | | 0 | 0 | 0 | 0 | 1 |
| **APODIFORMES** | | | | | | | | | |
| Trochilidae | *Amazilia violiceps* | Violet-crowned Hummingbird | RES | G S | 0 | 0 | 1 | 1 | 0 |
| Trochilidae | *Cynanthus latirostris* | Broad-billed Hummingbird | RES | S | 0 | 0 | 1 | 1 | 0 |
| Trochilidae | *Selasphorus sasin* | Allen's Hummingbird | TRN | S | 0 | 0 | 1 | 0 | 0 |
| **CHARADRIIFORMES** | | | | | | | | | |
| Recurvirostridae | *Himantopus mexicanus* | Black-necked Stilt | RES | | 0 | 0 | 0 | 0 | 1 |
| Scolopacidae | *Calidris pusilla* | Semipalmated Sandpiper | WIN | | 0 | 0 | 1 | 0 | 1 |
| Scolopacidae | *Gallinago gallinago* | Common Snipe | WIN | | 0 | 0 | 0 | 0 | 1 |
| Scolopacidae | *Phalaropus lobatus* | Red-necked Phalarope | WIN | | 0 | 0 | 0 | 0 | 1 |
| **COLUMBIFORMES** | | | | | | | | | |
| Columbidae | *Columba livia* | Rock Pigeon | RES | | 0 | 1 | 0 | 0 | 0 |
| Columbidae | *Columbina inca* | Inca Dove | RES | S T | 0 | 1 | 1 | 0 | 0 |
| Columbidae | *Columbina passerina* | Common Ground-Dove | RES | S T | 0 | 0 | 1 | 1 | 0 |
| Columbidae | *Streptopelia decaocto* | Eurasian Collared-Dove | RES | T | 0 | 1 | 1 | 1 | 0 |
| Columbidae | *Zenaida asiatica* | White-winged Dove | RES | S T | 0 | 1 | 1 | 1 | 0 |
| Columbidae | *Zenaida macroura* | Mourning Dove | RES | | 0 | 1 | 0 | 1 | 0 |
| **CUCULIFORMES** | | | | | | | | | |
| Cuculidae | *Crotophaga sulcirostris* | Groove-billed Ani | RES | S | 1 | 1 | 1 | 1 | 0 |
| **FALCONIFORMES** | | | | | | | | | |
| Falconidae | *Caracara cheriway* | Crested Caracara | RES | | 0 | 0 | 0 | 1 | 1 |
| Falconidae | *Falco columbarius* | Merlin | WIN | | 0 | 0 | 0 | 1 | 0 |
| Falconidae | *Falco peregrinus* | Peregrine Falcon | WIN | | 0 | 0 | 0 | 1 | 0 |
| Falconidae | *Falco sparverius* | American Kestrel | WIN | T | 0 | 0 | 1 | 1 | 0 |
| **GALLIFORMES** | | | | | | | | | |
| Odontophoridae | *Colinus virginianus* | Northern Bobwhite | RES | | 0 | 0 | 0 | 1 | 0 |
| **GRUIFORMES** | | | | | | | | | |
| Rallidae | *Fulica americana* | American Coot | RES | | 0 | 0 | 0 | 0 | 1 |
| **PASSERIFORMES** | | | | | | | | | |
| Cardinalidae | *Passerina caerulea* | Blue Grosbeak | RES | S T | 0 | 0 | 1 | 1 | 0 |
| Cardinalidae | *Piranga rubra* | Summer Tanager | WIN | T | 0 | 0 | 1 | 1 | 0 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Corvidae | *Corvus corax* | Common Raven | RES | T | 0 | 0 | 1 | 1 | 0 |
| Emberizidae | *Chondestes grammacus* | Lark Sparrow | WIN | G S | 0 | 0 | 1 | 1 | 0 |
| Emberizidae | *Melospiza lincolnii* | Lincoln's Sparrow | WIN | | 0 | 0 | 0 | 1 | 0 |
| Emberizidae | *Melozone fusca* | Canyon Towhee | RES | S | 0 | 0 | 1 | 1 | 0 |
| Emberizidae | *Passerculus sandwichensis* | Savannah Sparrow | RES | | 0 | 0 | 0 | 1 | 0 |
| Emberizidae | *Peucaea botterii* | Botteri's Sparrow | RES | | 0 | 0 | 0 | 1 | 0 |
| Emberizidae | *Spizella pallida* | Clay-colored Sparrow | WIN | | 0 | 0 | 0 | 1 | 0 |
| Emberizidae | *Spizella passerina* | Chipping Sparrow | RES | G S T | 0 | 0 | 1 | 1 | 0 |
| Fringillidae | *Haemorhous mexicanus* | House Finch | RES | T | 0 | 0 | 1 | 1 | 0 |
| Fringillidae | *Spinus psaltria* | Lesser Goldfinch | RES | S T | 0 | 0 | 1 | 1 | 0 |
| Hirundinidae | *Hirundo rustica* | Barn Swallow | RES | | 1 | 1 | 0 | 1 | 1 |
| Hirundinidae | *Stelgidopteryx serripennis* | Northern Rough-winged Swallow | RES | | 0 | 1 | 1 | 1 | 1 |
| Hirundinidae | *Tachycineta bicolor* | Tree Swallow | WIN | | 0 | 1 | 0 | 1 | 1 |
| Icteridae | *Icterus bullockii* | Bullock's Oriole | RES | | 0 | 0 | 0 | 1 | 0 |
| Icteridae | *Icterus galbula* | Baltimore Oriole | WIN | T | 0 | 0 | 1 | 1 | 0 |
