THESIS

EPIDEMIOLOGICAL CHARACTERIZATION AND NETWORK ANALYSIS OF COLORADO'S BACKYARD BIRD POPULATION, 2008-2009

Submitted by

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ABSTRACT

EPIDEMIOLOGICAL CHARACTERIZATION AND NETWORK ANALYSIS OF COLORADO'S BACKYARD BIRD POPULATION, 2008-2009

Backyard bird flocks are a minimally characterized population that could be influential in the spread of HPAI among bird populations, humans, and other animals. The general objectives of this study were to collect basic information on Colorado's backyard bird populations to provide an epidemiological characterization of the backyard flocks in Colorado from March 2008 to March 2009, specifically focusing on an association between poor health among the birds and the movement of birds by humans; and also to perform a network analysis evaluating potential relationships between backyard flocks and poultry exhibitions, and bird markets. Flock information was gathered by questionnaire sent to backyard flock owners. Questions covered the topics of backyard flock characteristics, movement, health, biosecurity, and human interaction. The descriptive statistical analyses were performed using the statistical software program, SPSS Graduate Pack 16.0© 2007. The network analyses were performed using the software packages for social network analysis, UCINET 6 for Windows- Version 6.230 © 2002 and NetDraw 2.087- Network Visualization Software © 2002.

A total of 317 surveys were returned out of 807 eligible surveys, providing a participation rate of 39.28%. In 2008, the backyard bird population surveyed consisted primarily of layer chickens (37.43%), waterfowl (14.92%), and show chickens (14.09%). We found that 68.6% of the flocks were smaller than 50 birds and were mostly kept as a source of food for the family (86.44%). A large number of flocks were also used for participation in 4-H or Future Farmers of America (FFA) or just kept as pets. The most commonly reported health problems included unexplained death (12.93%), external parasites (23.97%), respiratory problems (12.93%), and diarrhea (12.3%). Almost half of the participants reported moving their birds off of their home premises at least once during the year. Most of these birds were taken to fairs or bird shows (31.43%). We found that the flocks with birds that were moved frequently were more likely to develop respiratory problems than those that did not move their birds (1 time, (0.7, 5.11); 2-3 times, (1.37, 9.16); >4 times, (3.33, 19.94)).

With network analysis, we established the presence of a highly connected network among backyard bird flocks and poultry events. The event and flock networks were heterogeneous, small world, and scale-free networks with a few central events or flocks that were highly connected to a number of the other flocks/events.

The information gathered provides basic descriptive information useful for the development of future studies of this population or for integration into HPAI surveillance or HPAI control programs by providing essential population data for backyard bird populations. The information provided by the network analysis can be used to predict the potential spread of disease in this population and for targeted disease control.

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INTRODUCTION

Background and Significance

Avian influenza (AI) is a highly contagious viral disease that occurs naturally in poultry and waterfowl. It also infects a variety of mammals and is a zoonotic disease that can affect humans. Morbidity and mortality rates in poultry can vary depending upon the pathogenicity of the infective strain; however they can be as high as 100%, with little to no sign of illness prior to death (Brown et al. 2008).

The economic consequences of an outbreak of avian influenza among poultry populations can be devastating to poultry industries and the affected nation as well as a threat to human health (Pelzel et al. 2004; Rott 1992). Since 2003, the Office International des Epizooties (OIE), also known as the World Organization for Animal Health, and the World Health Organization (WHO) have reported continued incidences of animal and human cases of the most severe, highly pathogenic strains of avian influenza (HPAI) across the world. As of May 2010, 63 countries reported cases of HPAI H5N1 in domestic poultry or wildlife from 2003 to 2010 (OIE 2010) and as of July 2010, there have been 500 cases and 296 reported human deaths from HPAI H5N1 (WHO 2010).

Smaller bird populations, such as backyard flocks, may play a critical role in the spread of avian influenza during an outbreak (Akey 2002; Capua et al. 2003; Pelzel et al 2006). This study provided the first assessment of Colorado's backyard bird population, the first backyard poultry population characterized in the Western United States. The

United States Department of Agriculture's (USDA) National Animal Health Monitoring and Surveillance (NAHMS) group conducted a national assessment of backyard poultry in 2004. However, the study was limited to backyard poultry populations on premises within a one-mile radius of major commercial poultry operations and consequently gathered information from only the Eastern to South-Eastern United States, from California, and selected more rural flocks than urban (USDA NAHMS 2004).

General characteristics of backyard bird populations are not yet well described. Descriptive parameters of backyard flocks are important to establish complete and effective control measures for response to an outbreak of HPAI and to devise effective surveillance programs. Most backyard bird flocks are kept to show in fairs and shows and/or as sources of meat and eggs for the family. Consequently, movement of live birds, bird products, and equipment by humans is potentially important in the backyard bird population. Movement of birds and bird equipment by humans has proven to be a major form of transmission of avian influenza in recent outbreaks of HPAI across the world, including Italy in 1999-2000, Hong Kong in 2002, and Texas in 2004 (Capua et al. 2003**;** Kung et al. 2007; Pelzel et al 2006)**.**

The movement of backyard birds by humans within Colorado may also result in the establishment of networks among flocks with events at specific locations serving as central nodes of activity. The existence of central nodes and network movement could potentially accelerate the spread of avian influenza in the event of an outbreak. Therefore, the nodes of high activity may also be critical areas of focus when controlling spread.

<u>Research Goals and Hypotheses</u>

A cross-sectional study was conducted to characterize backyard bird populations in Colorado. The study focused on general characteristics, human movement of birds, and the potential network relationships among backyard bird populations. This study addresses two primary goals: to conduct an epidemiological characterization of Colorado's backyard poultry population; and to identify networks among the backyard poultry populations throughout Colorado.

<u>Goal 1</u>: To conduct an epidemiological characterization of the backyard poultry populations in Colorado and to test the hypothesis that there is an association between poor health events and frequent movement of birds from backyard flocks from home premises to events such as poultry shows/fairs/exhibits or feed stores.

<u>Specific Aim 1:</u> Send out mail-in questionnaires to gather information on backyard flocks and to be filled out by flock owners throughout Colorado. The questionnaires target:

- Flock Characterization
- Bird Movement
- Human Interaction
- Biosecurity
- Flock Health

<u>Specific Aim 2:</u> Conduct a descriptive epidemiological characterization of Colorado's backyard poultry populations.

<u>Specific Aim 3</u>: Estimate the association between:

- bird types within flocks and flock size
- bird type and flock purpose
- bird type and movement of birds by humans
- amount of movement and quarantine practices
- bird type and number of purchases
- flock size and purchase events throughout the year
- biosecurity practices and health events
- quarantine practices and health events
- reported bird health and human movement of flocks to poultry events such as, shows, fairs, or markets

<u>Goal 2</u>: To test the hypothesis that:

A network relationship exists among backyard bird populations and poultry events (fairs/shows/markets) due to human movement of birds to participate in the events.

> Specific Aim 4: Establish the existence of network relationships among sampled backyard flocks that reported movement to bird events during the twelve-month study period. Utilize Social Network Analysis software (UCINET, NetDraw) to explore the baseline existence of networks.

> Specific Aim 5: Determine the strength and connectivity of the network relationships among backyard populations and events by evaluating the centrality of the nodes and the strength of the ties between nodes to assess the importance of these as potential transmission pathways in the event of a potential AI outbreak.

This study will be limited to investigating the network structure of backyard poultry populations and does not consider a modeling of the flow of disease through the network.

LITERATURE REVIEW

Introduction

Avian influenza, commonly referred to as "bird flu", is a highly contagious viral disease that occurs naturally in poultry and waterfowl. It can infect a large range of avian species, along with a variety of mammals. Avian influenza (AI) is also a zoonotic disease that can cause clinical illness in humans. Morbidity and mortality rates in a flock vary depending upon the pathogenicity of the infective influenza strain; however, mortality can be as high as 100%, with little to no sign of illness prior to death in highly pathogenic influenza strains, such as HPAI H5N1 (Brown et al. 2008).

Since the initial outbreak of highly pathogenic avian influenza (HPAI) H5N1 in Hong Kong in 1997, avian influenza has drawn international attention as HPAI H5N1 in birds and humans has continued to circulate worldwide (Perdue & Swayne 2005; CDC 2009; WHO 2010). The 1997 HPAI H5N1 outbreak led to the death of millions of chickens, due to infection or slaughter. This event also marked the first recorded account of definite direct transfer of the virus from poultry to humans without viral adaptation (Claas et al. 1998). A total of 18 humans were clinically infected and 6 of these humans died as a result of severe respiratory disease (Claas et al 1998; CDC 2009).

The World Health Organization (WHO) and the World Organization for Animal Health (OIE) together defined an emerging zoonotic disease as "a pathogen that is newly recognized or newly evolved, or that has occurred previously but shows an increase in incidence or expansion in geographical, host or vector range" (Cutler et al. 2010). From 1959 to 1998, there were only a recorded 23 million birds affected by AI, whereas from 1999 to 2004, there were a recorded 200 million affected birds (Capua et al. 2004). With respect to highly pathogenic strain of avian influenza H5N1, from 2003 to May 2010, a total of 63 countries reported infections with HPAI H5N1 in domestic poultry and wildlife (OIE 2010). The affected countries spanned from Asia to the Middle East and some countries in Europe. Prior to 1997, AI was considered a disease of avian species that held little significance to human health (Beare et al. 1991). Currently, the World Health Organization (WHO) reported that as of July 5, 2010 there have been 500 human cases of reported HPAI H5N1 in humans, with 296 deaths, a case fatality rate of 59.2% (WHO 2010). Whether the increase in documented cases reflected more precise diagnostic tests or increased awareness, the emergence of HPAI H5N1 and the impact on human health is significant.

The apparent increase worldwide of HPAI H5N1 cases in birds, animals, and humans between 2003 to 2010, raises concerns about a potential influenza pandemic, which is expected to have significant implications for the health of economies, poultry, and humans (CDC 2009; WHO 2010).

Significance

A thorough understanding of the various methods of spread of HPAI H5N1 is critical to the control and prevention of disease. The large geographic area affected by HPAI H5N1 reflects the extensive spread of H5N1. Although wild waterfowl and shorebirds are noted as major sources of the initial introduction of avian influenza into a domestic population, the spread of AI within domestic flocks is likely due to human movement of contaminated equipment or infected birds (Alexander 2007). Backyard birds are often kept for show in bird exhibitions or fairs and/or are moved frequently by humans from their home premise to other events, thus providing an opportunity for spread of an infectious agent.

Backyard flocks are defined as residences with gallinaceous birds and a flock size of fewer than 1,000 birds. They are typically kept for the purpose of shows, exhibitions, fairs, 4-H events, food sources, poultry products, hobby, or pets (USDA NAHMS 2004). Participation in shows, fairs, and bird swaps can equate to high levels of movement of the birds. Such events involve congregation of birds from various locations in a single area for a period of time and then dispersal to their area of origin or to new locations.

The movement of backyard birds is not yet well characterized. However, it is crucial information in the event of an AI outbreak since these birds may serve as a significant route of AI transmission and spread. Although, studies have shown that the initial introduction of AI into a naïve population is associated with contact between infected wild waterfowl and susceptible domestic poultry (Wells 1963; Hinshaw et al. 1980), the primary cause of continuous transmission of AI among susceptible populations is due to human movement of birds or contaminated bird equipment, clothes, or vehicles (Wells 1963; Glass 1981; Manneli et al. 2007). The major risk factor in the spread of HPAI H7N1 in the 1999-2000 outbreak among Italy's poultry industry was human movement of contaminated equipment, vehicles, and movement of personnel (Capua et al. 2000**;** Capua et al. 2003; Terrigino et al. 2007*)*. In Hong Kong's 2002 HPAI H5N1 outbreak, the major risk factor for spread was similarly determined to be human movement of birds and fomites (Kung et al. 2007). Similarly, the 2002 outbreak of LPAI

H7N2 in Virginia and the 2004 outbreak of HPAI H5N2 in Texas were both attributed to human movement of birds and fomites (Akey 2003; Pelzel et al 2006). Husbandry practices clearly differ around the world and thus will have variable effects on the transmission of AIV; however, HPAI outbreaks are occurring globally, despite different husbandry and biosecurity practices.

Further, a majority of humans that have been infected with or died from HPAI H5N1 in recent years have been people that have contact with infected poultry, including poultry operation workers and owners of village flocks (Chotpitayasundondh 2005*)*. Therefore, the characterization of backyard populations is vital not only to bird health and human health, it is also especially important in developing effective surveillance programs and in devising appropriate methods of control in the event of an outbreak.

Etiology

Avian influenza virus (AIV) belongs to the family *Orthomyxoviridae* and the genus *Influenza A.* AIV is a negative sense, single-stranded RNA virus with a segmented genome (Strauss et al. 2002). There are variable subtypes of Type A influenza viruses, which are distinguished by two characteristic surface glycoproteins, hemagglutinin (HA) and neuraminidase (NA). There are a total of 16 HA glycoproteins and 9 NA glycoproteins; each influenza virus bears only one HA and one NA protein together in variable combinations and is named according to the combination, such as H5N1 or H7N7 (WHO 1971).

The AI viral strains are also differentiated by pathogenicity and classified as highly pathogenic avian influenza (HPAI) or low pathogenic avian influenza (LPAI)

(OIE 2009a). The pathogenicity of the subtypes is defined by the amino acid sequence structure at the cleavage site of the receptor binding protein (HA) and by the ability of the virus to cause disease in chicks (Webster et al. 1978; Klenk et al. 1988; Rott 1992).

Infection with highly pathogenic avian influenza (HPAI) viruses results in severe, acute clinical disease of poultry (Brown et al. 2008). HPAI viruses are composed of either H5 or H7 surface proteins (Alexander 2000). Low pathogenic avian influenza (LPAI) viruses typically manifest asymptomatically or as mild clinical diseases and include any one of the 16 HA subtypes (Brown et al. 2008).

Genetic reassortment and mutation of influenza virus strains are unique and important mechanisms to create novel influenza viruses with the potential to exhibit increased pathogenicity (Rott 1992). RNA virus replication is often faulty and can lead to a number of mutations in amino acid sequences (Strauss et al. 2002). Overtime, these minor mutations can accumulate to alter the genome and eventually produce a new subtype; this is referred to as antigenic drift (Bean et al. 1980; Webster et al 1971; Webster et al. 1974). The segmented genome allows for frequent reassortment, which is referred to as antigenic shift (Strauss et al. 2002). Reassortment can occur when one of the viral segments is replaced by segments from another source, from another strain of avian influenza or even from a mammalian strain of influenza (Webster et al. 1971; Webster et al. 1974). Antigenic shift can lead to increased pathogenicity, such as an LPAI virus evolving into a HPAI virus, or into a novel virus to which birds or mammals do not have prior immunity (Shaw et al. 2002; Wright et al 1992).

Clinical Aspects of Avian Influenza in Birds

Development of clinical disease in birds is variable and dependent upon the pathogenicity of the infectious strain, host species, host health, concurrent infections, and environmental factors (Brown et al. 2008). The length of the incubation period is similarly dependent upon these varying factors. For an individual bird the incubation period can be anywhere from 1 day for the more pathogenic strains to 7 days (Brown et al. 2008). At the flock level, the incubation period can vary greatly from days to weeks, depending on environmental conditions and housing (caged, free-range, etc) (OIE 2009a).

LPAI viruses typically result in asymptomatic infections in poultry and usually do not induce a symptomatic disease in the reservoir hosts, wild waterfowl and shorebirds (Stallknect et al. 1988). In poultry, disease may present as a very mild disease characterized by decreased egg production, thin-shelled and misshapen eggs, decreased feeding and watering, and mild respiratory signs such as wheezing, matted eyelids, swollen sinuses, and nasal discharge (Brown et al. 2008). Infected birds may also tend to act chilled, huddling near heaters and close together in hunched stances with ruffled feathers. The more common clinical respiratory syndrome can affect all domestic poultry. Egg laying poultry may also exhibit drops in egg production; turkeys tend to be more severely affected by reproductive disease (Brown et al. 2008).

Environmental conditions and concurrent infections can play an important role in the severity of disease for a LPAI virus (Becker 1966; Homme et al. 1970). Stressful environmental conditions, such as cold or frequent movement, can be important determining factors in infection rates or severity of disease (Becker 1966; Homme et al.

1970). HPAI has been isolated from birds of all ages. However, younger birds tend to be more susceptible to infection and develop more severe clinical disease (Pantin-Jackwood et al, 2007, Stallknect et al. 1988).

HPAI infections produce a drastically different clinical disease compared to an LPAI infection (Brown et al 2008). HPAI infections typically result in sudden death of large numbers of poultry before any clinical signs are noted. If clinical signs are exhibited prior to death they are less likely to be characterized as respiratory disease than in LPAI infections. Infected birds exhibit depression, ruffled feathers, decrease in egg production, decreased interest in water and food consumption, watery diarrhea, and may develop neurological disorders. Mortality rates in outbreaks of clinical disease caused by H5N1 can near 100% and can occur within 2 to 12 days after the first signs of disease. (Brown et al. 2008).

Epidemiology

History

Highly pathogenic strains of avian influenza have been identified in domestic bird populations for decades. First defined in 1878, the disease that caused high mortality in flocks was referred to as "fowl plague" (Alexander 2000). There are documented outbreaks of both HPAI and LPAI among domestic bird populations throughout the world since the 1950s, especially in turkey populations and in some chicken populations (Alexander 2000). The association between wild bird populations and domestic birds and the transmission of avian influenza was first noted when the first avian influenza virus, HPAI H5N2, was isolated from wild birds, from common terns (*Sterna hirundo)*, in

South Africa in 1961 (Becker et al. 1966). The zoonotic feature of HPAI in natural settings was not noted until the 1997 outbreak of HPAI H5N1 in Hong Kong. Prior to this outbreak, Beare et al. (1991) noted that there had not been any virological evidence of a documented transmission of avian influenza to a human outside of laboratory conditions, even among workers that were in constant close contact with infected waterfowl (Beare et al. 1991). Yet in 1997, the HPAI H5N1 outbreak in Hong Kong, which originated in feral geese and spread to domestic chickens, eventually infected 18 people, 6 of whom died (Claas et al. 1998; CDC 2009). Following the 1997 Hong Kong outbreak, numerous H5N1 outbreaks erupted throughout Southeast and Eastern Asia and eventually expanded into Africa, the Middle East, and Europe. Many of these subsequent outbreaks involved both human and bird cases (WHO 2009; OIE 2010). HPAI H5N1 outbreaks have not yet been documented in North America (OIE 2009b; WHO 2009); however, there have been a few significant outbreaks of HPAI viruses in Canada and the United States since 2002 (Senne 2007). In 2004, the United States experienced an outbreak of HPAI H5N2 among meat birds in Texas (Pelzel et al. 2006). The outbreak was small and confined to two live bird markets and the one index farm. Also in 2004, an outbreak of HPAI H7N3 occurred in Canada (Senne 2007). This was a much larger incident, including 42 premises. Both of these outbreaks interestingly originated as LPAI viruses that were believed to have been circulating undetected anywhere between 2 weeks and 2 years. The LPAI viruses eventually mutated into the problematic HPAI viruses (Senne 2007). A number of LPAI viruses are frequently identified in the United States in domestic flocks of chickens, turkeys, game birds, and in wild birds in several states (USDA NAHMS 2008). Recently, there were two outbreaks of LPAI (H7N9) in the United States (OIE 2009b). In March 2009, LPAI H7N9 was identified in commercial meat chickens in Kentucky and in April 2009 in commercial turkeys in Minnesota. In Canada, there was one outbreak of LPAI H5N2 in January 2009 among a few turkey farms (OIE 2009b). Since 1997, HPAI H5N1 has been considered a threatening zoonotic disease, creating disease in birds in increasing numbers, and carrying the looming threat of a potential pandemic.

Reservoir Host

Avian influenza virus has a broad host range. It has been isolated from a variety of species including a large number of wild birds as well as domestic chickens and turkeys (Stallknecht et al. 1988). Wild waterfowl and shorebirds serve as the natural reservoir host of AIV (Hinshaw et al. 1980a; OIE 2002).