| **PASSERIFORMES** | | | | | | | | | |
| Icteridae | *Icterus pustulatus* | Streak-backed Oriole | RES | T | 0 | 0 | 1 | 1 | 0 |
| Icteridae | *Molothrus aeneus* | Bronzed Cowbird | RES | G T | 1 | 1 | 1 | 1 | 0 |
| Icteridae | *Molothrus ater* | Brown-headed Cowbird | RES | GST | 1 | 1 | 1 | 1 | 0 |
| Icteridae | *Quiscalus mexicanus* | Great-tailed Grackle | RES | GST | 1 | 1 | 1 | 1 | 1 |
| Icteridae | *Xanthocephalus xanthocephalus* | Yellow-headed Blackbird | WIN | S T | 1 | 1 | 1 | 1 | 0 |
| Laniidae | *Lanius ludovicianus* | Loggerhead Shrike | RES | S | 0 | 0 | 1 | 1 | 0 |
| Mimidae | *Melanotis caerulescens* | Blue Mockingbird | RES | S T | 0 | 0 | 1 | 0 | 0 |
| Mimidae | *Toxostoma curvirostre* | Curve-billed Thrasher | RES | S T | 0 | 0 | 1 | 1 | 0 |
| Motacillidae | *Anthus rubescens* | American Pipit | WIN | | 0 | 1 | 0 | 1 | 1 |
| Parulidae | *Cardellina pusilla* | Wilson's Warbler | WIN | S T | 0 | 0 | 1 | 1 | 0 |
| Parulidae | *Mniotilta varia* | Black-and-white Warbler | WIN | S T | 0 | 0 | 1 | 1 | 0 |
| Parulidae | *Oreothlypis celata* | Orange-crowned Warbler | WIN | S T | 0 | 0 | 1 | 1 | 0 |
| Parulidae | *Setophaga coronata* | Yellow-rumped Warbler | WIN | S T | 1 | 1 | 1 | 1 | 0 |
| Passeridae | *Passer domesticus* | House sparrow | RES | S T | 1 | 1 | 1 | 0 | 0 |
| Polioptilidae | *Polioptila caerulea* | Blue-gray Gnatcatcher | WIN | S T | 0 | 0 | 1 | 1 | 0 |
| Troglodytidae | *Campylorhynchus brunneicapillus* | Cactus Wren | RES | | 0 | 0 | 0 | 1 | 0 |
| Troglodytidae | *Catherpes mexicanus* | Canyon Wren | RES | S | 0 | 0 | 1 | 0 | 0 |
| Troglodytidae | *Thryomanes bewickii* | Bewick's Wren | RES | S | 0 | 0 | 1 | 1 | 0 |
| Troglodytidae | *Troglodytes aedon* | House Wren | WIN | S | 0 | 0 | 1 | 0 | 0 |
| Turdidae | *Turdus rufopalliatus* | Rufous-backed Robin | RES | S T | 0 | 0 | 1 | 1 | 0 |
| Tyrannidae | *Empidonax wrightii* | Gray Flycatcher | WIN | | 0 | 0 | 0 | 1 | 0 |
| Tyrannidae | *Myiodynastes luteiventris* | Sulphur-bellied Flycatcher | SRS | T | 0 | 0 | 1 | 0 | 0 |
| Tyrannidae | *Myiozetetes similis* | Social Flycatcher | RES | T | 0 | 0 | 1 | 0 | 0 |
| Tyrannidae | *Pitangus sulphuratus* | Great Kiskadee | RES | T | 0 | 0 | 1 | 1 | 0 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tyrannidae | *Pyrocephalus rubinus* | Vermilion Flycatcher | RES | S T | 0 | 0 | 1 | 1 | 0 |
| Tyrannidae | *Tyrannus melancholicus* | Tropical Kingbird | RES | T | 0 | 0 | 1 | 1 | 0 |
| Tyrannidae | *Tyrannus vociferans* | Cassin's Kingbird | RES | T | 0 | 1 | 1 | 1 | 0 |
| **PELECANIFORMES** | | | | | | | | | |
| Ardeidae | *Ardea alba* | Great Egret | RES | | 0 | 0 | 0 | 0 | 1 |
| Ardeidae | *Bubulcus ibis* | Cattle Egret | RES | G T | 1 | 1 | 1 | 1 | 0 |
| Ardeidae | *Egretta tricolor* | Tricolored Heron | WIN | | 0 | 0 | 0 | 0 | 1 |
| Threskiornithidae | *Plegadis chihi* | White-faced Ibis | RES | | 1 | 1 | 0 | 1 | 1 |
| **PICIFORMES** | | | | | | | | | |
| Picidae | Melanerpes aurifrons | Golden-fronted Woodpe. | RES | T | 0 | 0 | 1 | 0 | 0 |
| Picidae | Melanerpes formicivorus | Acorn Woodpecker | RES | | 0 | 0 | 0 | 1 | 0 |
| Picidae | Picoides scalaris | Ladder-backed Woodpecker | RES | | 0 | 0 | 0 | 1 | 0 |
| **PODICIPEDIFORMES** | | | | | | | | | |
| Podicipedidae | *Podilymbus podiceps* | Pied-billed Grebe | RES | | 0 | 0 | 0 | 0 | 1 |
| Podicipedidae | *Tachybaptus dominicus* | Least Grebe | RES | | 0 | 0 | 0 | 0 | 1 |
| **SULIFORMES** | | | | | | | | | |
| Phalacrocoracidae | *Phalacrocorax brasilianus* | Neotropic Cormorant | RES | | 0 | 0 | 0 | 0 | 1 |