Variable combinations of all 16 HA subtypes and all 9 NA subtypes are maintained in Anseriformes (ducks and geese) and Charadriiformes (shorebirds), with ducks and geese serving as the most dominant hosts (Stallknecht et al. 1988; Alexander 2000; Swayne et al. 2003). As the primary reservoir hosts, aquatic wild birds act as the source of avian influenza viruses that spread to other species (Webster et al. 1992).

Although AI virus is highly prevalent throughout wild bird populations, infection rarely manifests itself as clinical disease (Stallknecht et al. 1988). Maintenance of the avian influenza virus in these wild bird populations is attributed to the endemic, asymptomatic infection of wild birds, particularly waterfowl and shorebirds (Hinshaw et al. 1980b; Markwell et al. 1982). These birds shed high levels of virus via feces into bodies of fresh water where it can then persist for up to 30 days in lower temperatures (4^{o}C) and low salinity (Webster et al. 1978; Brown et al. 2007). Introduction of susceptible birds to the contaminated water body, either from seasonal migration or young birds, will lead to continuous infection, thus maintaining AIV in wild bird populations (Hinshaw 1980b; Markwell et al. 1982).

Perpetual infection of wild waterfowl poses a threat to domestic poultry populations that interact with infected, yet healthy, ducks and geese *(*Alexander 2000). The initial isolation of an avian influenza virus HPAI H5N2 from wild birds was reported in 1961 from common terns in South Africa (Becker et al. 1966). This isolation stimulated questions on the role of wild birds in the spread of AIV to domestic bird populations. Domestic birds, such as ducks or turkeys, raised as free-range birds attract migrating waterfowl and stimulate intermingling between domestic and wild birds (Alexander 2000; Terrigino et al. 2007). Outbreaks of HPAI H5N2 in Pennsylvania in 1983 and 1984 were attributed to wild-domestic bird co-mingling (Bean et al. 1985). Halvorson et al. (1983) found free-range turkeys in Minnesota also to be frequently infected with AI viruses from interactions with wild birds.

Avian influenza viruses can also infect a wide range of mammalian species such as humans, horses, cats, pigs, and sea mammals (Tumova 1980; Geraci et al. 1982; Wright et al. 1992; Class et al. 1998; Keawcharoen et al. 2004; Songserm et al 2006).

Transmission

Transmission of avian influenza virus can occur via respiratory droplets, feces, or fomites, including contaminated clothing, hands, or equipment and supplies (fomites) (Alexander 2007). Transmission between poultry flocks is quite complex. Successful transmission is dependent upon the virus strain, bird species, and environmental factors (Alexander et al. 1978; Westbury et al. 1981; Alexander et al.1986).

Poultry transmission of AI virus occurs primarily through respiratory secretions. Virus is carried in respiratory droplets from secretions of the nose, mouth, and eye and can be transmitted directly (Rott 1992). Consequently, bird-to-bird transmission by respiratory droplets is particularly problematic for poultry housed in close living quarters (Wells 1963).

Transmission of AIV in waterfowl and shorebirds occurs primarily through fecal shedding (Webster et al. 1978). As a result, influenza virus is shed in rather large quantities in feces for periods of 2 to 4 weeks, making fecal transmission a common method of indirect transmission (Hinshaw 1980a; Webster et al 1978). This method of transmission is particularly common in waterfowl as waterfowl rarely develop respiratory clinical disease from AIV infection (Webster et al. 1978). AIV can be fairly resilient in freshwater conditions. Viral persistence is inversely related to water temperature and salinity. Virus can remain infectious in the feces in water at cooler temperatures ($4^{o}C$) for 30 days to well over a year or up to 7 days in warmer water (20^{o} C) (Brown et al. 2007; Webster et al. 1977; Stalknecht D.E et al 2009). Consequently, bodies of water inhabited by waterfowl can become heavily contaminated by the virus-containing feces (Hinshaw et al 1980b; Markwell et al 1982). Uninfected birds can then become exposed by waterborne transmission while drinking or bathing in the contaminated water.

A significant method of indirect transmission is mechanically via humans and fomites (contaminated inanimate objects). Virus shed in large concentrations in feces can contaminate human clothing, shoes, hands or other inanimate objects such as feed, litter, cages, equipment, and transportation vehicles (Glass 1981; Wells 1963).

As early as 1963, Wells described an outbreak of avian influenza among turkey farms that was most likely spread between farms by the driver of an abattoir truck (Wells, 1963). Recently more emphasis has been placed on AIV transmission by human movement and fomites as an important method of viral spread (Alexander 2007). Investigation of the 2002 LPAI H7N7 outbreak in Virginia concluded that the primary method of transmission of the LPAI virus was in fact by fomites, people and contaminated equipment (Akey 2003*)*. These same modes of transmission were concluded to be the most significant risk factors in a 2002 outbreak HPAI H5N1 among poultry populations in Hong Kong (Kung et al. 2007) and in Italy's recent outbreaks of HPAI H7N1 in 1997 and 1999-2000 (Capua et al. 2003).

These modes of transmission are important when considering the spread of AIV among individual domestic birds and bird populations, such as backyard poultry flocks. Initial introduction of avian influenza virus into a naïve domestic bird population may occur by direct contact with infected wild species of birds, typically waterfowl (Glass 1981; Wells 1963). This statement is supported by studies that demonstrate a higher prevalence of AIV infection in poultry along the migratory routes of waterfowl (Hinshaw et al. 1980b), and similar viral subtypes among migrating waterfowl and the domestic poultry living along these migratory flyways (Senne 2003). Further, outbreaks among domestic poultry display seasonal trends congruent with the migratory patterns of water fowl (Halvorson et al. 1983). Naïve populations can also be exposed to AIV by the mechanical spread via equipment/animals/humans contaminated with wild bird feces (McQuiston et al. 2006).

Secondary spread of AIV is critical in determining the potential magnitude of an outbreak. Secondary spread is most problematic because of the potential for spread to multiple flocks in the immediate geographic area and beyond. Humans are the major cause of secondary spread among domestic poultry populations (Wells 1963; Glass 1981; Akey 2003; Capua et al. 2003; Kung et al. 2007). Dent et al. (2008) emphasized the critical role of bird movement in the spread of AIV. In this study, an outbreak in Great Britain was enhanced by the movement of birds from their initial premises to slaughterhouses, thus spreading the outbreak over long distances (Dent et al. 2008). Additionally, the 2004 outbreak of HPAI H5N2 in Texas resulted from movement of poultry and subsequently AI. The index birds in this outbreak were from a commercial meat bird operation. They were likely exposed to the HPAI virus at a live bird market where the virus was circulating (Pelzel et al. 2004). These newly AI exposed birds returned to the commercial meat bird operation from the live bird market, introducing the virus to other birds at the operation. From there, the birds at the meat bird operation were taken to other live bird markets resulting in further spread of the HPAI virus (Pelzel et al. 2004). This is an excellent example of the potential role of movement of birds between premises as a major risk factor for the introduction and spread of avian influenza.This method of secondary spread is of particular importance in backyard bird populations that travel frequently to bird fairs and shows. In this setting, birds as well as humans are exposed to a variety of birds, which could potentially be shedding AIV. This cycle may thus expose birds that will then leave and travel to new locations or return to their home premises, and begin to shed virus not long after infection.

Network Analysis:

An understanding of bird movement by humans in the smaller, less characterized backyard flock population may be important to consider when planning control or preventative methods for avian influenza. Social network analysis is an increasingly used method in disease transmission studies. Network analysis is based on graph theory to study relationships among nodes (such as animals, farms, fairs, markets etc) and to assess the patterns and the implications of the relationships (Dube et al. 2009). It provides a conceptual framework to express the elements in the network and the nature of their relationships linking them, such as the movement of backyard flocks among events. An understanding of network structure provides insight into how information, such as an infectious agent, may spread through the described network, how resilient the network is to infection, and the social role of the involved individuals (Webb 2005). The strength of the network can reveal the level of connectivity of the network and which nodes within the defined population are more likely to be involved in disease transmission (Network Analysis Workshop 2006).

Until recently, network analysis has primarily been used in studies focusing on contact networks in the transmission of sexually transmitted diseases in humans (Ghani et al 1997; Liljeros et al 2001). Since 2003, researchers have been utilizing network analysis in studies of infectious disease transmission among animal populations. Network analysis can be useful in studying relationships among pairs of farms, livestock operations, fairs/shows, or markets included in the network and the paths of animal movement to understand the potential paths open to spread of infectious agents (Dube et al. 2009). The first published study in veterinary epidemiology that utilized social network analysis was from Corner et al (2003), in which social network analysis was applied to model the social behavior patterns of brushtail possums affecting tuberculosis transmission (Corner et al. 2003). This method of analysis has also been used to analyze the role of horse trainers in disease spread among horses attending equine race events (Christley et al. 2003) and movements of livestock to fairs, market, and slaughter to assess the most influential locations to focus control or preventative measures in the spread of foot-and-mouth disease (Christley et al. 2003; Webb 2005;Webb 2006; Bigras-Poulin et al. 2006; Ortiz-Pelaez et al. 2006; Bigras-Poulin et al 2007; Robinson et al. 2007). Network analysis of the movement of backyard bird populations in Colorado may reveal a connected network among flocks and events that could be useful in prevention and control of avian influenza.

Zoonotic Disease

A zoonotic disease is one that is transmissible between animals and humans under natural conditions (Cutler et al. 2010). Infections of a few humans with an animal pathogen may develop into epidemics that pose a public health risk. A majority of human pathogens are zoonotic (60%), originating from animals (Cutler et al. 2010). Avian influenza viruses can be zoonotic and can be transmitted to humans and cause infection and disease (Perdue et al. 2005). In 1997, the first clearly documented cases of human infection with avian influenza virus HPAI H5N1 were documented in Hong Kong (Claas et al. 1998). This event highlighted the zoonotic potential of avian influenza virus.

Avian influenza viruses do not commonly infect humans due to the differences in cell receptor preferences of human influenza strains and avian influenza strains. Most humans who become infected with AIV are in situations where they have close contact with the infected poultry (WHO 2008). Numerous studies have shown that the most important risk factor for humans becoming infected with HPAI viruses is exposure to poultry (Bridges et al. 2002; Chotpitayasunondh et al 2004; Koopmans et al. 2004; Tweed et al. 2004; Dinh P et al. 2006). In various outbreaks from Asia to Canada, the people who became infected with HPAI viruses were employed at poultry operations, living in the same house as infected birds, slaughtering poultry, or cleaning poultry housing. Additionally, studies in the United States have found serological evidence of antibodies to LPAI viruses in poultry workers and duck hunters (Gray et al. 2008; Myers et al. 2007).

In addition to people in close contact with sick birds, the other significant at-risk group associated with infection with HPAI H5N1 includes children and young adults (Chotpitayasunondh et al 2004; Thanh Liem et al. 2009). The median age of those infected is 18 years old and 90% of the cases are <40 years of age (WHO 2007). Currently, there is not a definite association between children and young adults and increased risk of HPAI H5N1. One theory is that it could be due to increased exposure to infected poultry among the younger populations simply due to the role of children and young adults in caring for poultry or possibly in the degree of reporting sickness among age groups (Kandeel A, et al. 2010; Oner AF et al. 2006; Sedyaningsih ER, et al. 2007).

Clinical symptoms in infected humans range from mild respiratory illness to severe pneumonia to multiple organ failure (WHO 2008). Most frequently, patients develop influenza-like symptoms, which include a fever >38^{o} C, cough, and dyspnea. Gastrointestinal symptoms may also develop, including watery diarrhea, vomiting, and abdominal pain (Thanh Liem et al. 2009; WHO 2008).

Direct transmission from person-to-person is very rare, but has been documented primarily in small family clusters, in which family members caring for the sick have also become infected. In two situations in Thailand and China, the infected family members did not have recent contact with infected poultry and the isolated virus genotypes were almost identical to the isolated virus in the index cases (Ungchusak K et al. 2005; Wang H et al 2008). However, although the cases likely became ill due to direct transmission from their family member, transmission was limited and did not extend to further person-to-person transmission. To date, the person-to-person transmitted viruses have been purely avian, not yet adapting to the human host (Ungchusak K et al. 2005; Wang H et al 2008). The potential for the virus to genetically resort or mutate to a more human-adapted virus that could be readily transmitted from human to human is a realistic concern (Webster et al. 1974). AIV outbreaks and patterns across the world are currently under careful monitoring in anticipation of a potential mutation of the virus that could spread through human populations (CDC 2009, WHO 2010). An avian influenza virus that becomes host adapted for humans has the potential to spread from human to human and could cause a devastating global pandemic as a novel and pathogenic virus in the human population (CDC 2009).

Economic Impact

The economic consequences of an outbreak of HPAI can be substantial. Outbreaks of H5 or H7 AI virus infections are reportable on an international level to the OIE. Under the circumstances of a disease outbreak, under guidelines of OIE, all domestic and international trade of poultry products from the affected country will likely come to a complete halt (OIE 2009a). Economic consequences of trade restrictions can be prolonged and add to the many other economic side effects of a disease outbreak. Losses are due to large expenses on a local level for the depopulation of all infected birds and affected flocks, and hired personnel required to control the outbreak (Pelzel et al. 2004).

Prevention/Control

Prevention of future outbreaks of AIV is highly dependent upon increased emphasis on biosecurity measures and national surveillance programs (OIE 2008). The OIE established a standard set of biosecurity measures available for each country to follow to prevent HPAI outbreaks. These measures include maintaining clean and uncontaminated feed, water, tools, equipment, vehicles, cages; avoiding sharing equipment and cages with neighbors; preventing visitors and other birds (especially wild birds) from coming in contact with birds; education of bird owners to understand and recognize the early clinical signs of the disease; and finally educating flock owners and workers to report sick birds (OIE 2008).

In the event of an outbreak, the OIE guidelines include slaughtering of all birds, proper disposal of carcasses and animal products, followed by thorough cleaning and disinfection of the premise. A minimum of 21 days should be followed before restocking the premise with new birds (OIE 2008).

In conclusion, an outbreak of HPAI H5N1 in the United States could be a severe health risk to birds, humans, as well as a significant economic concern. Previous studies of HPAI and LPAI outbreaks in domestic birds have found associations between the spread of AI and contaminated equipment and vehicles and/or the movement of infected birds. Backyard bird flocks could play a major role in the spread of HPAI H5N1 if it were introduced as some backyard birds are used for show in exhibitions or fairs or to sell at bird markets. Attendance to such events includes transportation of birds and equipment and high levels of interaction with other birds and humans. Therefore, backyard bird populations may play a significant role in the spread of H5N1 HPAI if it were introduced to the United States.

MATERIALS AND METHODS

Description of Study Area

Colorado is a Rocky Mountain State whose agriculture industry contributes an estimated $16 billion to the economy each year (CDA 2010). As of 2007, the poultry/egg industry in Colorado ranked tenth among the top ten agricultural commodities in the State. Colorado ranks 23rd in egg production in the nation and 24th in the layer industry (CDA 2010).

Although the commercial agriculture industry is highly regulated and monitored, the non-commercial poultry industry has not been measured. The non-commercial poultry industry is rising in popularity as cities review and alter regulations regarding poultry. Since 2008, both Fort Collins, CO and Longmont, CO have passed new laws that allow chickens to be kept within city limits. In accordance with a variety of rules and regulations, citizens of Fort Collins can have up to 6 hens within the city (Colorado Code Publishing Company 2010) and those in Longmont can have up to four hens with the purchase of a permit (City of Longmont 2010). Other cities in Colorado that also permit chickens within the city limits include Colorado Springs and Denver. The owner must obtain a city chicken permit and can only keep chickens on properties zoned for agriculture in Denver suburbs of Northglenn, Thornton, and Westminster (City Chicken 2010). In addition to flocks within city limits, flocks kept outside of city limits do not fall under any licensing requirements and remain essentially undocumented flocks.

Backyard Flock Population

The study population selected for study was derived from two separate databases maintained by the Colorado State University's Colorado Avian Disease Surveillance Program (CADSP).

The first database included 459 contacts and was comprised of bird owners that have had contact with or are participating in the Colorado Avian Disease Surveillance Program over the past five years. Study participants utilized CADSP's veterinary health services, provided samples for disease surveillance, or had contact with the program employees at county/state fairs, bird swaps, bird shows.

The second database included 479 contacts that were compiled from permits sent to the Colorado NPIP office from poultry breeders across the country that are participants in the National Poultry Improvement Plan (NPIP). NPIP is a nationwide, voluntary, surveillance program based on Federal-State-Industry cooperation to successfully evaluate poultry breeding stock and hatchery products in order to prevent the transmission of disease (USDA 2009). Participation in the NPIP provides certification that poultry and poultry products are free of all tested diseases and suitable for interstate and international shipment. Participating hatcheries and poultry producers are required to send copies of permits to the appropriate State Agency (USDA 2009).

Questionnaire Development

The original questionnaire was developed by the Colorado Avian Disease Surveillance Program prior to the start of this study. The questionnaire was approved by the Institutional Review Board (IRB) for research with human subjects at Colorado State

University. At the initiation of the study, we revised the questionnaire to include a focus on disease transmission and network analysis oriented questions. These additions were also approved by the IRB.

The questionnaire contained 27 questions, with both binary and open-ended formats (Appendix A). The questionnaire was divided into five main sections: Flock Characterization, Bird Movement, Human Interaction, Biosecurity, and Flock Health. The survey questioned flock owners on their actions for the past twelve months, from March 2008 to March 2009. Each questionnaire was given a two letter, four digit code placed in the upper right corner of each survey. This was used to identify each survey once they were returned in order to maintain anonymity.

Beginning in February 2009, a total of 938 surveys were printed and sent out in blocks of 100. Each survey was accompanied by a pre-paid return envelope and two cover letters; one a more personal letter that introduced the graduate student conducting the study and a second that discussed the purpose and intentions of the study. The contacts were given a three week period to return the completed survey. After which, if a survey had not been returned or the flock owner had not declined participation we sent out a second copy of the survey a reminder letter asking for participation.

Surveys were accepted until May 15, 2009. Completed surveys were organized by code numbers, placed in binders, and kept locked up in an office in the Colorado State University's Veterinary Diagnostic Laboratory. Survey data was entered into Microsoft Office Access © 2003.

Statistical Analysis for Epidemiological Characterization

The majority of statistical analyses were performed by using the statistical software program, SPSS Graduate Pack 16.0 © 2007. A few basic statistical analyses were also performed in Microsoft Office Excel © 2003.

The frequency distributions of each categorized variable included on the survey were calculated to develop basic descriptive statistics of the Colorado backyard flock population. The specific variables of interest that were further explored included bird type and flock type (e.g. layer, waterfowl, multipurpose), flock size, flock purpose, bird movement, bird purchases, quarantining practices, biosecurity practices, and bird health outcomes.

Bird type within a flock was treated as a binary variable. A flock reporting at least one of a bird type was categorized as "yes" for that type and otherwise categorized as "no". Flock type referred to classifying a flock as a "Layer flock", a "Waterfowl Flock" or a "Multi-purpose Flock".

A number of cross tabulations (crosstabs) were created to assess frequency distributions between variables of specific interest. Crosstabs were performed for: Flock Type x Flock Size; Bird Type x Flock Purpose; Bird Type x Number of Movement Events; Number of Movement Events x Quarantining upon Return; Bird Type x Number of Purchases; Flock Size x Number of Purchase Events per Year; Health Problems x Movement Events.

With each crosstab assessment, Pearson's chi-square was run to assess the strength of association between the two variables. A significant association between variables was interpreted based upon a chi-square value greater than the critical value, (determined by the degrees of freedom) and by a probability value less than a 5% level of significance (p value <0.05).

Specific variables of interest that were determined to be strongly associated by p-values less than 0.05 were further analyzed by estimating odds ratios and 95% confidence intervals. The odds ratio (OR) was estimated by creating 2x2 tables between the risk factor and the outcome for each variable and by the equation, OR = ad/bc. An OR equal to 1.0 was interpreted as no association between variables. An OR greater than 1.0 was interpreted as increased odds of developing the disease with exposure to the risk factor. An OR less than 1.0 was interpreted as decreased odds of developing the disease with exposure to the risk factor. The greater the OR was than 1.0, the stronger the association between the risk factor and outcome. Confidence intervals were determined in conjunction with OR estimates. We used a 95% confidence interval for each statistical test. With a 95% confidence interval we can infer that 95 out of 100 times the confidence interval will contain the true OR value. Furthermore, if the 95% confidence interval did not include 1.0, we say that at a 0.05 level of significance, there is a statistically significant association between the risk factor and the outcome. However, if the confidence interval does contain 1.0, we cannot say that the association is statistically significant.

Statistical Analyses for Network Analysis

A network analysis of bird movement was performed using two software packages for social network analysis, UCINET 6 for Windows-Version 6.230 © 2002 and NetDraw 2.087- Network Visualization Software © 2002. The study survey included detailed questions regarding bird movement, providing necessary data for the network analyses. The survey participants used in this component of the analysis were only those that reported movement of their birds to specific locations during the twelve-month study period. We defined “event” as a location to which the flock owner took birds and bird equipment, regardless of whether the birds returned to the original flock. This included: live bird markets, other premises with birds, farm or feed stores, swap meets or farmer’s markets, auctions, fairs or shows, or directly to slaughter. Visits to each of these locations with birds and/or equipment could potentially provide opportunities for disease spread via birds or fomites. We did not include those participants that moved birds off their premise by releasing them into the wild.

Initially, the network was assessed by creating a valued two-mode affiliation matrix ($n \times m$) in Microsoft Office Excel © 2003. The matrix was used to record the valued relationships between backyard flocks and bird movement to specific poultry events. In this affiliation matrix, n = the backyard flock, recorded as the premise zip code, and m = the poultry event (fair/show/market, etc.) which was recorded by the event’s name and zip code. The flocks were coded numerically and the events were coded alphabetically. The matrix cells contained valued numbers to represent the reported movement of flocks from their home premise to a poultry event.

A network map of the two-mode matrix was created in NetDraw for visualization of the network between backyard flocks and poultry events. The illustrated affiliation networks were quite large and complex. To simplify the maps, we looked at ego-networks of a few specific “Event” nodes to better visualize the level of connectivity in the network.

Analysis of a two-mode network is limited in the UCINET network analysis software, as it requires the square matrix of a one-mode matrix, not the rectangular data matrix of two-mode matrices. Therefore, the two–mode (flock x event) matrix was converted into two one-mode data sets by UCINET, producing “flock x flock” (*nxn)* and “event x event” (*mxm*) matrices. Flocks were labeled with numerical identifications, while the poultry events were labeled with alphanumerical identification.

In the Flock matrix, the cells represent the poultry event in common between the two flocks. In the Event matrix, the cells represent the backyard flocks that attended common poultry events. The matrices were dichotomized to create a binary data set. In the Flock Network, either the particular backyard flock attended the same event as another flock (1) or did not (0) and in the Event Network, the poultry event of interest was attended by a common flock (1) or was not (0). From this point, both one-mode data sets could be further analyzed to characterize each network.

NetDraw was used to map both one-mode matrices. The network maps were useful to visualize the strength of ties between nodes, the number of different components in the network, and the cutpoints essential to maintaining the flow of the network. The amount of information that could be extracted about the networks from the maps was limited with such a large network. Therefore, further statistical analysis of the individual nodes and the network as a whole was done to draw accurate conclusions about the relationships within the network and the amount of connectivity in the network.

UCINET software was used for analysis of the two one-mode networks with simple descriptive statistics. Individual nodes were assessed to determine the most influential nodes by measuring of centrality with degree, betweenness, and closeness. The network as a whole was analyzed by estimating density, centralization indices, degree distribution, clustering coefficient, geodesic distances, diameter and reachability.

RESULTS

Part I. Epidemiological Characterization of the Backyard Bird Population

Of the 938 questionnaires initially sent out, 23 contacts declined participation and 317 people returned completed questionnaires; 84 were returned because of wrong addresses or the contact had moved; 31 contacts claimed to not have kept poultry for over a year and were not eligible to participate; 16 questionnaires were sent out twice to the same contact due to multiple entries in the database under different names. Out of all 938 questionnaires, the response rate for returned questionnaires was 33.79% (317/938). The total number of eligible questionnaires, subtracting those that were not valid addresses, no longer kept poultry, or were repeated questionnaires was 807, with an overall participation rate of 39.28% (317/807).

The 317 completed surveys received came from 139 cities and 43 different counties across Colorado, representing the Southern, Eastern, Northern, and Western regions. The state map in Figure 1 highlights in yellow each of the counties represented in our study.

Epi Info was used to determine optimal sample size and power calculations. It was estimated that with a 95% confidence interval and a power of 80%, if there is an assumed 10% prevalence of disease in the unexposed population, then with a sample size of 324 total, we would be able to detect an odds ratio (OR) of 2.54. If we were to lower the confidence interval to 90%, yet still maintain a power of 80% and keep a similar sample size of 326, we would be able to detect a smaller odds ratio, OR=2.32.

Flock Characterization

Major Bird Types

The bird types kept in flocks were calculated treating bird type as a binary variable. Participants were able to choose more than one bird type, so out of all 724 reported bird types in Colorado's backyard flocks, 37.43% of the flocks had layer chickens. This was the highest reported percentage of bird type kept in flocks. Secondly, 14.92% of the flocks had waterfowl, such as ducks or geese. Finally, the third most frequent bird type kept in the sampled Colorado backyard flocks were show chickens, 14.09% (Table 1).

Flock Type

We also estimated "Flock Type" which specifically labeled a flock as consisting of only one type of bird or multiple types of birds. The sampled backyard poultry flocks in Colorado were primarily combined flocks, meaning that the flock was composed of more than one type of bird. For instance, 27.76% of respondents reported having two different bird types in their backyard flock and 21.77% reported over three types of birds in their flock. Additionally, 23.66% of study participants reported flocks with only layer chickens (Table 1).

Flock Size

A total of 309 participants reported a specific flock size. The majority of flocks were smaller than 50 birds per flock (68.6%) (Table 2). The greatest percentages of birds were distributed more heavily in the smaller flock size range of less than 40 birds per flock (Table 2), 18.45% of the reported flocks ranged in size from 11 birds to 20 birds, 16.5% of the flocks were slightly smaller with 1 to 10 birds, and 15.21% of flocks are just slightly larger with 21 to 30 birds per flock. Table 2 also shows that there were few large flocks, with 25 flocks consisting of 100-200 birds and few flocks with >200 birds.

Bird Type by Flock Size

We created a cross tabulation table and ran a Pearson's chi-square test to estimate the association between bird types and flock size. The p-value < 0.001 shows that there was a significant association between the size of the flock and the bird type in the flock. Table 3 demonstrates that out of all backyard flocks, layer chickens were typically part of mid-sized flocks; 31.0% of the total layer chickens belonged to a flock that ranged from 21 to 50 birds and 29.5% to a flock that ranged from 11 to 20 birds. Similarly, out of all meat chickens reported, 31.9% of the meat chickens were in a flock with 21 to 50 birds. Turkeys, game birds, and waterfowl comparatively were part of smaller sized flocks. Out of all reported turkeys, 52.2% were in flocks of 1 to 5 birds; 49.1% of all waterfowl were in flocks of the same size, as were 37.9% of all game birds. Guinea fowl, peafowl, pigeons and doves, and the type "other" were combined into one category and the variable, "indoor pet birds", was dropped to assess the distribution of bird types with larger sample sizes. These "other" bird types were also predominantly in smaller flock sizes of 1 to 5 birds (44.0%).

Primary Flock Purpose

We examined the primary purpose of keeping backyard flocks in our study population by determining the frequency of each reported primary flock purpose among all participating backyard flock owners. The participants were able to answer yes to multiple defined flock purposes, so the percentages do not add up to 100%.

Out of 317 participants, 86.44% of backyard flock owners kept birds primarily for food purposes for their family, such as eggs and/or meat (Table 4). Other responses included recreational purposes, 42.27% of respondents kept birds primarily for hobby or pet purposes and 26.81% kept birds for club activities such as 4-H or Future Farmers of America (FFA). The least common purpose for owning backyard flocks was breeding birds to sell; 11.04% of the participants reported that they primarily kept birds for selling purposes.

Participants were given the opportunity to provide multiple answers for the primary purpose of their flocks. The frequency distribution of flocks with a single purpose as well as those used for multiple purposes shows that 33.0% of participants used their flocks for two purposes and 17.8% used their flocks for three purposes, while 29.2% primarily used their flocks solely as a food source for their families (Table 5).

Flocks Purpose by Bird Type Groups

We further examined the purpose of backyard flocks by creating multiple crosstabulations to assess the frequency distribution of each bird type by each purpose. A chi-square test was run for each to determine whether an association between the specific bird type and the specific purpose among the backyard bird population was present. The chi-square values and p-values of each bird type by purpose are listed in Table 6.

Layer Chickens

Table 6 shows that the primary purpose of layer chickens was food for the family. Out of all survey participants, 271 total participants reported owning at least one layer chicken in their flock; 92.6% of these flocks were used for food for the family. The association between layers and purpose was tested by Pearson's chi-square. We found a significant association ($p<0.001$) between flocks with layer chickens and use of birds as food for the family, as well as a significant association ($p<0.05$) for use of layer chicken flocks for show purposes. Thus, flocks with layer chickens were more likely used for food and show purposes than those flocks that did not have layer chickens.

Meat Chickens

Among flocks with meat chickens, the most significant association for flock purpose was the use of the flock for food products to sell and keeping the birds as a hobby or pet ($p <0.05$). Therefore, flocks that included meat chickens were more likely used for selling the food products or for hobby than those flocks without meat chickens.

Show/Exhibition Chickens:

Flocks that kept show chickens were found to be significantly associated ($p<0.001$) with a number of flock purposes including food for the family, keeping birds as hobbies or pets, showing or exhibiting birds, participation in 4-H or FFA, and breeding birds to sell.

Turkeys

We found a significant association ($p<0.001$) between flocks with turkeys and keeping birds for 4-H or FFA participation, indicating that flocks with turkeys were more likely kept for participation in 4-H or FFA clubs than flocks without turkeys.

Waterfowl

Flocks that included waterfowl were significantly associated ($p < 0.001$) with keeping the flocks for breeding and selling. Additionally, of the participants that reported keeping waterfowl in their flocks, 53.7% reported that they kept their flocks for hobby or companion and pet purposes. We performed a chi-square test to find that flocks with waterfowl were significantly associated ($p < 0.005$) with the use of the flock for hobby or pet purposes. Thus, flocks that include waterfowl were more likely kept for the breeding and selling or for hobby or pet purposes than were flocks that did not.

Game Birds

Table 6 also displays the frequency distribution of game birds for each flock purpose. Of the participants that reported keeping game birds in their flocks, 72.4% reported that they kept their flocks for hobby or companion and pet purposes. We performed a chi-square test to find that there was a strong association ($p < 0.05$) between those flocks with game birds and the use of the flock for hobby or pet purposes as well as keeping birds for breeding and selling purposes. Thus, flocks with game birds were more likely to be used for breeding and selling purposes or as hobbies than flocks without game birds.

"Other" Birds

In Table 6, "other" includes peafowl, guinea fowl, pigeons, doves, and other miscellaneous birds. We performed a Pearson's chi-square test and found that flocks that included "Other" birds were significantly associated ($p=0.002$) with keeping birds for show or exhibition purposes along with keeping them for 4-H or FFA participation ($p=0.013$). Therefore, the backyard flocks that include peafowl, guinea fowl, pigeons, doves, and/or miscellaneous birds were more likely keep these birds for exhibition purposes or participation in 4-H or FFA clubs than flocks that did not include these “other” birds.

Movement of Birds by Humans

Of the 317 participants, 46.06% reported moving their birds off their home premises at least one time in the twelve-month study period and 53.94% reported that their birds never left their home premises (Table 7).

Of the participants that moved their birds, 85.53% stayed within the State of Colorado, 1.75% left the State of Colorado, and 12.72% did not specify a destination for bird movement (Table 7).

About one-third, 31.43%, of the flocks that were moved were taken to fairs or bird shows; 26.15% went to another premise with birds, such as a new farm; 10.11% went to bird swaps or flea markets, and 9.89% went directly to slaughter (Table 8).

Event by Bird Type

We created multiple tables to assess the relationship between human movement of flocks and each bird type. We found that the bird types associated with human movement were show chickens, turkeys, game birds, and “other” birds.

Table 9 is a condensed table of the multiple crosstabulations created. It shows that among participants that kept show chickens in their flock, 21.6% reported no movement of their birds; whereas 30.4% of the flocks with show chickens moved their birds once and 47.9% moved their birds 2 or more times in the twelve-month study period. We found a strong association ($p< 0.001$) between flocks with show chickens and human movement of the flocks.

Additionally, 41.4% of owners that kept flocks with game birds reported moving their birds at least three times per year in the study period. We found that the flocks that included game birds were significantly associated ($p < 0.001$) with human movement of the flocks.

Quarantine Practices following Flock Movement

Out of all 317 participants, 12.30% (39) quarantined birds when they brought them home from traveling events; 25.24% (80) did not quarantine birds; and 62.46% (198) answered "not applicable", meaning that they either did not bring home birds or never traveled with their birds.

We assessed the frequency distribution of the number of movement events by quarantining practices. Table 10 shows that as the number of movement events increased, so did the percentage of birds that were quarantined upon returning home. We ran a Pearson's chi-square to test for an association between the two variables. We found a significant association ($p < 0.05$) between the human movement of flocks and the practice of quarantining birds upon returning from the event.

Bird Purchases

Overall, 314 participating backyard flock owners responded to an open-ended question on bird purchasing activities during the twelve-month study period, to which participants could list multiple purchasing events; 69.4% of participants (218) reported that they did buy birds over the twelve-month period; and 30.6% (96) reported that they did not purchase any additional birds to add to their flocks. Of those participants that reported purchasing birds, 41.91% received their birds from a bird wholesaler or dealer; 18.71% purchased birds from a farm or feed store; 18.52% reported that this question did not apply to them and they did not purchase new birds (Table 11). Among participants that purchased birds over the past twelve months, 40.49% came from Colorado; 18.52% came from Texas and 17.78% came from Iowa (Table 12).

Purchases by Bird Type

The association of number of purchasing events by bird type was assessed with a crosstabulation of each bird type by the number of purchase events. In Table 13, we can see that 32.9% of the flocks with meat chickens reported purchasing birds at least once and 12.9% of flocks with meat chickens reported no new bird purchases. We found a significant association ($p < 0.001$) between flocks with meat chickens and purchasing new birds.

Similarly, flocks with turkeys and waterfowl were also significantly associated ($p < 0.001$) with purchasing new birds throughout the year. Flocks with layer chickens, show chickens and “other” birds were not associated with the purchasing of new birds.

Purchases by Flock Size

An association between flock size and frequent purchases of new birds was determined with a crosstabulation of flock size by purchasing events. Table 14 shows an association between increasing flock size and more purchases ($p <0.001$), so as the flock size increased it was more likely that the owners were also purchasing new birds more frequently throughout the year.

Human Interaction

Out of the 317 study participants, 47.95% reported that one to five people had contact with their flock within the twelve-month study period and 47.69% of the participants reported that over 6 people were in contact with their flocks (Table 15).

Additionally, the age group in contact with the backyard flocks most frequently was adults; 27.81% of participants reported that adults were in contact with the flocks on a daily basis. Additionally, 8.01% of the participants reported that children were in frequent contact with their flocks and 8.33% of participants reported teens had contact with the birds (Table 16).

Visitor contact with flocks on a weekly basis was also examined. In an average week, 63.31% of the participants reported that they did not have any visitors to their flocks and 36.70% reported some visitors to their flocks, primarily by family members or friends (Table 17).

Additionally, 11.04% of the participants reported that they allowed adult birds from the flocks into their homes and 96.21% of the participants reported living on the same premise as their flocks (Table 18).

Biosecurity

Among the participants, 59.94% (190) reported that they quarantined new birds and nearly half, 40.06% (127) reported that they did not.

The majority of flock owners did not report sharing any equipment in the twelve-month study period; 93.38% reported zero occasions of sharing equipment and 6.62% reported sharing equipment more than one time (Table 19).

The most common (59.94%) housing management style was an inside coop/barn/house with outdoor access but the birds were unable to leave the property. About one-third, 34.07% of the participants claimed that their birds also had inside coops/barn/houses and they were able to leave the property (Table 20).

Table 21 shows wild and domestic animal contact with flocks, in which 47.95% of the study participants reported other wild birds (not ducks or geese) to be in daily contact with their backyard flocks; 66.25% reported that their own dogs or cats were in daily contact with their flocks, and 27.13% reported that they saw rodents in contact with their flocks on a daily basis.

The most frequently (35.65) reported body of water within $1/10^{th}$ of a mile of the flock premise was irrigation ditches. Overall, 79.5% of the participants had a body of water within $1/10^{th}$ of a mile of the property where they housed their flocks (Table 22).

We further assessed the quality of biosecurity practiced by backyard flock owners by collapsing a multi-option question into three main categories of biosecurity practices. The first level of biosecurity included the basic practices of washing one's hands before and/or after contact with the flock. Those who answered yes on showering after contact with the flock were included in this category as well. The second level of biosecurity was disinfection of one's shoes, either or both before and after contact with the flock. Finally, the third level of disinfection involved changing ones clothes before and/or after contact with the flock. This includes changing in and out of specific flock shoes and/or coveralls.

As shown in Table 23, 79.05% of all participants marked that they always or usually washed their hands before or after contact with the flock; 20.63% of backyard flock owners reported changing into separate clothes before and/or after contact with the flock, and 4.76% of the participants reported disinfecting or scrubbing their flock shoes before and/or after contact with the flocks.

Flock Health

Health Events

Study participants were asked to answer an open-ended question regarding the frequency of certain health events during the twelve-month study period. As shown in Table 24, 23.97% of the flock owners experienced unexplained deaths in their flocks; 18.93% reported external parasites among their flocks; 12.93 % had respiratory problems among their birds; and 12.3% reported diarrhea illnesses.

Bird Mortalities

Table 25 presents the various causes of bird mortalities reported by flock owners that experienced at least one death during the study period. The majority of bird mortalities, 31.88%, were reported by owners to be due to wild predators; 19.81% were of unknown causes; 10.14% were reportedly due to old age; and 7.73% were associated with domestic predators (dogs and cats).

Flock Health and Biosecurity Practices

We tested for associations between three health events (diarrhea, respiratory illnesses, and unexplained death) and the lack of practicing specific categories of biosecurity that were previously listed in Table 23. As shown in Table 26, among the three measures of biosecurity, not changing clothes before or after was the only significantly associated biosecurity variable with diarrhea problems ($p=0.006$); respiratory problems ($p = 0.001$) and unexplained death in the flock ($p=0.004$). These associations were further tested by estimating the odds ratio (Table 27). We found there to be a significant protective association between the practice of changing shoes or clothing before or after contact with flocks and the health problems, diarrhea, respiratory distress, or unexplained deaths (OR<1).

We also tested for an association between flock owners not quarantining their birds upon returning home from poultry events and the occurrence of diarrhea, respiratory illness, and unexplained deaths in a flock (Table 28). We did not find there to be a significant association between the lack of quarantining practices and the health events (all p>0.05). Odds ratio estimates were also calculated for association. There was not a statistically significant association between quarantine practices after bird movement and the occurrence of health events as all 95% confidence intervals contained the value 1.

An association between health-related problems and the frequency of human movement of birds was assessed by crosstabulations and Pearson's chi-square test. We ran each health event against categorized frequencies of human movement that occurred during the twelve-month study period. Table 29 condenses the frequency distribution and statistical estimates into one table to compare the occurrence of health events with different degrees of movement. Table 29 shows a significant association between the number of times a bird is moved off home premises throughout the year and occurrence of respiratory events in the flock (p<0.001). Few incidences of respiratory illness were reported with no movement (6.4%), little with one movement event (11.5%), more with 3-5 movement events (29.4%) and the most with over 5 movement events in the year

(47.1%). The most significant results for an association between health events and movement were for respiratory problems and external parasites ($p<0.000$).

An association between respiratory problems and the number of reported movement events was further explored by estimating an odds ratio. An association between diarrhea and unexplained death loss with movement events was also further explored, as the p-values in Table 29 were marginally significant ($p = 0.06$). Although the p values for internal and external parasites were statistically significant, we did not calculate an odds ratio estimate because they are not clinical symptoms seen from infection with avian influenza.