In order to understand the role of the wild bird – poultry interface phenomenon, explained as the site or space where an interaction between individuals is developed, five environments were identified ***(figure 3)***. The observations made in each one of these environments allowed the identification of an assembly dominated by avian communities highly adapted to the disturbance and in some cases an elevated number of individuals.

The interface wild birds-commercial birds is considered the principal risk factor to provoke an AIV transmission in a direct, indirect and bidirectional way. The entrance of these birds to the IN, depended on the correlation between the size of the organisms and the porosity of the stall. Small birds enter more easily and in more quantity than those of bigger size. As an epidemiological background that enhances the observations in this geographical region, the AIV H7N3 HP outbreak in the year 2012 in Great-tailed Grackle population (Navarro-López *et al.* 2014) and in Barn Swallow (Soto *et al.* 2014) stands out. This event demonstrated the pathogen exchange through an interface. The birds found in the IN, sought to satisfy their basic needs through balanced forages and the protein complement of at least five orders of invertebrates, mainly in larval stages associated to the hen droppings and feathers (Vergara-Pineda *et al.* 2013). The bird that more frequently was found inside the poultry stalls was the House Sparrow (*Passer domesticus*). However, its grade of interaction with other environments resulted low (***table 1*** and ***figure 4***). The AI, even without vegetation elements present, offers shady conditions and enough perches for sparrows, pigeons and swallows to be favored using their installations for nesting, satisfying practically all their biological needs in the same facilities. Both in and around the farms, populations of wilds birds highly exposed to the AIV were found, because of the feather management, concentrated food remains, compost, piled hen droppings and in some cases, hen carcasses. Poultry installations with elevated cages in a row, favor that fresh dejections get in contact with wading birds like Cattle Egret (*Bubulcus ibis*) and White-faced Ibis (*Plegadis chihi*), who seek their food on the ground of the stalls. This environment, without considering elements of the vegetation present, linked 19 interactions ***(figure 3)***.