We found a significant dose response relationship between reported respiratory problems in birds and increasing movement events in the twelve-month study period. Table 30 shows that flocks in which moved more than four times were 8.15 (3.33, 19.94) times more likely to develop a respiratory problem than those flocks in which that were not moved. Flocks in which birds were moved two to three times were only 3.54 (1.37, 9.16) times more likely to develop respiratory problems than flocks without birds that were not moved. Finally, flocks in which birds were moved only one time in the twelve months were only 1.89 (0.70, 5.11) times more likely to develop a respiratory problem than those that were not moved.

As shown in Table 30, the birds in flocks that were moved more than four times in the twelve months were 1.98 (0.76, 5.17) more likely to develop diarrhea than those that were moved in the twelve months. We did not find a dose response in this association as those birds in flocks that were moved two to three times were 2.52 (1.06, 5.95) times more likely to develop diarrhea than those that were not moved.

We found an increase in likelihood in flocks experiencing sudden unexplained death losses in birds with frequent movement (Table 30). Birds in flocks that were moved more than four times in twelve months were 2.26 (1.08, 4.5) times more likely to experience unexplained death losses than birds in flocks that were no moved. Birds that were moved two to three times were 1.14 (0.53, 2.46) times more likely to experience unexplained death losses than birds that were not moved.

Part II. Network Analysis of the Movement of Backyard Birds by Humans

Overall Network

The network map in Figure 2 is a visualization of the affiliation network created by the movement of flocks from the home premise to the event. The links between home flock and event are valued and the thickness of the tie between flock and event reflects the frequency of the flock attending that particular event in the twelve-month study period.

Figure 3 is an illustration of the components of the affiliation network. Each subgroup is represented in a different color. In Figure 3 the primary network is colored red and the few smaller networks subgroups are grey and purple. There are also a number of two-node networks with just one tie between them.

Figure 4 demonstrates the relationships between the specific event nodes K, AW, Q, and AM2 and the various flocks. Simplifying the network to look at these ego-networks shows the connection between certain events and specific flocks and other events. Figure 4 also shows that specific events serve as hubs, with a large number of flocks connected to that specific event.

Assessment of Network Matrices

Analyses of the two one-mode matrices provided visualization and quantification of the relationship between backyard flocks via attendance to common poultry events and between poultry events via the presence of birds from common backyard flocks.

Reviewing the Flock Network's matrix, the established relationships between flocks and events is evident by looking at the numbers in the cells. The numbers present in the diagonal cells represents the number of events that particular flock attended. For example, Figure 5 is an excerpt of the Flock Network matrix that demonstrates that Flock 1 participated in a total of two events in the twelve-month study period and Flock 3 participated in a total of twelve poultry events. The numbers in the rest of the cells, the off-diagonals, indicate the number of events that the different flocks jointly attended. For example, we can see in Figure 5 that Flock 5 and Flock 3 participated in the same five events over the course of the twelve-month time period.

Similar to the Flock Network's matrix, the Event Matrix can also be assessed for a preliminary understanding of the relationships among flocks and events. In the Event Matrix (*mxm*), the diagonals represent the number of flocks that participated in that particular poultry event. In Figure 6 we can see that for Event A, only one flock reported attendance in the twelve-month study period and seven flocks attended Event K. The numbers in the rest of the cells indicate the number of flocks that jointly participated in different events. For example, one flock attended both Events E and Q in the twelve-month study period.

Flock Network Map

The network map in Figure 7 is a complete presentation of the flock network, containing all the nodes included in the *nxn* matrix. The map shows one large and complex network, a few smaller networks, and a number of flocks that did not share a common poultry event to create a tie with another node in the network.

Figure 8 is a network map color-coordinated to differentiate each unique subgroup within the Flock Network. This figure displays one large network (red), a much smaller network (dark green), a slightly simpler network (blue) and a number of two-flock relationships. Additionally, the thickness of the ties between the flocks was congruent with the strength of the tie. For example, node 126 has a thick link to node 11; this indicates that these two flocks attended a large number of the same poultry events. Whereas, node 115 and node 135 are connected by a rather thin link, indicating that they both only attended one event in common.

Figure 9 highlights the specific "cutpoints" of the network in the color blue. The Flock Network had six total cutpoints, nodes 115, 86, 52, 60, 29, and 77.

Event Network Map

Figure 10 displays a preliminary network map of the Event Network, containing all the nodes included in the *mxm* matrix. It is apparent that there was one large, complex network of events, a few smaller networks, and a number of events that did not share a common backyard flock to create a tie with another node in the network.

Figure 11 demonstrates a color-coordinated map of the Event Network. Each unique network group within the Event Network is represented by a different color to display the connectivity of the network as a whole. The map illustrates one large network (blue), a much smaller network (purple), an even simpler network (green) and a number of two-flock relationships. Additionally, the thickness of the ties between the flocks was congruent with the strength of the tie. For example, node AT has a thick link to node BA1; this indicates that these two events had a large number of the same flocks in attendance at both poultry events. Whereas, node N and node AX were connected by a rather thin link, indicating that only one common backyard flock attended both of these events.

Figure 12 highlights the specific “cutpoints” of the network in the color blue. The Event Network had eleven total cutpoints, nodes AB2, Y1, AN5, AM2, AI1, AV2, AY2, AW, K, N, and BL1.

Analysis of Individual Nodes:

Degree

In the Flock Network, out of 140 total nodes (flocks), there were 44 total nodes that had degree values greater than the mean degree value (10.61). In Table 31, one can see that the node with the highest degree value was Node 58 (52). Node 58 had 52 links to other flocks via bird events and was a highly central flock in this network. Out of all the links (1,486), Node 58 accounted for 3.9%.

In the Events Network, out of 108 total nodes (events), there were 36 total nodes that had degree values greater than the mean degree (3.565). Table 32 displays that the node with the highest degree value was Node Q (23). Node Q had 23 links to other flocks via bird events and was a highly central event in this network. Out of all the links (385), Node Q accounted for 5.97%. Node AY2 was similar in degree value at 21. Node AY2 accounted for 5.45% of all links in the network.

Betweenness

In the Flock Network, out of 140 nodes, there were only 32 that had betweenness values. The remaining nodes, with 0 betweenness did not fall between pairs of other nodes on the paths connecting nodes. Out of the 32 nodes with a betweenness value, only 18 had values greater than the mean (37.18). Table 31 lists the most central nodes based on betweenness values. Node 86 had the greatest betweenness value of 849.61. Node 58 follows behind with a value of 649.90. Therefore, Nodes 86 and 58 were more central nodes based upon the betweenness measure of centrality.

In the Events Network, out of 108 nodes, there were only 17 that had betweenness values. The remaining nodes, with 0 betweenness did not fall between pairs of other nodes on the paths connecting nodes. Out of the 17 nodes with a betweenness value, 14 had values greater than the mean (22.009). Table 32 includes the most influential nodes in the network based upon betweenness values. Node Q had the greatest betweenness value of 549.94. Node AY2 follows behind with a value of 405.37. Therefore, Nodes Q and AY2 were more central nodes based upon the betweenness measure of centrality.

Closeness

Table 31 lists the nodes from the Flock Network with the most central values for closeness and farness measures. Node 58 had the smallest farness value, indicating that it was the node closest to all other nodes in the network, thus more of a central node. Node 58 also had a high closeness value (1.95), implying again that it is a more central node.

Table 32 lists nodes from the Events Network that had the most central values for closeness and farness. Node Q had the smallest farness value and the highest closeness value, indicating that it was the closest node to all other nodes in the network. Node AY2 was also a very central node in the Events Network with similar farness and closeness values.

Overall, a comparison of all measures of centrality in the Flock Network reveals that Node 58 displayed high levels of centrality with a high degree, high betweenness value, and a high closeness and low farness value. Node 86 similarly proved to be a highly central node along with node 67. Therefore, in the flock network, the flock that node 58 represented was a highly central flock in the sampled backyard bird population in Colorado.

In the Events Network, a comparison of all measures of centrality reveals that Nodes Q and AY2 displayed similarly high levels of centrality. Each node maintained the two highest values of betweenness, degree, and closeness, along with a low farness value. Node AM2 also demonstrated a high level of centrality as the third highest value for degree, betweenness, and closeness. Therefore, in the Event Network, the poultry events represented by nodes Q and AY2 were highly central events in this study's sampled backyard bird population.

Ego-Networks were created to display the links and related nodes to the highly central nodes in both the Flock Network and the Event Network. Figure 13 displays the three nodes that were assessed to be highly central nodes in the Flock Network by the measures of centrality. The primary node of interest is colored bright green, while the other two nodes are colored blue. Figure 14 displays the three nodes that were determined to be highly central nodes in the Events Network through measures of centrality. The primary node of interest is colored bright green, while the other two nodes are colored dull blue. These ego-networks display highly connected and central nodes in the Event Network.

Analysis of the Network as a Whole

Both the Flock and the Event Network are undirected networks. A simple, undirected network has ½(k(k-1)) unique pairs of nodes. Thus, the Flock Network had ½(140(139)) = 9,730 unique pairs of nodes (or total number of possible links) and 140 individual nodes (backyard flocks). The Event Network had ½ (108(107))= 5,778 unique pairs of nodes (or total number of possible links) and 108 individual nodes (poultry events).

Density

The matrix average density for the Flock Network was 7.58%. Of all possible undirected links present in the Flock Network, 7.58% were actually present in the network. In an undirected network, the maximum number of possible links was, ½(k(k-1). Therefore, with k = nodes, the maximum number of links in this network was, ½ (140(139)) = 9730. 7.58% of 9730 total possible links was 738. There were 738 undirected links in the network.

The matrix average density for the Event Network was 3.30%. Out of all possible undirected links present in the Events Network 3.3% were actually present in the network. In an undirected network, the maximum number of possible links was, ½(k(k-1). Therefore, with k = nodes, the maximum number of links in this network was,

½(108(107) = 5778. 3.30% of 5778 total possible links is 191 links. Thus there were 191 total undirected links in the network.

Centralization Index of Degree

The degree centralization index for the Flock Network was estimated to be 0.2998, closer in value to 0 than 1. This index indicates that the network was heterogeneous and that one node did not dominate the network**.** The network centralization index for the Events Network was estimated as 0.18333, closer in value to 0 than 1. Thus, there was not one node dominating the network, making the network a heterogeneous network.

Degree Distribution

Figure 15 of the Flock Network illustrates a characteristic distribution of a scale-free network. In contrast to a random network where links are randomly distributed among nodes, in this network, there are a number of flocks that have less than four links to other flocks, very few flocks with a medium numbers of links, and a number of flocks that act as the hubs of the network and are highly linked to other flocks with more than fifteen links.

Figure 16 illustrates the scale-free Events Network. In contrast to a random network with a normal distribution of links, the majority of the poultry events were tied to one to two other poultry events. There was a decreasing trend of ties after six and there were a few poultry events linked to more than 15 other poultry events, the hubs which maintain a high level of connectivity to the rest of the network.

Clustering Coefficient

The overall clustering coefficient of the Flock Network was 0.872, suggesting that the network was highly clustered with a number of nodes connected to one another and that this network may be a small world network.

The overall clustering coefficient of the Events Network was 0.797. This indicates that the network was highly clustered with a number of nodes being connected to one another and that this network may also be a small world network.

Geodesic Distance/Diameter/Reachability

Table 33 lists the estimated geodesic distances and the frequency and proportion of which they occur in the Flock Network. The average geodesic distance (or average shortest path length) among reachable pairs of nodes in the Flock Network was 2.292. The most frequent geodesic distance between reachable pairs was 2, with a frequency of 3,588. Thus, there were 3,588 nodes (or 1,794 reachable pairs) in the network with a geodesic distance of 2. The largest geodesic distance (diameter) was 5. Therefore, the longest geodesic between pairs of nodes in the Flock Network was 5. Using the matrix of geodesic distances in excel, the geodesic length of 5 was found to be between 16 nodes.

The total number of reachable pairs was 9,730; determined by the equation: ½ (k(k-1) = ½ [(140)(139)]. The total frequency of possible geodesic distances between reachable pairs in the network was 8,019. Therefore, out of all possible pairs in the Flock Network, 82.42% of the pairs were reachable pairs and thus were connected in some manner.

Figure 17 provides a display of the geodesic distances between reachable pairs. In the geodesic-distance matrix, the cell for nodes 1→ 6 contain a three, indicating that the path between 1 and 6 had a length of three. In Figure 17, it is apparent that the path between the nodes was: 1-86-76-6.

Overall, the average geodesic distance was the second component (along with the clustering coefficient) in defining the type of network. The Flock Network was likely a Small World Network, as it was highly clustered (CC=0.872) and had a short average path length (2.92)

Table 34 lists the geodesic distances estimated in the Events Network. The average geodesic distance (or average shortest path length) among reachable pairs of nodes in the Events Network is 2.635. The most frequent geodesic distance between reachable pairs was 3, with a frequency of 1,206. Thus, there were 1,206 nodes (or 603 reachable pairs) in the network with a geodesic distance of 3.

The largest geodesic distance (diameter) was 5. Therefore, the longest geodesic between pairs of nodes in the Events Network was 5. Using the matrix of geodesic distances in excel, the geodesic length of 5 was found to be between 20 nodes, all of which are associated with the node AX.

The number of total reachable pairs in the Events Network was 2,893, which was 50.06% of all 5,778 possible reachable pairs (½ (k(k-1))). Therefore, out of all possible pairs in the Events Network, 50.06% of the pairs are reachable pairs and thus are connected in some manner.

Looking at the matrix for geodesic frequencies it is visible that between nodes B and C, there was a geodesic of 3. Figure 18 illustrates the path from B →AM6 → Q → C. Overall, the Events Network was likely a Small World Network, as it was highly clustered (CC=0.797) and had a short average path length (2.635). Table 35 provides a summary of all the major measures of connectivity for the analysis of the network as a whole.

DISCUSSION

Backyard poultry flocks are an important population to consider in the spread of avian influenza. However, little documented information exists about backyard populations in the United States. This study provided an epidemiological characterization and a network analysis of the 2008 Colorado backyard bird population.

The backyard bird flocks included in this study were small in size, the majority smaller than 50 birds per flock. The primary bird types were layer chickens followed by show chickens and waterfowl. Reflective of the major bird types, flocks were primarily kept for food purposes (eggs or meat), as pets, or for participation in club activities such as 4-H or Future Farmers of America (FFA). More specifically, layer chickens were kept for food purposes and show chickens were kept for food, as pets, or for 4-H/FFA. Each of these purposes for keeping backyard flocks is associated with frequent human contact and thus increases the risk of bird-to-human transmission of zoonotic diseases or the risk of humans transmitting infectious diseases between bird populations through movement of birds and fomites.

The most frequent health problems reported were unexplained death with almost 25% of participants reporting this health issue. Other frequent health problems reported included respiratory problems (12.93%) and diarrhea (12.30%). The high prevalence of unexplained deaths and respiratory problems are of great interest as these health issues could be indicative of infectious disease, including AI virus.

Human interaction with birds and the owner's attention to biosecurity practices are important in a backyard bird population, as AI is a zoonotic disease. The primary risk factor for human infection with HPAI H5N1 is interaction with infected birds. Almost half of the participating flock owners reported that only a few people (<5) had frequent contact with their flocks during the study period. However, the other half of the participants reported over six people in contact with their flocks during the study period; 2.21% of which reported over 50 people interacting with their birds. Additionally, 11% of the participants reported allowing adult birds into their homes and almost every participant lived on the same property as their flocks. Overall, these findings imply that the level of human interaction with these backyard birds is high. If a flock were to be carrying a zoonotic pathogen, such as HPAI, these practices could be extremely risky for human health and the spread of disease to other birds.

Initial introduction of HPAI to domestic populations can occur on the home premises without the birds ever leaving due to interaction with wild waterfowl, such as migrating geese or ducks (Wells 1963; Glass 1981). More than half of the study's backyard flocks were housed in an enclosed structure such as a chicken coop, barn or hen house with access to an enclosed outdoor area to prevent the birds from leaving the property. These birds are less likely to directly interact with migrating waterfowl but can still have contact. However, there were also a large number of flocks that were housed in a similar coop, but were able to leave the property. These birds have more opportunity to co-mingle with migrating wild waterfowl. Almost 10% of the participants reported that their backyard flocks did have frequent interaction with wild ducks or geese.

Premises that have water sources, such as ponds or irrigation ditches, may attract migrating waterfowl and increase the chance of the wild waterfowl interacting with the backyard birds. A number of participants reported having water sources within one-tenth of a mile of the property where the birds were housed. About 35% had irrigation ditches within one-tenth of a mile, 22% of participants reported ponds, and 13% had streams located close to their flocks. Backyard flocks that are allowed to leave the property, are housed close to a body of water, or are frequently co-mingling with wild waterfowl are at risk of exposure to AI if the reservoir host is infected.

Initial introduction of AI into a domestic population is more likely due to interaction with wild waterfowl, but the continuous spread of HPAI among domestic bird populations is largely due to human movement of birds, equipment, and transportation vehicles (Alexander 2007). About half of the participants reported moving their birds off the home premises to another location at least one time in twelve months. Human movement of birds was mostly kept within the state and the birds were primarily taken to fairs or bird shows (32%). A number of flocks (26%) were also moved to other locations with birds, such as other farms. The third most frequent location of human movement of the birds was to bird swaps or flea or farmer's markets (10%). Therefore, this population of backyard birds is moving frequently within the state and primarily moving to locations that have other birds. This creates an optimal opportunity for disease spread, such as HPAI H5N1. Interaction with other birds at these events is high and the shorter distances traveled may increase the chance of an infected bird co-mingling with a naïve flock at the event or once the birds have returned home from the event.

Show chickens and upland gamebirds were the bird types most frequently moved (Figure 13). Show chickens were moved off their home premises about one time a year, whereas gamebirds were moved much more frequently, from three to five times per year. Waterfowl and turkeys were also reported as being moved often, whereas more than half of the reported layer chickens never left their home locations. Wild waterfowl and shorebirds are the reservoir host for AI, so they typically do not develop clinical disease. The frequent movement of backyard waterfowl could present a situation in which an asymptomatically infected duck is being moved to various events, shedding AI virus, and thus exposing a variety of birds that are present at these shows or markets.

Purchasing of new birds by flock owners is another form of movement of birds by humans that is influential in the spread of disease. In the study backyard flock population, birds were primarily purchased from bird wholesalers or dealers. Birds were largely purchased from both local, in-state dealers (breeders) and from out-of-state dealers (breeders). Purchases made from farther distances create the potential for an infectious disease to spread over greater distances and may place more stress on the traveling bird, increasing its susceptibility to infectious diseases. Additionally, the introduction of a sick bird into an already established flock is a perfect opportunity for spread of the disease.

The primary bird types purchased included meat chickens, turkeys, upland gamebirds, and waterfowl. Additionally, the participants that reported making the most purchases of new birds were mostly owners of the larger flocks (>51 birds). These are important characteristics to consider as disease, such as HPAI, often thrives in situations of higher bird densities and could be an issue if these larger flocks are densely housed. Also, susceptibility to AI virus infection is increased in immunocompromised birds; such as young chicks or stressed birds being shipped long distances.

Proper biosecurity practices by flock owners can prevent the introduction of disease by new birds into an established flock. New birds should be quarantined for thirty days before they are introduced to the flock (USDA 2010). Over half of the sampled backyard bird owners quarantined newly purchased birds before introducing them to the rest of their flock, which still leaves a large proportion (40%) of backyard flock owners that do not quarantine new birds before they are introduced into a new flock. Very few (12%) participants reported quarantining birds that they took to poultry events and then brought back home before re-introducing them to the flock. This behavior may create an opportunity for a pathogen acquired at the bird event, to spread to other birds in the home flock.

The results for the association between biosecurity practices and health problems were not as expected. We did not find a significant association between health problems and poor biosecurity practices such as not quarantining new birds, not washing hands, and not disinfecting shoes. We also found there to be a protective association between not changing ones shoes and/or clothing before or after contact with the flock and developing a health problem in the flock. This outcome is counterintuitive to what is biologically expected as biosecurity measures are implemented to reduce the risk of disease spread. The protective association could be due to a variety of errors in study design or data collection. For example, it could be due to random error from small sample size, increasing the chance of a Type II error; it could also be a consequence of reporting errors in biosecurity practices in which participants lied about poor biosecurity practices. Additionally, confounding or interactive variables such as flock size or bird type kept in the flock could be associated with biosecurity practices or flock health and influence the true association. This outcome requires further analysis.

Interestingly, the backyard flocks that were moved from their home premises had an increased likelihood of developing respiratory problems. We demonstrated a strong dose-response association between increased human movement of birds and the increased development of respiratory illness among birds in the same flock. We also demonstrated that there was a strong association between frequent movement of the birds (>4 times) and the occurrence of unexplained death in flocks. This data implies that birds that are frequently moved are at a greater risk of developing health problems, particularly respiratory illness. Most respiratory infectious diseases are highly contagious between birds and an increased association between frequent movement and respiratory problems can lead to rapid spread of disease across a number of backyard populations. Therefore, it is crucial that proper biosecurity is practiced in flocks that are frequently moved to reduce the spread of disease.

Flocks that are moved by humans to various poultry events have an increased susceptibility to respiratory illness due to the stress of travel and increased interaction with other birds. Therefore, it is important to understand the relationship among backyard flocks and various poultry events. The movement of animals between farms, to slaughter, to shows, or markets can be very influential in the spread of disease by creating pathways for transmission. Countries and states maintain regulations for animal movement for the purpose of controlling disease spread. Understanding the potential paths of disease spread is important for control and prevention. Social Network Analysis allows for the study and characterization of networks created from the human movement of birds from flock-to-flock or from flock-to-event. With network analysis, one can study the relationships among flocks and events that may produce a path upon which infectious disease may spread.

In our descriptive analysis of the backyard flock network, we were able to identify specific events or flocks central to the flow of information in the network. The events that were of particular importance were found to be an annual national agriculture show, fair, and a bird swap. Excellent biosecurity at these events may be essential to prevent an outbreak of HPAI H5N1 considering the high traffic volume of backyard birds to these events.

Maps generated by the network analysis illustrated largely connected and complex networks that were comprised of one major interconnected group and a few smaller subgroups. The Flock Network consisted of 140 total flocks with 738 links connecting the flocks. The Event Network had 108 total events connected by 191 links. Thus, in the first network 738 paths connected flocks through which disease could be spread while in the Event Network, 191 paths linked together events. Neither network was dominated by one flock or one event. Instead, the networks were both heterogeneous. In a heterogeneous network, connections are dispersed between nodes to create a highly connected network. Such heterogeneous networks create more pathways for disease to spread to a variety of more flocks or events.

Both networks were also small world networks. In a small world network, the majority of the flocks or events are highly clustered to one another in smaller groups with short distances between the nodes. However, a few longer distance links that jump from cluster to cluster are present allowing for a greater level of overall connectivity, reducing fragmentation in the network (see examples in Figure 21). A small world network will therefore generate more connectivity between the flocks or events with more possible paths for disease spread.

The distribution of the number of links to an event or flock showed that most were connected by just a few links; whereas a few exhibited a large number of links to them (Figures 15,16) . These “hubs” are highly influential in the network and maintain a lot of connectivity to a number of other events and flocks. This distribution pattern is characteristic of scale-free networks which are highly connected networks. Due to the high number of minimally connected nodes, a scale-free network is generally quite tolerant of random disease outbreaks (Network Analysis Workshop 2006). In this type of network, the probability that the disease will occur in one of the flocks or the events that has very few connections to others is much higher and the disease will have little chance to spread. However, scale-free networks are also extremely vulnerable to epidemics. The presence of hubs in these networks is equivalent to a “super-spreader” (Network Analysis Workshop 2006). If an infectious disease was introduced to one of the specific flocks or events that is a hub, the disease could be quickly spread to a large number of other flocks or events from that hub, greatly enhancing pathogen transmission. However, a scale-free network is also extremely responsive to targeted control strategies or targeted surveillance (Network Analysis Workshop 2006). The presence of highly influential hubs creates an easy target to knock out the spread of disease. Therefore, both the Flock and the Event Networks are small world, scale-free networks that could potentially be highly impacted by the introduction of a highly infectious agent, such as AI. However, the structure of the networks creates great possibilities for effective targeted disease control and prevention strategies.

Overall, a more detailed understanding of the backyard flock populations in the United States may be important to incorporate in future surveillance plans or disease control for HPAI. We have found that a number of the backyard flocks were frequently moved by owners away from their home location to events such as bird fairs, shows, markets, or to slaughter. Among those flocks being moved, biosecurity practices, such as quarantining, were moderate and the odds of developing respiratory illness were increased. The movement of these birds among the backyard flocks and the events they attended creates an intricately connected network. A thorough understanding of the structure and behavior of this network could be quite helpful in the design strategy for incorporating this population of birds into AI surveillance or control plans.

The results of this study apply only to the backyard bird population in the study and cannot be generalized to a population outside of the specific study population. The study population was not an entirely random sample of the backyard bird population in Colorado. The population came from a two database list serves maintained by the Colorado Avian Disease Surveillance Program (CADSP) at CSU. The first database included flock owners that interacted with CADSP employees at fairs, shows, or markets, or sought veterinary consultation. The second database included flock owners that purchased their birds from poultry breeders participating in the National Poultry Improvement Plan (NPIP). As a result, the study population likely included backyard flock owners that traveled with their birds and were concerned about the overall health of their birds. Additionally, out of the 807 eligible participants, there were 490 backyard flock owners that choose not to participate. This also reduces the external validity of this study as those that choose to participate could represent a very different population of flock owners invested in the health of their flocks while those that chose not to participate could have done so because they had unhealthy flocks.

Overall the study results do hold to the study population, but there were a few biases that could influence the study results. First of all, the questionnaire was designed to ask participants to remember specific events that occurred over a previous twelve-month period, which can lead to recall bias. For example, participants may not remember traveling to certain events with their birds and fail to report every traveling event or they may not recall the exact number of illnesses that occurred over the course of the year.

A reporting bias of disease in the flocks can cause nondifferential misclassification of health problems. For example, flock owners that had healthy birds may have reported health incidents correctly while those participants that had unhealthy birds may have been tempted to underreport health issues. As a result, the observed association between health problems and the risk factor of interest may be decreased. Similarly, reporting of disease among the birds is influenced by the owner's ability to identify disease. Diarrheal diseases are very difficult to identify, whereas respiratory diseases are much more easily identified. The nondifferential misclassification of health problems can influence results either toward or away from the null association.

Reporting bias may also have been an issue in participant reporting of exposures, such as biosecurity practices. Education about biosecurity practices has increased with the heightened concern over avian influenza, especially within more active backyard flocks including show birds, NPIP participants, or flocks that sell products. This knowledge of the correct practices, yet potentially relaxed practicing of the methods may influence how participants reported their own biosecurity practices. For example, those participants that have good biosecurity practices are more likely to report those accurately. However, those with relaxed or poor biosecurity may be less likely to report the truth. This may cause nondifferential misclassification of biosecurity practices. Consequently, the misclassified observed association between the biosecurity and health outcomes may lean toward a null association.

Additionally, reporting bias of biosecurity practices may also be influenced by disease status of flocks, leading to differential misclassification. For example, participants that own less healthy flocks with high incidence of disease and have poor biosecurity may have been motivated to falsely report excellent biosecurity. Participants who own healthier flocks and have excellent biosecurity may have been more likely to report truthfully. Overall, observed association between disease status and biosecurity practices may lean toward a null association.

Finally, the person interpreting the survey answers may have introduced observer/interviewer bias. A number of open-ended questions could be misinterpreted, thus altering the data either toward or away from the null. Also, instrument bias may influence the result as the surveys were mail-in and not given in person. As a result, the participants were left to their own interpretation of the question. The open-ended questions could also be answered quite differently among participants leading to inconsistency and invalid answers.

A limitation of the Network Analysis was that time was not considered. For example, the dates in which two different flocks attended the same event could have been months apart if the event was held multiple times during the year. In our analysis, this would have been counted as a tie between the flocks, when in reality the time period was so long that the risk of disease transmission is almost zero. However, the major events reported in this study were once a year events, thus the chance of this occurring was small.

This study also had a number of strengths. It was the first to characterize backyard bird populations in the western region of the United States. The study was also the first to establish the presence of a network relationship among backyard bird population due to common attendance at specific poultry events. The information provided by this study is helpful to provide guidelines for future studies, in drafting disease control protocol for potential HPAI outbreaks, or to incorporate in current surveillance programs. For example, flock sizes and bird type are helpful backyard flock characterizations to estimate accurate sample numbers needed for surveillance purposes.

Additionally, the information provided from the network analysis can be helpful in designing disease control. The analysis was performed on a simple level, just enough to verify the presence of a network between flocks and events that could serve to spread disease. As a result, this network analysis is not designed to model AI disease outbreaks in this specific population. However, it can be useful as foundation information for developing more detailed models to plan for an outbreak. The network analysis can also be useful to predict potential disease spread in a potential HPAI outbreak. If an outbreak begins at one of the central poultry events, it is possible to predict the degree of possible spread to other flocks by reviewing the output of the network analysis. Similarly, if HPAI were to be introduced to a flock, possibly from interaction with wild waterfowl, we can see from the network analysis that introduction into a more central flock will be much more influential on the rapid spread of disease than if it were introduced to a flock with little connection to other flocks. This information can be used to provide direction for implementing disease control measures in the event of an outbreak. With the network analysis data of the backyard flocks, we can predict which flocks and more importantly, events could be strongly influential and thus be targeted for control measures.

This study emphasized a strong dose-response relationship between increased bird movement by humans and respiratory illness in the flocks and the presence of a strong social network among flocks and poultry events. It also revealed that flock owners did not all strictly follow biosecurity practices. Therefore, in the event of an HPAI epizootic, the backyard bird population could be one of specific importance in the transmission of HPAI from bird-to-human and bird-to-bird.

Overall, following the completion of this study, we recommend that the importance of biosecurity practices are even more heavily emphasized to backyard bird owners, as this is essential to preventing disease introduction into flocks and spread to humans. Additionally, a further analysis with a larger sample size representing more than one state's population of backyard flocks would be beneficial for surveillance and disease control. Finally, we demonstrated that a social network is present among backyard flocks and certain poultry events. Thus, a more focused study of this network would be beneficial to pinpointing potential epicenters of disease spread in the event of an outbreak of HPAI in the backyard bird population.

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TABLES

Table 1: Frequency Distribution of Each Bird Type Reported in a Flock and of the Flock Type Reported in Colorado Backyard Bird Flocks, 2008.

Bird Type	Flocks with Bird Type		Flock Type	Number of Flocks	
Layer Chickens	**n** **%** **CI**	271 37.43 (0.34, 0.41)	**Layer Chicken Only Flock**	**n** **%** **CI**	75 23.66 (0.19, 0.28)
Meat Chickens	**n** **%** **CI**	72 9.94 (0.08, 0.12)	**Meat Chicken Flock Only**	**n** **%** **CI**	4 1.26 (0.00, 0.02)
Show Chickens	**n** **%** **CI**	102 14.09 (0.12, 0.17)	**Show Chicken Flock Only**	**n** **%** **CI**	13 4.10 (0.02, 0.06)
Turkeys	**n** **%** **CI**	67 9.25 (0.07, 0.11)	**Turkey Flock Only**	**n** **%** **CI**	2 0.63 (0.00, 0.02)
Waterfowl (ducks, geese, etc.)	**n** **%** **CI**	108 14.92 (0.12, 0.18)	**Waterfowl Flock Only**	**n** **%** **CI**	3 0.95 (0.00, 0.02)
Game Birds (pheasant, quail, chukar)	**n** **%** **CI**	29 4.01 (0.03, 0.05)	**2 Bird Types in Flock**	**n** **%** **CI**	88 27.76 (0.23, 0.33)
Guinea Fowl	**n** **%** **CI**	36 4.97 (0.03, 0.07)	**3 Bird Types in Flock**	**n** **%** **CI**	53 16.72 (0.13, 0.21)
Peafowl	**n** **%** **CI**	16 2.21 (0.01, 0.03)	**>3 Bird Types in Flock**	**n** **%** **CI**	69 21.77 (0.17, 0.26)
Pigeons, Doves	**n** **%** **CI**	19 2.62 (0.01, 0.04)	**Don’t Specify**	**n** **%** **CI**	10 3.15 (0.01, 0.05)
Other birds	**n** **%** **CI**	4 0.55 (0.00, 0.01)	**----**	---	----
Total		724	**Total**		317

Table 2. Frequency Distribution of Categorized Total Backyard Flock Size, Colorado 2008

Flock Size	Number of Flocks	
1- 10 Birds	**n** **%** **CI**	51 16.50 (0.12, 0.21)
11 - 20 Birds	**n** **%** **CI**	57 18.45 (0.14, 0.23)
21-30 Birds	**n** **%** **CI**	47 15.21 (0.11, 0.19)
31-50 Birds	**n** **%** **CI**	57 18.45 (0.14, 0.23)
50-100 Birds	**n** **%** **CI**	55 17.80 (0.14, 0.22)
101-150 Birds	**n** **%** **CI**	19 6.15 (0.03, 0.09)
151-200 Birds	**n** **%** **CI**	4 1.29 (0.000, 0.03)
>200 Birds	**n** **%** **CI**	19 6.15 (0.03, 0.09)
Total	**n**	309

Table 3. Frequency Distribution of Regrouped Backyard Flock Bird Types by Flock Size, Colorado 2008

Bird Type		Flock Size					
		1 - 5	6 - 10	11-20	21 - 50	>51	Total
Chickens-Layers	n	33	45	80	84	29	271
	%	12.2	16.6	29.5	31.0	10.7	
	CI	(0.08, 0.16)	(0.12, 0.21)	(0.24, 0.34)	(0.25, 0.37)	(0.07, 0.14)	
Chickens-Meat	n	11	5	17	23	16	72
	%	15.3	6.9	23.6	31.9	22.2	
	CI	(0.07, 0.23)	(0.01, 0.13)	(0.14, 0.33)	(0.21, 0.43)	(0.13, 0.32)	
Chickens-Show	n	24	26	25	19	8	102
	%	23.5	25.5	24.5	18.6	7.8	
	CI	(0.15, 0.32)	(0.17, 0.34)	(0.16, 0.33)	(0.11, 0.26)	(0.03, 0.13)	
Turkeys	n	35	13	9	9	1	67
	%	52.2	19.4	13.4	13.4	1.5	
	CI	(0.40, 0.64)	(0.10, 0.29)	(0.05, 0.22)	(0.05, 0.22)	(0.00, 0.04)	
Waterfowl	n	53	20	20	9	6	108
	%	49.1	18.5	18.5	8.3	5.6	
	CI	(0.40, 0.59)	(0.11, 0.26)	(0.11, 0.26)	(0.03, 0.14)	(0.01, 0.10)	
Game Birds	n	11	5	3	4	6	29
	%	37.9	17.2	10.3	13.8	20.7	
	CI	(0.20, 0.56)	(0.03, 0.31)	(0.00, 0.21)	(0.01, 0.26)	(0.06, 0.35)	
Other*	n	33	11	18	10	3	75
	%	44.0	14.7	24.0	13.3	4.0	
	CI	(0.33, 0.55)	(0.07, 0.23)	(0.14, 0.34)	(0.06, 0.21)	(0.00, 0.08)	

*Others category includes a collapse of the bird types: guinea fowl, peafowl, pigeons and doves, and others. Indoor birds are not included in this table

Pearson Chi-Square = 1.426E2; df = 24; p value = <0.000

Table 4: Frequency Distribution of the Primary Purposes of Backyard Flocks in Colorado, 2008

Primary Purpose of Flock	Number of Flocks		Total
Food (meat or eggs) for family	n % CI	274 86.44 (0.83, 0.90)	317
Selling food products to outside sources	n % CI	71 22.40 (0.18, 0.27)	317
Hobby/Companion/Pet	n % CI	134 42.27 (0.37, 0.48)	317
Show/Exhibition	n % CI	64 20.19 (0.16, 0.25)	317
4-H or FFA	n % CI	85 26.81 (0.22, 0.32)	317
Breeding to Sell	n % CI	35 11.04 (0.08, 0.15)	317

*Percentages do not add up to 100% as respondents were able to answer yes to multiple options.

Table 5: Frequency Distribution of Single or Multiple Purposes for Colorado Backyard Flocks, 2008

Purpose	Number of Flocks	
Single Purpose: Food for Family	**n** **%** **CI**	92 29.02 (0.24, 0.34)
Single Purpose: Sell Food Products	**n** **%** **CI**	3 1.0 (0.00, 0.02)
Single Purpose: Hobby/Companion	**n** **%** **CI**	13 4.10 (0.02, 0.06)
Single Purpose: Show/Exhibitions	**n** **%** **CI**	1 0.30 (0.00, 0.01)
Single Purpose: 4-H or FFA	**n** **%** **CI**	5 1.60 (0.00, 0.03)
2 Purposes	**n** **%** **CI**	104 33.00 (0.28, 0.38)
3 Purposes	**n** **%** **CI**	56 17.80 (0.14, 0.22)
>3 Purposes	**n** **%** **CI**	41 13.00 (0.09, 0.17)
Total	**n**	315

Table 6. Chi-Square Results for Association between Bird Type by Flock Purpose in Colorado Backyard Bird Flocks, 2008

Purpose		Bird Type						
		Chicken Layers	Chicken Meat	Chicken Show	Turkey	Water-fowl	Game Birds	Other
Food for the Family	n	251	66	76	56	92	24	56
	%	92.6	91.7	74.5	83.6	85.2	82.8	96.6
	CI	(0.90,0.96)	(0.85,0.98)	(0.66,0.83)	(0.20,0.42)	(0.78,0.92)	(0.69,0.97)	(0.92,1.0)
	Chi-Square	78.58	2.24	17.94	0.57	0.20	0.36	6.20
	PValue	<0.000	0.135	<0.000	0.450	0.652	0.549	0.013
Sell Food Products	n	67	24	15	19	30	7	20
	%	24.7	33.3	14.7	28.4	27.8	24.1	34.5
	CI	(0.19,0.30)	(0.22,0.44)	(0.08,0.22)	(0.18,0.39)	(0.19,0.36)	(0.09,0.40)	(0.22,0.47)
	Chi-Square	3.80	6.23	5.30	1.69	2.66	0.05	5.97
	PValue	0.051	0.013	0.021	0.193	0.103	0.821	0.015
Hobby/ Pet	n	109	29	58	32	58	21	20
	%	40.2	40.3	56.9	47.8	53.7	72.4	34.5
	CI	(0.34,0.46)	(0.29,0.52)	(0.47,0.66)	(0.36,0.60)	(0.44,0.63)	(0.56,0.89)	(0.22,0.47)
	Chi-Square	4.26	6.23	13.86	1.12	9.08	12.05	1.77
	PValue	0.039	0.013	<0.000	0.289	0.003	0.001	0.184
Show or Exhibition	n	49	14	45	18	32	6	3
	%	18.1	19.4	44.1	26.9	29.6	20.7	5.2
	CI	(0.13,0.23)	(0.10,0.29)	(0.34,0.54)	(0.16,0.37)	(0.21,0.38)	(0.06,0.35)	(0.0,0.11)
	Chi-Square	7.23	0.02	54.84	2.56	9.66	0.01	9.94
	PValue	0.007	0.893	<0.000	0.110	0.002	0.915	0.002
4-H or FFA	n	196	25	55	33	40	7	8
	%	72.3	34.7	53.9	49.3	37.0	24.1	13.8
	CI	(0.67,0.78)	(0.24,0.46)	(0.44,0.64)	(0.37,0.61)	(0.28,0.46)	(0.09,0.40)	(0.23,0.05)
	Chi-Square	0.03	2.84	55.55	21.61	8.58	0.12	6.13
	PValue	0.86	0.092	<0.000	<0.000	0.003	0.725	0.013
Breed to Sell	n	27	11	21	10	21	10	5
	%	10.0	15.3	20.6	14.9	19.4	34.5	8.6
	CI	(0.06,0.14)	(0.07,0.23)	(0.13,0.28)	(0.06,0.23)	(0.12,0.27)	(0.17,0.52)	(0.01,0.16)
	Chi-Square	2.44	1.95	15.03	1.54	12.89	18.72	0.42
	PValue	0.119	0.163	<0.000	0.215	<0.000	<0.000	0.515

*Each Chi-Square was calculated with Degrees of Freedom = 1

Table 7. Frequency Distribution of Bird Movement by Humans off Home Premises in Colorado Backyard Flocks, 2008

Movement of Birds by Humans	Number of Flocks		Total
Movement	n % CI	146 46.06 (0.41, 0.52)	317
No Movement	n % CI	171 53.94 (0.48, 0.59)	317
In-State (Colorado)	n % CI	390 85.53 (0.82, 0.89)	456*
Out of State	n % CI	8 1.75 (0.01, 0.03)	456*
Destination Not Specified	n % CI	58 12.72 (0.10, 0.16)	456*

*Participants were able to answer more than once

Table 8. Frequency Distribution of the Location Types of Bird Movement by Humans in Colorado Backyard Flocks, 2008.