The SV and FC environments possibly represent the lower epidemiological risks, nonetheless, they contain the highest species richness, therefore bigger number of interactions with 37 and 35 respectively ***(figure 3)***. It should be noticed that as the element of vegetation in their three strata was added (herbaceous, shrub and arboreal), the richness of species increased ***(table 2)***.

Other RF detected included poultry farms nearby or with cattle establishments, which are an alluring for opportunist bird populations like cowbirds, ibis, herons and grackles. Especially in the presence of pig farms, quite common in the zone, the possibility of an AIV exchange increases (Webster *et al.* 1992).

The present study documented the existence of water bodies which surface, ecological conditions and closeness to poultry farms, confer them important implications in terms of RM (Vandegrift *et al.* 2011). One of these ponds was as close as 6.3 m from de poultry production stall. These water bodies dwell waterfowl like teals, abundant during the winter; such is the case of *Anas cyanoptera*, regionally identified as the reservoir of H7N3 avian influenza virus (unpublished). It is fundamental to point out that the wetlands in Los Altos de Jalisco are located under the Central Flyway. The regional orography contributes that marshes in the neighbor state of Nayarit, interconnect with a corridor of alluvial valleys and scattered lagoons down to the wetland system Sayula-Chapala. In consequence, organisms from the Pacific and Central Flyways find a path to reencounter during their winter stay. The implications of this effect involve the recombination of viral strains from different geographical origins, such is the case of the AIV H7N3 HP outbreak present in Los Altos de Jalisco during 2012 (Maurer-Stroh *et al.* 2013; Kapczynski *et al.* 2013; Lu *et al.* 2014).

## CONCLUSION

The results of this study show the existence of epidemiological determinants for the AIV to introduce, establish and propagate in a poultry population.

The epidemiological, spatial and temporal dynamic of species like *Quiscalus mexicanus*, and the role it may be performing as "bridge bird", should be elucidated, given its high affinity for the number of environments it was observed and its continuous incidence inside the poultry production stalls.

The RM should consider the results here exposed to minimize the possibility of AIV transmission. As well as start to eliminate the RF associated, for example, isolate the hen droppings from the wild birds, maintain in good state the poultry netting, close de access gates and keep an adequate management of the food, among others. These measures require a paradigm shift to design new installations or restructure the existing ones.

Finally, we consider that in this pilot study, we have used a methodology that demonstrates the existing epidemiological relations in the interface wild birds-commercial birds.

## ACKNOWLEDMENTS

*The present study was financed with resources from the Project N° 5612-32000-064-18S celebrated between the US Department of Agriculture – Agricultural Research Service (USDA-ARS) and the Servicio Nacional de Sanidad Inocuidad y Calidad Agroalimentaria (SAGARPA-SENASICA). A special mention to the farm owners and the people in charge for the support granted.*

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