Location Type	Number of Movement Events	
Live Bird Market	**n** **%** **CI**	11 2.42 (0.01, 0.04)
Another Premises with Birds	**n** **%** **CI**	119 26.15 (0.22, 0.30)
Farm or Feed Store	**n** **%** **CI**	31 6.81 (0.05, 0.91)
Swap Meet or Flea/Farmer's Market	**n** **%** **CI**	46 10.11 (0.07, 0.13)
Fair/Show	**n** **%** **CI**	143 31.43 (0.27, 0.36)
Auction	**n** **%** **CI**	12 2.64 (0.01, 0.04)
Directly to Slaughter	**n** **%** **CI**	45 9.89 (0.07, 0.13)
Into the Wild	**n** **%** **CI**	11 2.42 (0.01, 0.04)
Other	**n** **%** **CI**	37 8.13 (0.06, 0.11)
Total	**n**	455

*Frequency estimates are only out of reported bird movements

Table 9. Frequency Distribution of Colorado Backyard Flock Bird Type by Number of Movement Events in 2008

Bird Type		Number of Movement Events							
		0	**1**	**2**	**3-5**	**>5**	**Total**	**Chi-Square**	**P-Value**
Layer Chickens	**n**	151	53	28	26	13	271	7.743	0.101
	%	55.7	19.6	10.3	9.6	4.8			
	CI	(0.50,0.62)	(0.15,0.24)	(0.07,0.14)	(0.06,0.13)	(0.02,0.07)			
Meat Chickens	**n**	28	16	12	10	6	72	10.083	0.039
	%	38.9	22.2	16.7	13.9	8.3			
	CI	(0.28,0.50)	(0.13,0.32)	(0.08, 0.25)	(0.06,0.22)	(0.02,0.15)			
Show Chickens	**n**	22	31	18	18	13	102	70.515	<0.000
	%	21.6	30.4	17.6	17.6	12.7			
	CI	(0.14,0.30)	(0.21,0.39)	(0.10,0.25)	(0.10,0.25)	(0.06,0.19)			
Turkeys	**n**	26	12	15	9	5	67	15.985	0.003
	%	38.8	17.9	22.4	13.4	7.5			
	CI	(0.27,0.50)	(0.09, 0.27)	(0.12,0.32)	(0.05,0.22)	(0.01, 0.14)			
Game Birds	**n**	12	3	2	6	6	29	21.052	<0.000
	%	41.4	10.3	6.9	20.7	20.7			
	CI	(0.23,0.59)	(0.00.0.21)	(0.00,0.16)	(0.06,0.35)	(0.06,0.35)			
Waterfowl	**n**	43	24	15	16	10	108	16.630	0.002
	%	39.8	22.2	13.9	14.8	9.3			
	CI	(0.30,0.49)	(0.14,0.30)	(0.07,0.20)	(0.08,0.22)	(0.04,0.15)			
Others	**n**	25	8	9	9	7	58	12.584	0.013
	%	43.1	13.8	15.5	15.5	12.1			
	CI	(0.30,0.56)	(0.05,0.23)	(0.06,0.25)	(0.06,0.25)	(0.04,0.20)			

*Each Chi-Square was estimated with Degrees of Freedom = 3

Table 10. Frequency Distribution of Number of Movement Events among Colorado Backyard Flocks in 2008 by Quarantine Practices upon Returning

Number of Movement Events		Quarantine upon returning from Movement Event		
		Yes	**No**	**Total**
1	**n** **%** **CI**	8 19.5 (0.07,0.32)	33 80.5 (0.68,0.93)	41 100.0
2	**n** **%** **CI**	9 37.5 (0.18,0.57)	15 62.5 (0.43,0.82)	24 100.0
3 to 5	**n** **%** **CI**	8 30.8 (0.13,0.49)	18 69.2 (0.51,0.87)	26 100.0
>5	**n** **%** **CI**	8 66.7 (0.40,0.93)	4 33.3 (0.07,0.60)	12 100.0
Total	**n** **%**	33 32.0	70 68.0	103 100.0

***Pearson Chi-Square: 9.911; df = 3; p-value = .019**

Table 11. Frequency Distribution of the Facility Type where Birds are Purchased by the Number of Purchasing Events among Colorado Backyard Flocks in 2008

Facility Type of Bird Purchases	Number of Purchasing Events	
Bird wholesaler or dealer	n	215
	%	41.91
	CI	(0.38, 0.46)
Farm or Feed store	n	96
	%	18.71
	CI	(0.15, 0.22)
Another premises with birds	n	51
	%	9.94
	CI	(0.07, 0.13)
Fair or show	n	17
	%	3.31
	CI	(0.02, 0.05)
Auction	n	5
	%	0.97
	CI	(0.00, 0.02)
Swap meet or Market	n	5
	%	0.97
	CI	(0.00, 0.02)
Other	n	29
	%	5.65
	CI	(0.04, 0.08)
Does Not Apply	n	95
	%	18.52
	CI	(0.15, 0.22)
Total	n	513

*Participants were able to answer with multiple facility types

Table 12. Frequency Distribution of the Top States of Bird Purchases among Colorado Backyard Flock Owners, 2008

Cities		Purchasing Events
Colorado	n % CI	164 40.49 (0.40, 0.50)
Texas	n % CI	75 18.52 (0.17, 0.25)
Iowa	n % CI	72 17.78 (0.16, 0.24)
Missouri	n % CI	25 6.17 (0.04, 0.10)
New Mexico	n % CI	15 3.70 (0.02, 0.06)
Ohio	n % CI	11 2.72 (0.01, 0.05)
Total	n	362

* Numbers do not add up to 100% because these are only the top states of purchases.

Table 13. Frequency Distribution of Colorado Backyard Flock Bird Type by Number of Purchases in 2008

Bird Type		Number of Purchases						
		None	1	2	>3	Total	Chi-Square	P-Value
Layer Chickens	**n** **%** **CI**	83 31.1 (0.26,0.37)	92 34.5 (0.29,0.40)	53 19.9 (0.15,0.25)	39 14.6 (0.10,0.19)	267	1.132	0.769
Meat Chickens	**n** **%** **CI**	9 12.9 (0.05, 0.21)	23 32.9 (0.22,0.44)	20 28.6 (0.18,0.39)	18 25.7 (0.15,0.36)	70	20.211	< 0.000
Show Chickens	**n** **%** **CI**	23 23.0 (0.15,0.31)	33 33.0 (0.24,0.42)	24 24.0 (0.16,0.32)	20 20.0 (0.12,0.28)	100	6.976	0.073
Turkeys	**n** **%** **CI**	8 11.9 (0.04,0.20)	19 28.4 (0.18,0.39)	18 26.9 (0.16,0.37)	22 32.8 (0.22,0.44)	67	32.712	<0.000
Game Birds	**n** **%** **CI**	8 27.6 (0.11,0.44)	7 24.1 (0.09,0.40)	3 10.3 (0.00,0.21)	11 37.9 (0.20,0.56)	29	15.108	0.002
Waterfowl	**n** **%** **CI**	22 20.4 (0.13,0.28)	28 25.9 (0.18,0.34)	30 27.8 (0.19,0.36)	28 25.9 (0.18,0.34)	108	29.499	<0.000
Pigeons, Doves	**n** **%** **CI**	6 31.6 (0.11,0.52)	4 21.1 (0.03,0.39)	2 10.5 (0.00,0.24)	7 36.8 (0.15,0.58)	19	9.236	0.026
Others	**n** **%** **CI**	13 28.3 (0.15,0.41)	11 23.9 (0.11,0.36)	11 23.9 (0.11,0.36)	11 23.9 (0.11,0.36)	46	5.824	0.120

*Each Chi-Square was estimated with Degrees of Freedom = 3

Table 14. Frequency Distribution of Total Flock Size by the Number of Purchase Events among Colorado Backyard Flocks in 2008

Total Flock Size		Purchase Events per Year				
		No Purchases	1 Purchase	2 Purchases	>3 Purchases	Total
1- 10 Birds	n % CI	31 60.8 (0.47,0.74)	18 35.3 (0.22,0.48)	1 2.0 (0.00,0.06)	1 2.0 (0.00,0.06)	51 100.0
11 - 20 Birds	n % CI	19 33.9 (0.22,0.46)	18 32.1 (0.20,0.44)	15 26.8 (0.15,0.38)	4 7.1 (0.00,0.14)	56 100.0
21-30 Birds	n % CI	14 31.1 (0.18,0.45)	17 37.8 (0.24,0.52)	11 24.4 (0.12,0.37)	3 6.7 (0.00,0.14)	45 100.0
31-50 Birds	n % CI	19 33.9 (0.22,0.46)	20 35.7 (0.23,0.48)	9 16.1 (0.06,0.26)	8 14.3 (0.05,0.23)	56 100.0
>51 Birds	n % CI	9 9.2 (0.03,0.15)	35 35.7 (0.26,0.45)	26 26.5 (0.18,0.35)	28 28.6 (0.20,0.38)	98 100.0
Total	n % CI	92 30.1 (0.25,0.35)	108 35.3 (0.30,0.41)	62 20.3 (0.16,0.25)	44 14.4 (0.10,0.18)	306 100.0

***Pearson Chi-Square: 66.517; df = 12; p-value <0.000**

Table 15. Frequency Distribution of Total Number of People in Contact with Colorado Backyard Flocks in 2008

Number of People		Number of People in Contact with Birds
No People	n	17
	%	5.36
	CI	(0.03, 0.08)
1 to 5 people	n	152
	%	47.95
	CI	(0.42, 0.53)
6 to 10 people	n	76
	%	23.97
	CI	(0.19, 0.29)
11 to 15 People	n	24
	%	7.57
	CI	(0.05, 0.10)
16 to 20 People	n	14
	%	4.42
	CI	(0.02, 0.67)
21 to 25 People	n	10
	%	3.15
	CI	(0.01, 0.05)
26 to 30 People	n	9
	%	3.84
	CI	(0.01, 0.05)
31 to 35 People	n	3
	%	0.95
	CI	(0.00, 0.02)
36 to 40 People	n	1
	%	0.32
	CI	(0.00, 0.01)
41 to 45 People	n	0
	%	0.00
	CI	----
46 to 50 People	n	4
	%	1.26
	CI	(0.00, 0.02)
Over 50 People	n	7
	%	2.21
	CI	(0.00, 0.04)
Total	n	317

Table 16. Frequency Distribution of the Age Group in Contact with Colorado Backyard Flocks by Level of Contact in 2008.

Age Group	Level of Contact with Flocks					
		Daily	Weekly	Monthly	Rarely	Total
Adults	n CI %	257 27.81 (0.25,0.31)	76 8.23 (0.06,0.10)	50 5.41 (0.04,0.07)	117 12.66 (0.11,0.15)	500 54.11
Teens	n CI %	77 8.33 (0.066,0.10)	33 3.57 (0.02,0.05)	19 2.06 (0.01,0.03)	54 5.84 (0.04,0.07)	241 19.80
Children	n CI %	74 8.01 (0.06,0.10)	47 5.09 (0.04,0.07)	29 3.14 (0.02,0.04)	91 9.85 (0.08,0.12)	183 26.09
Total	n CI %	408 44.16 (0.41,0.47)	156 16.88 (0.14,0.19)	98 10.61 (0.09,0.13)	262 28.35 (0.25,0.31)	924 100

Table 17. Frequency Distribution of Visitors to Colorado Backyard Flocks in an Average Week in 2008

Visitors	Number of Visitors	
No Visitors	n % CI	226 63.31 (0.58, 0.68)
Customers	n % CI	8 2.24 (0.01, 0.04)
Family Members	n % CI	58 16.25 (0.12, 0.20)
Friends or Neighbors	n % CI	59 16.53 (0.13, 0.20)
Paid/Unpaid Workers	n % CI	2 0.56 (0.00, 0.01)
Others	n % CI	4 1.12 (0.00, 0.02)
Total	n	357

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Table 18. Frequency Distribution of Various Measures of Human Interaction with Colorado Backyard Flocks, 2008

Human Interaction with Flock	Yes		No	Total
Adult Birds Allowed in Home	n % CI	35 11.04 (0.08, 0.14)	282 88.96 (0.86, 0.92)	317
Live on the Same Premises	n % CI	305 96.21 (0.94, 0.98)	12 3.79 (0.02, 0.06)	317

Table 19. Frequency Distribution Amount of Flock Equipment Sharing among Colorado Backyard Flock Owners in 2008

Amount of Flock Equipment Sharing over 12 Month Period	Number of Flocks	
Zero	n % CI	296 93.38 (0.91, 0.96)
1 to 3 Times	n % CI	20 6.30 (0.04, 0.09)
4 to 12 Times	n % CI	1 0.32 (0.00, 0.01)
Over 12 Times	n % CI	0 0 ---
Total	n	317 100

Table 20. Frequency Distributions of Colorado Backyard Flock Housing Management Style, 2008

Housing Management Style		Yes	No	Total
Inside, confined to coop/barn/house (no outdoor access)	n % CI	10 3.15 (0.01, 0.05)	307 96.85 (0.95, 0.99)	317
Inside coop/barn/house with outdoor access, unable to leave property (flight pen).	n % CI	190 59.94 (0.55, 0.65)	127 40.06 (0.35, 0.45)	317
Inside coop/barn/house with outdoor access, able to leave property.	n % CI	108 34.07 (0.29, 0.39)	209 65.93 (0.61, 0.71)	317
Outdoors only, confined to property.	n % CI	6 1.89 (0.00, 0.03)	311 98.11 (0.97, 1.00)	317
Outdoors only, able to leave property.	n % CI	3 0.95 (0.00, 0.02)	314 99.05 (0.98, 1.00)	317

Table 21. Frequency Distribution of Wild and Domestic Animals in Contact with Colorado's Backyard Flocks in 2008

Animal		Daily	Weekly	Monthly	Rarely	Never	NA	Total
Wild Ducks	**n**	6	6	4	13	281	7	317
	%	1.89	1.89	1.26	4.10	88.64	2.21	
	CI	(0.00,0.03)	(0.00,0.03)	(0.00,0.02)	(0.02,0.06)	(0.85,0.92)	(0.00,0.04)	
Wild Geese	**n**	7	7	3	16	277	7	317
	%	2.21	2.21	0.95	5.05	87.38	2.21	
	CI	(0.00,0.04)	(0.00,0.04)	(0.00,0.02)	(0.03,0.07)	(0.84,0.91)	(0.00,0.04)	
Other Wild Birds	**n**	152	39	15	37	68	6	317
	%	47.95	12.30	4.73	11.67	21.45	1.89	
	CI	(0.42,0.53)	(0.09,0.16)	(0.02,0.07)	(0.08,0.15)	(0.17,0.26)	(0.00,0.03)	
Rodents	**n**	86	44	33	90	58	6	317
	%	27.13	13.88	10.41	28.39	18.30	1.89	
	CI	(0.22,0.32)	(0.10,0.18)	(0.07,0.14)	(0.23,0.33)	(0.14,0.23)	(0.00,0.03)	
Wild Animals	**n**	30	46	40	103	93	4	317
	%	9.46	14.51	12.62	32.49	29.34	1.26	
	CI	(0.06,0.13)	(0.11,0.18)	(0.09,0.16)	(0.27,0.38)	(0.24,0.34)	(0.00,0.02)	
Domestic birds (do not belong)	**n**	12	2	1	9	286	7	317
	%	3.79	0.63	0.32	2.84	90.22	2.21	
	CI	(0.02,0.06)	(0.00,0.01)	(0.00,0.01)	(0.01,0.05)	(0.87,0.93)	(0.00,0.04)	
Cattle/Sheep/ Goats	**n**	66	8	8	28	201	6	317
	%	20.82	2.52	2.52	8.83	63.41	1.89	
	CI	(0.16,0.25)	(0.01,0.04)	(0.01,0.04)	(0.06,0.12)	(0.58,0.69)	(0.00,0.03)	
Pigs	**n**	19	5	2	12	271	8	317
	%	5.99	1.58	0.63	3.79	85.49	2.52	
	CI	(0.03,0.09)	(0.00,0.03)	(0.00,0.01)	(0.02,0.06)	(0.82,0.89)	(0.01,0.04)	
Owner's Dogs or Cats	**n**	210	35	8	16	44	4	317
	%	66.25	11.04	2.52	5.05	13.88	1.26	
	CI	(0.61,0.71)	(0.08,0.14)	(0.01,0.04)	(0.03,0.07)	(0.10,0.18)	(0.00,0.02)	
Neighbor's dogs or cats	**n**	27	22	16	83	165	4	317
	%	8.52	6.94	5.05	26.18	52.05	1.26	
	CI	(0.05,0.12)	(0.04,0.10)	(0.03,0.07)	(0.21,0.31)	(0.47,0.58)	(0.00,0.02)	
Other	**n**	11	5	3	8	98	191	317
	%	3.48	1.58	0.95	2.53	31.01	60.44	
	CI	(0.01,0.05)	(0.00,0.03)	(0.00,0.02)	(0.01,0.04)	(0.26,0.36)	(0.55,0.66)	

Table 22. Frequency of Bodies of Water Located Near Colorado Backyard Flock Premises, 2008

Body of Water		Yes	No	Total
Pond	n	70	247	317
	%	22.08	77.92	
	CI	(0.18, 0.27)	(0.73, 0.82)	
Lake	n	10	307	317
	%	3.15	96.85	
	CI	(0.01, 0.05)	(0.95, 0.99)	
Stream	n	41	276	317
	%	12.93	87.07	
	CI	(0.09, 0.17)	(0.83, 0.91)	
River	n	18	299	317
	%	5.68	94.32	
	CI	(0.03, 0.08)	(0.92, 0.97)	
Irrigation Ditch	n	113	204	317
	%	35.65	64.35	
	CI	(0.30, 0.41)	(0.59, 0.70)	

*Percentages do not add up to 100% as respondents were able to answer yes to multiple options.

Water location is within one-tenth of a mile of the flock premise

Table 23. Frequency of Biosecurity Practices in Colorado Backyard Flocks in 2008

Biosecurity Practices		Yes	No	Total
Wash Hands Before/After Flock Contact	n	249	66	315
	%	79.05	20.95	
	CI	(0.7455, 0.8354)	(0.1646, 0.2545)	
Disinfect Shoes Before/After Flock Contact	n	15	300	315
	%	4.76	95.24	
	CI	(0.0241, 0.0711)	(0.9288, 0.9759)	
Change Clothing/Shoes Before/After Flock Contact	n	65	250	315
	%	20.63	79.37	
	CI	(0.1617, 0.2510)	(0.7490, 0.8383)	

Table 24. Frequency of Health Events among 317 Colorado Backyard Flocks in 2008

Health Problem	Number of Flocks	
Unexplained Death	n % CI	76 23.97 (0.1926, 0.2869)
External Parasites	n % CI	60 18.93 (0.1460, 0.2325)
Respiratory	n % CI	41 12.93 (0.0923, 0.1664)
Diarrhea	n % CI	39 12.30 (0.0868, 0.1593)
Lameness	n % CI	32 10.09 (0.0676, 0.1342)
Neurological	n % CI	30 9.46 (0.0623, 0.1270)
Rapid Production Loss	n % CI	29 9.15 (0.0596, 0.1233)
Weight Loss	n % CI	23 7.26 (0.0439, 0.1012)
Feed Refusal	n % CI	23 7.26 (0.0439, 0.1012)
Other	n % CI	10 3.15 (0.0122, 0.0508)
Internal Parasites	n % CI	4 1.26 (0.0003, 0.0249)
Total	n	317

*Percentages were taken out of 317 flocks. They do not add up to 100% because participants were able to report multiple health problems.

Table 25. Distribution of Flock Mortality among Colorado Backyard Flocks in 2008

Cause of Flock Mortality	Flock Mortality*		Cause of Flock Mortality	Flock Mortality*	
Wild Predators	**n** **%** **CI**	66 31.88 (0.27, 0.37)	**Miscellaneous**	**n** **%** **CI**	5 2.42 (0.0072, 0.0411)
Unknown	**n** **%** **CI**	41 19.81 (0.15, 0.24)	**Not Specified**	**n** **%** **CI**	5 2.42 (0.01, 0.04)
Old Age	**n** **%** **CI**	21 10.14 (0.07, 0.13)	**Injury**	**n** **%** **CI**	3 1.45 (0.00, 0.03)
Domestic Predators	**n** **%** **CI**	16 7.73 (0.05, 0.11)	**Egg bound**	**n** **%** **CI**	2 0.97 (0.00, 0.02)
Pecking/Cannibalism	**n** **%** **CI**	11 5.31 (0.03, 0.08)	**Neurological**	**n** **%** **CI**	2 0.97 (0.00, 0.02)
Cold	**n** **%** **CI**	7 3.38 (0.01, 0.05)	**Transportation**	**n** **%** **CI**	2 0.97 (0.00, 0.02)
Disease	**n** **%** **CI**	7 3.38 (0.01, 0.05)	**Heat**	**n** **%** **CI**	1 0.48 (0.00,0.01)
Weak/New Young	**n** **%** **CI**	6 2.90 (0.01, 0.05)	**Lameness**	**n** **%** **CI**	1 0.48 (0.00,0.01)
Drowning	**n** **%** **CI**	5 2.42 (0.01, 0.04)	**Unexplained Weight Loss**	**n** **%** **CI**	1 0.48
Respiratory	**n** **%** **CI**	5 2.42 (0.01, 0.04)	---		

* 207 total participants reported at least 1 mortality event

Table 26. Pearson's Chi-Square Estimates of Biosecurity Measures and Specific Health Events

Biosecurity		Health Event: Diarrhea	Health Event: Respiratory	Health Event: Unexplained Death
Do Not Wash Hands Before/After or Shower	Chi-Square P-Value	0.93 0.33	0.45 0.50	1.74 0.19
Do Not Disinfect Shoes	Chi-Square P-Value	3.38 0.07	0.52 0.47	1.00 0.33
Do Not Change Clothes Before/After	Chi-Square P-Value	7.58 0.006	10.49 0.001	4.23 0.04

*Each Chi-Square was estimated with Degrees of Freedom = 1

Table 27. Odds Ratios for Specific Biosecurity Measure (Not Changing Shoes or Clothing Before/After Flock Contact) and Health Events in Colorado Backyard Flocks in 2008

Biosecurity	Diarrhea		Respiratory		Unexplained Death	
	Yes n % CI	OR CI	Yes n % CI	OR CI	Yes n % CI	OR CI
Don't Change Clothing/ Shoes	23 9.2 (0.06,0.13)	0.37 (0.18,0.77)	24 9.6 (0.06,0.13)	0.33 (0.16, 0.66)	54 21.6 (0.16,0.27)	0.54 (0.30, 0.98)

Table 28. Measures of Association for Participants that Do Not Quarantine Birds and Specific Health Events

Do Not Quarantine Birds after Movement	Health Event		
	Diarrhea	**Respiratory**	**Unexplained Death**
Chi-Square **P-Value**	0.89 0.34	2.93 0.09	0.14 0.71
Odds Ratio **CI**	1.62 (0.59, 4.42)	2.23 (0.88, 5.64)	1.18 (0.50, 2.79)

*Each Chi-Square was estimated with Degrees of Freedom = 1

Table 29. Frequency Distribution of Colorado Backyard Flock Health Problems by Number of Movement Events in 2009

Health Problem		Movement Event						
		0	1	2	3 to 5	>5	Chi Square	P-Value
Diarrhea	n	17	5	9	5	3		
	%	9.9	8.2	26.5	14.7	17.6	8.794	0.066
	CI	(0.05,0.14)	(0.01,0.15)	(0.12,0.41)	(0.03,0.27)	(0.00,0.36)		
Respiratory	n	11	7	5	10	8		
	%	6.4	11.5	14.7	29.4	47.1	32.406	<0.000
	CI	(0.03,0.10)	(0.03,0.19)	(0.03,0.27)	(0.14,0.45)	(0.23,0.71)		
Neurological	n	14	7	3	3	3		
	%	8.2	11.5	8.8	8.8	17.6	1.975	0.740
	CI	(0.04,0.12)	(0.03,0.19)	(0.00,0.18)	(0.00,0.18)	(0.00,0.36)		
Weight Loss	n	8	6	2	4	3		
	%	4.7	9.8	5.9	11.8	17.6	6.142	0.189
	CI	(0.02,0.08)	(0.02,0.17)	(0.00,0.14)	(0.01,0.23)	(0.00,0.36)		
Feed Refusal	n	10	8	1	3	1		
	%	5.8	13.1	2.9	8.8	5.9	4.728	0.316
	CI	(0.02,0.09)	(0.05,0.22)	(0.00,0.09)	(0.00,0.18)	(0.00,0.17)		
Sudden Production Loss	n	16	4	2	5	2		
	%	9.4	6.6	5.9	14.7	11.8	2.341	0.673
	CI	(0.05,0.14)	(0.00,0.13)	(0.00,0.14)	(0.03,0.27)	(0.00,0.27)		
Unexplained Death	n	37	13	6	12	8		
	%	21.6	21.3	17.6	35.3	47.1	8.857	0.065
	CI	(0.15,0.28)	(0.11,0.31)	(0.05,0.30)	(0.19,0.51)	(0.23,0.71)		
Lameness	n	16	7	3	3	3		
	%	9.4	11.5	8.8	8.8	17.6	1.420	0.841
	CI	(0.05,0.14)	(0.03,0.19)	(0.00,0.18)	(0.00,0.18)	(0.00,0.36)		
External Parasites	n	18	12	6	16	8		
	%	10.5	19.7	17.6	47.1	47.1	34.225	<0.000
	CI	(0.06,0.15)	(0.10,0.30)	(0.05,0.30)	(0.30,0.64)	(0.23,0.71)		
Internal Parasites	n	2	0	0	0	2		
	%	1.2	0.0	0.0	0.0	1.17	16.712	0.002
	CI	(0.00,0.03)	---	---	----	(0.00,0.27)		
Other	n	3	3	2	2	0		
	%	1.8	4.9	5.9	5.9	0.0	3.928	0.416
	CI	(0.00,0.04)	(0.00,0.10)	(0.00,0.14)	(0.00,0.14)	---		

Table 30. Odds Ratios for Bird Movement by Humans and Health Events in Colorado Backyard Flocks in 2008

Movement	Respiratory			Diarrhea			Unexplained Death		
	Yes	OR	CI	Yes	OR	CI	Yes	OR	CI
>4 Times	14	8.15	(3.33, 19.94)	7	1.98	(0.76, 5.17)	15	2.26	(1.08, 4.75)
2 to 3 Times	9	3.54	(1.37, 9.16)	10	2.52	(1.06, 5.95)	11	1.14	(0.53, 2.46)
1 Time	7	1.89	(0.7, 5.11)	5	0.81	(0.29, 2.30)	13	0.98	(0.48, 2.00)

Table 31. Summary of the Network Analysis Centrality Measures for the Most Central Flock in the Backyard Bird Flock Network of 140 Flocks, 2008.

Degree		Betweenness		Closeness		
Flock (Node)	**Value**	**Flock (Node)**	**Value**	**Flock (Node)**	**Farness**	**Closeness**
58	52	**86**	489.61	**58**	7132	1.95
12	43	**58**	649.90	**12**	7141	1.95
67	37	**67**	418.34	**67**	7147	1.94
62	35	**48**	402.14	**86**	7147	1.94
86	34	**51**	380.28	**62**	7150	1.94

Table 32. Summary of the Network Analysis Centrality Measures for the Most Central Event in the Backyard Bird Event Network of 108 Events, 2008.

Degree		Betweenness		Closeness		
Event (Node)	**Value**	**Event (Node)**	**Value**	**Event (Node)**	**Farness**	**Closeness**
Q	23	**Q**	549.94	**Q**	5917	1.81
AY2	21	**AY2**	405.37	**AY2**	5925	1.81
AM2	17	**AM2**	359.95	**AM2**	5933	1.80
AM6	14	**AI1**	163.00	**AM6**	5935	1.80
AO	13	**AM6**	135.07	**AC**	5936	1.80

Table 33. Measures of Network Cohesiveness by Average Geodesic Distances between Flocks in the Backyard Bird Flock Network of 140 Nodes, 2008.

Geodesic Distance	Frequency	Proportion
1	1338	0.17
2	3588	0.45
3	2531	0.32
4	546	0.07
5	16	0.002

Table 34. Measures of Network Cohesiveness by Average Geodesic Distances between Events in the Backyard Bird Event Network of 108 Nodes, 2008.

Geodesic Distance	Frequency	Proportion
1	277	0.096
2	979	0.338
3	1206	0.417
4	391	0.135
5	40	0.014

Table 35. Summary of Measures of Cohesiveness for both the Flock and Events Network in the Backyard Bird Population, 2008.

Measurement	Flock Network	Events Network
Number of Nodes	140	108
Density (undirected)	7.58%	3.3%
Number of Undirected Links	738	5,778
Degree of Centralization Index	0.29988	0.18333
Clustering Coefficient	0.872	0.797
Average Geodesic Distance	2.292	2.635
Diameter	5	5
Number of Reachable Pairs	9730	2,893
% Reachable Pairs	82.42%	50.06%

FIGURES

Figure 1. Colorado Counties included in the Backyard Bird Flock Survey, 2008

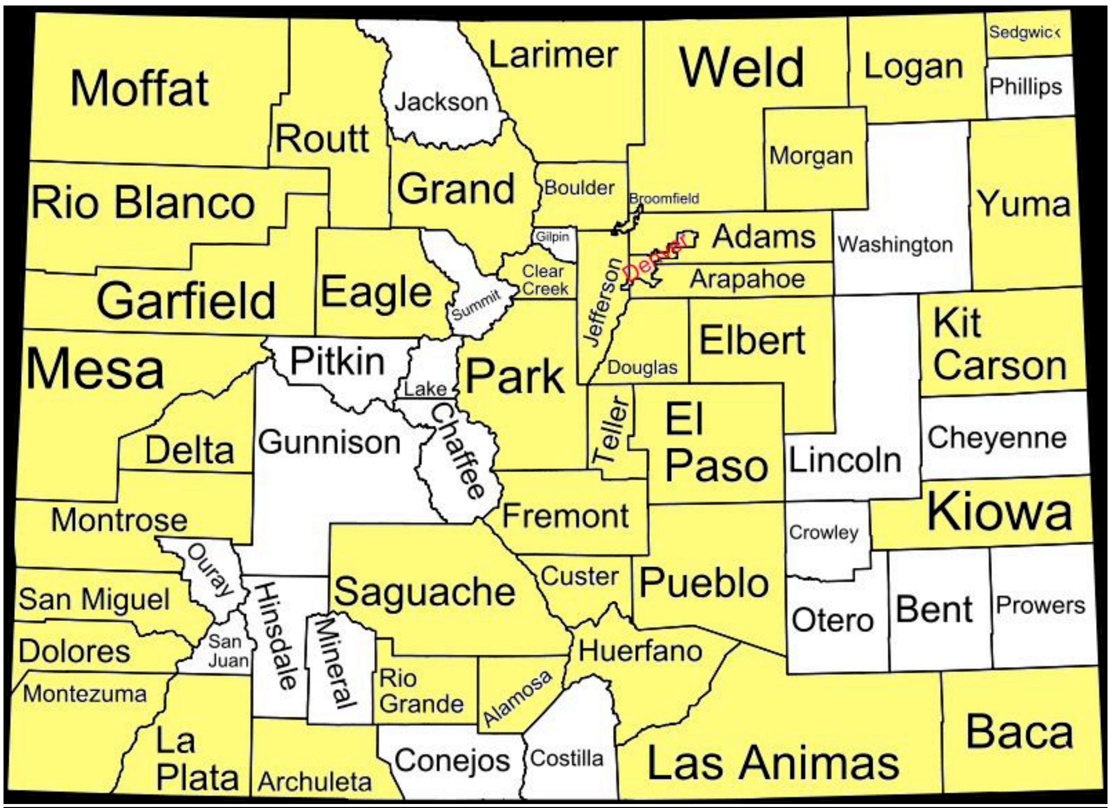
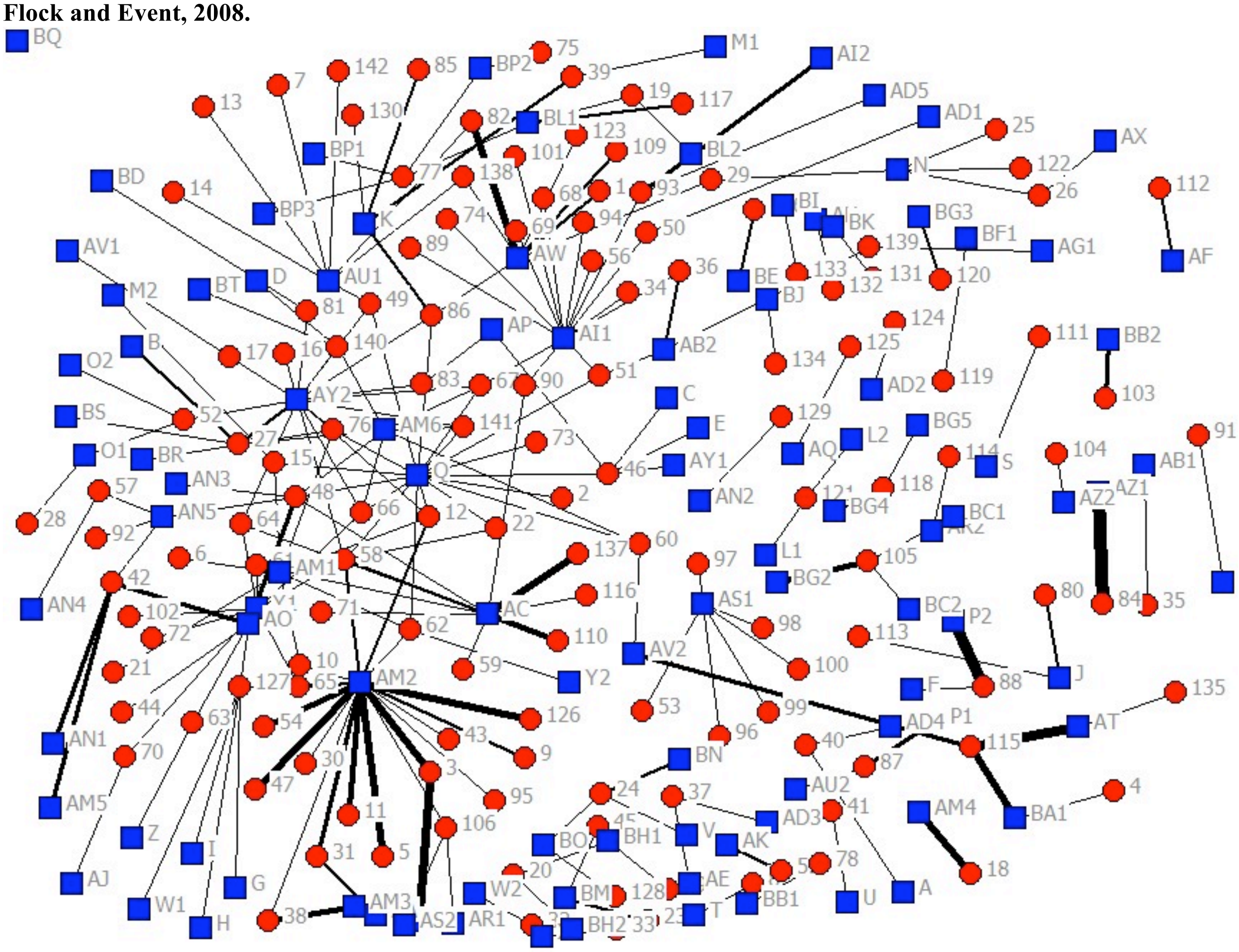
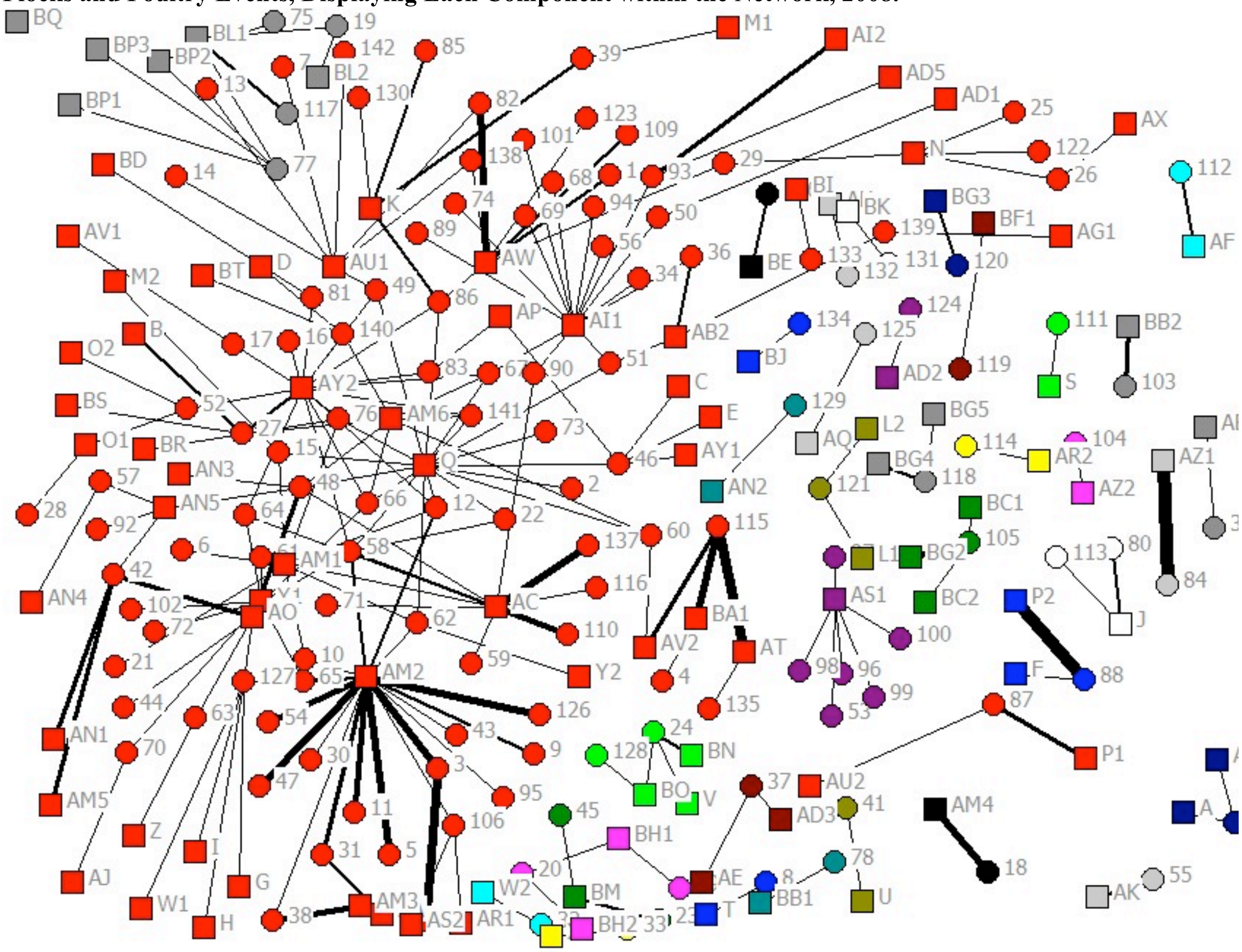


Figure 2. Network Analysis Map of the Backyard Bird Network Displaying Relationships between Flocks and Poultry Events, Including Valued Ties Reflecting Strength of Relationships between Flock and Event, 2008.



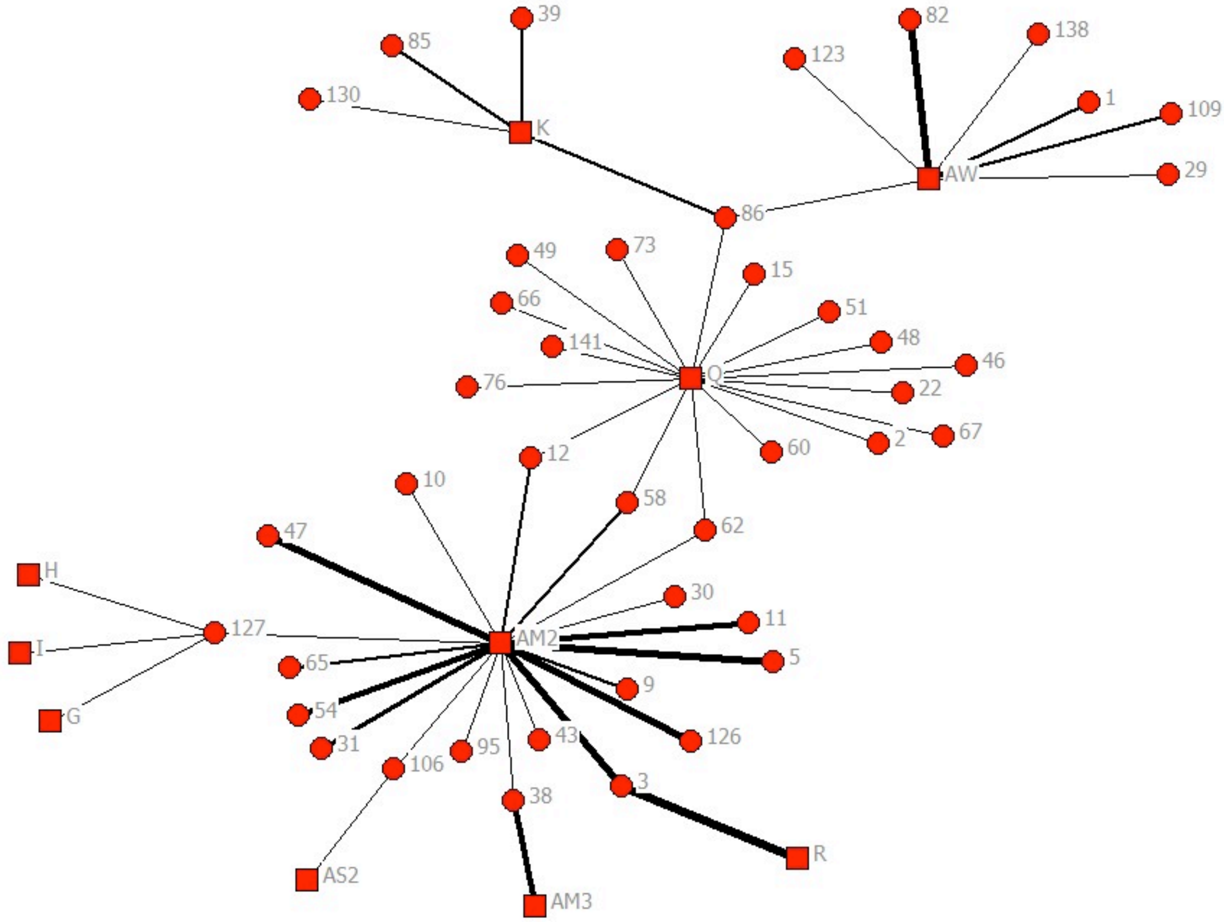
Red Circles = Backyard Flocks
Blue Squares = Poultry Events

Figure 3. Network Analysis Component Map of the Backyard Bird Affiliation Network between Flocks and Poultry Events, Displaying Each Component within the Network, 2008.



Circles = Backyard Flocks
Squares = Poultry Events

Figure 4. Network Analysis Map of Ego-Networks from the Backyard Bird Network Affiliation Network, Displaying Ties to Specific "Ego" Nodes, 2008.



Squares = Events
Circles = Flocks

Figure 5. Excerpt of the Network Analysis "Flock x Flock" Matrix of the Backyard Bird Flock Network, 2008.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1
3	0	0	12	0	5	0	0	0	2	1	4	2	0	0	0
4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	5	0	6	0	0	0	2	1	4	2	0	0	0
6	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1
7	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
9	0	0	2	0	2	0	0	0	2	1	2	2	0	0	0
10	0	0	1	0	1	1	0	0	1	2	1	2	0	0	1
11	0	0	4	0	4	0	0	0	2	1	4	2	0	0	0
12	0	1	2	0	2	1	0	0	2	2	2	5	0	0	2
13	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
14	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
15	0	1	0	0	0	1	0	0	0	1	0	2	0	0	3
16	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Figure 6. Excerpt of the Network Analysis "Event x Event" Matrix of the Backyard Bird Event Network, 2008.

	A	B	C	D	E	F	G	H	I	J	K	L1	L2	M1	M2	N	O1	O2
A	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	7	0	0	1	0	0	0	0
L1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
L2	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
M1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
M2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
O1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
O2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
P1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Q	0	0	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 7. Network Analysis Map of the Backyard Bird Flock Network, Displaying the Relationships between 140 Flocks by Common Attendance to Poultry Events, 2008

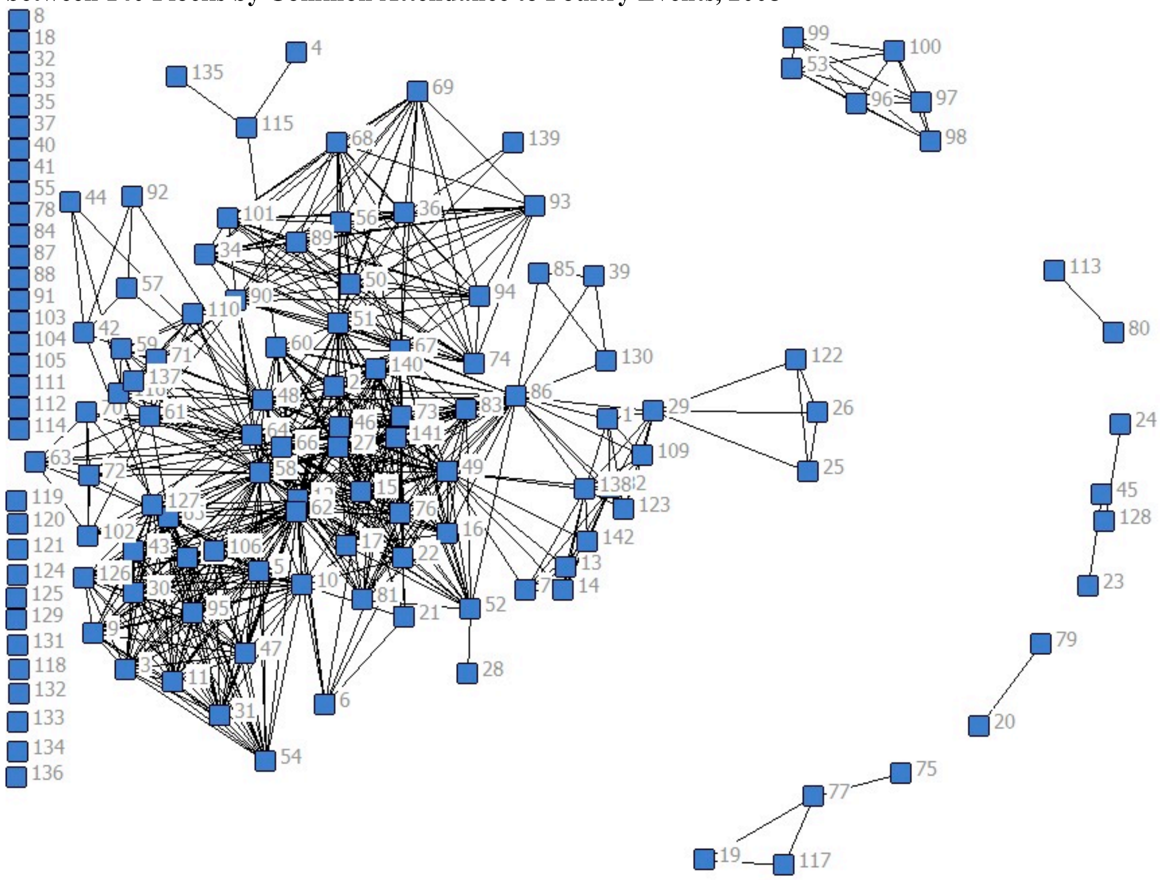


Figure 8. Network Analysis Map of the Backyard Bird Flock Network, Displaying the Various Components of the Network, along with the Strength of the Ties (relationships) between each Flock, 2008.

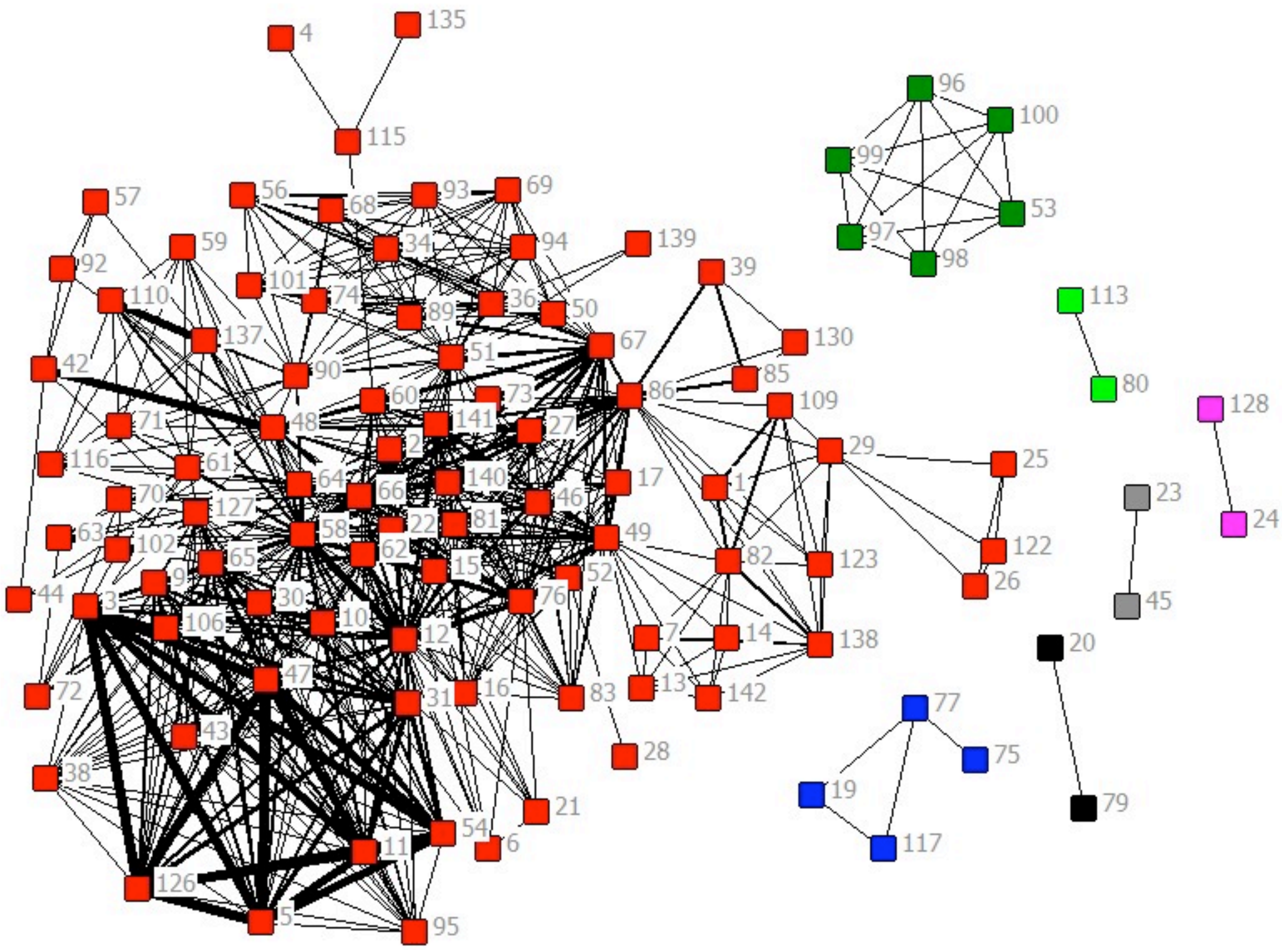


Figure 9. Network Analysis Map of the Backyard Bird Flock Network, displaying the Specific Network "cutpoints", essential to the Fluidity of the Network with 140 Total Flocks, 2008.

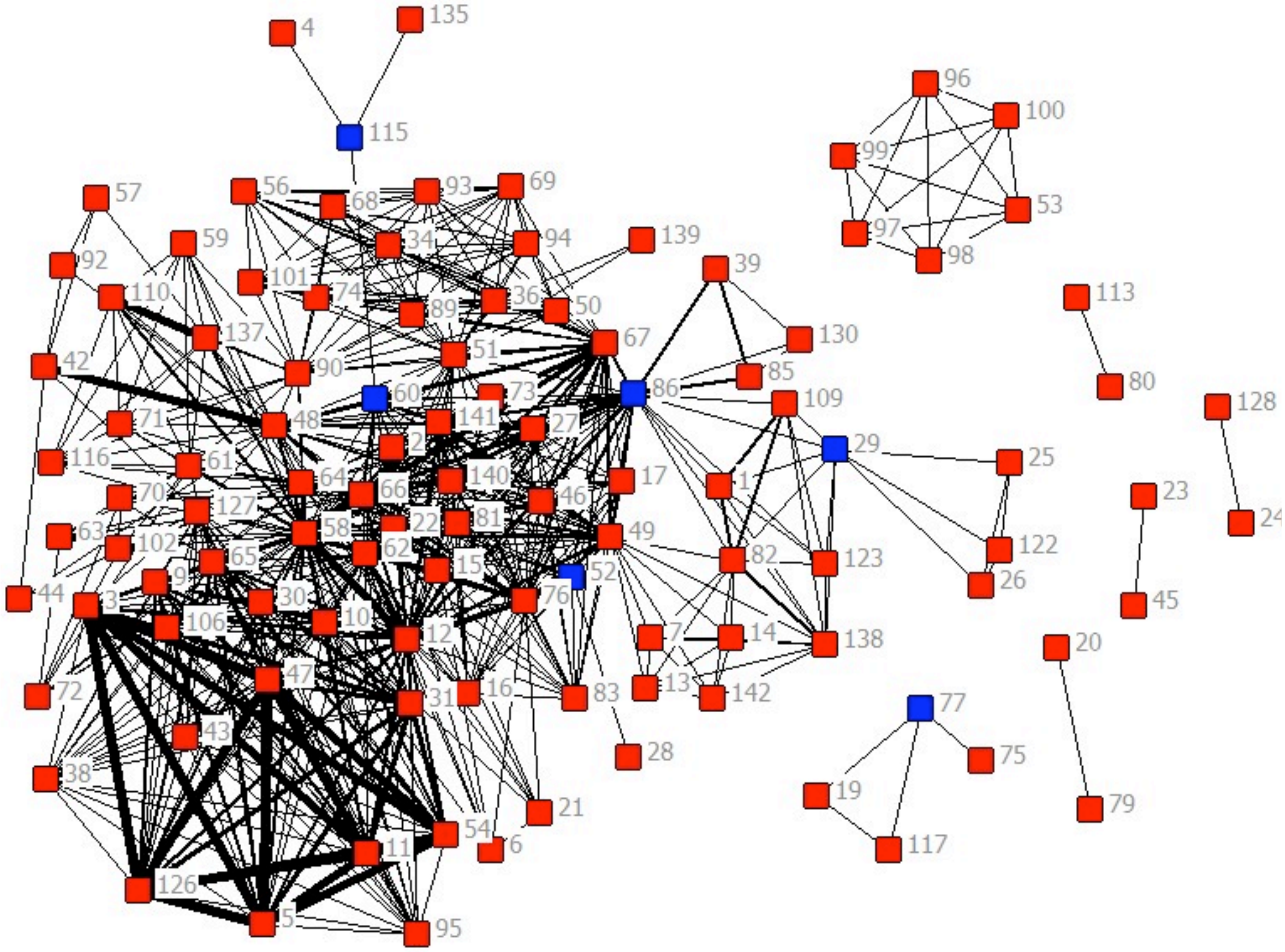


Figure 10. Network Analysis Map of the Backyard Bird Event Network, Displaying the Relationships between 108 Events by Common Attendance of Backyard Flocks to Different Poultry Events, 2008

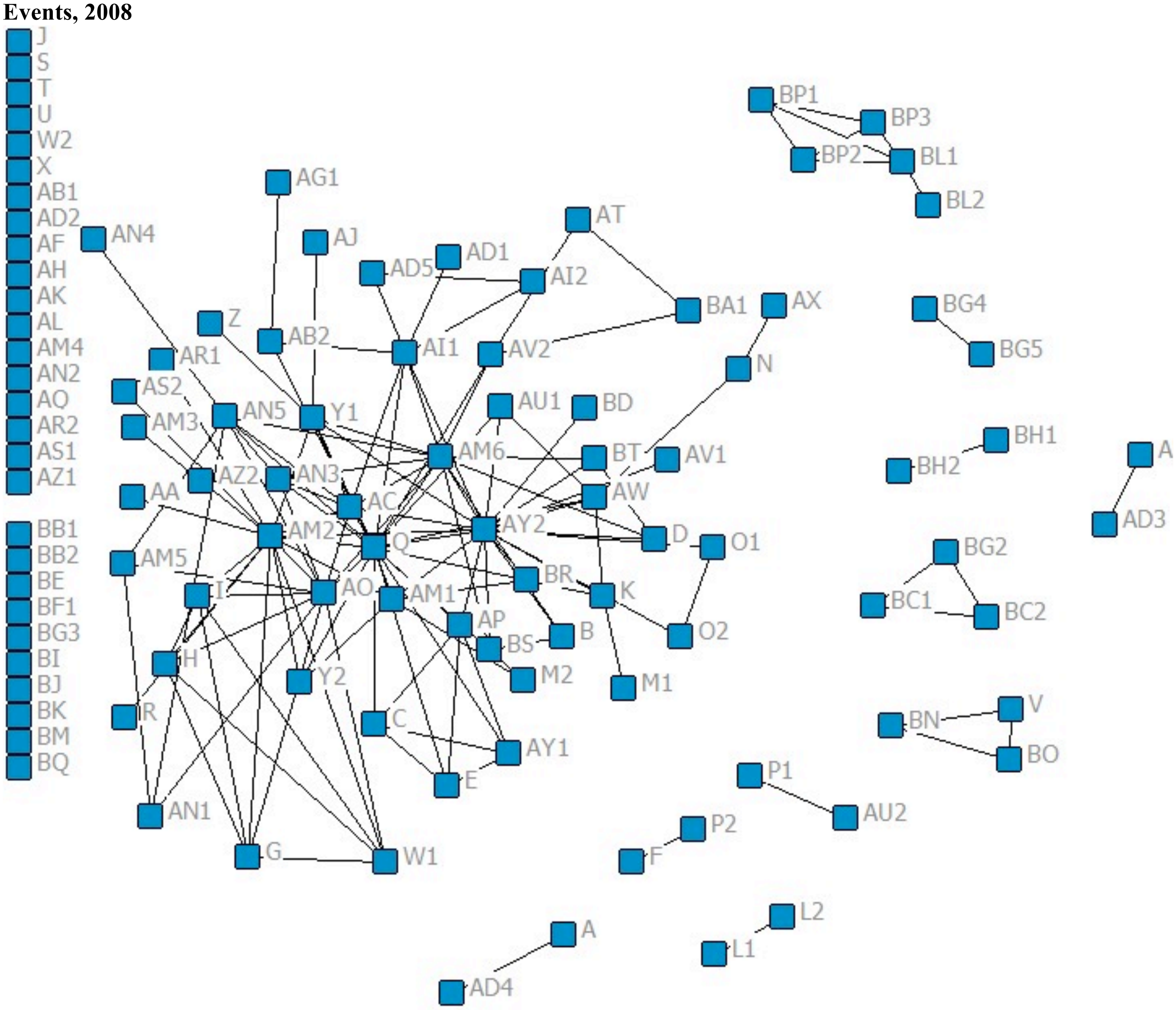


Figure 11. Network Analysis Map of the Backyard Bird Event Network, Displaying the Various Components of the Network, along with the Strength of the Ties (relationships) between each Event, 2008.

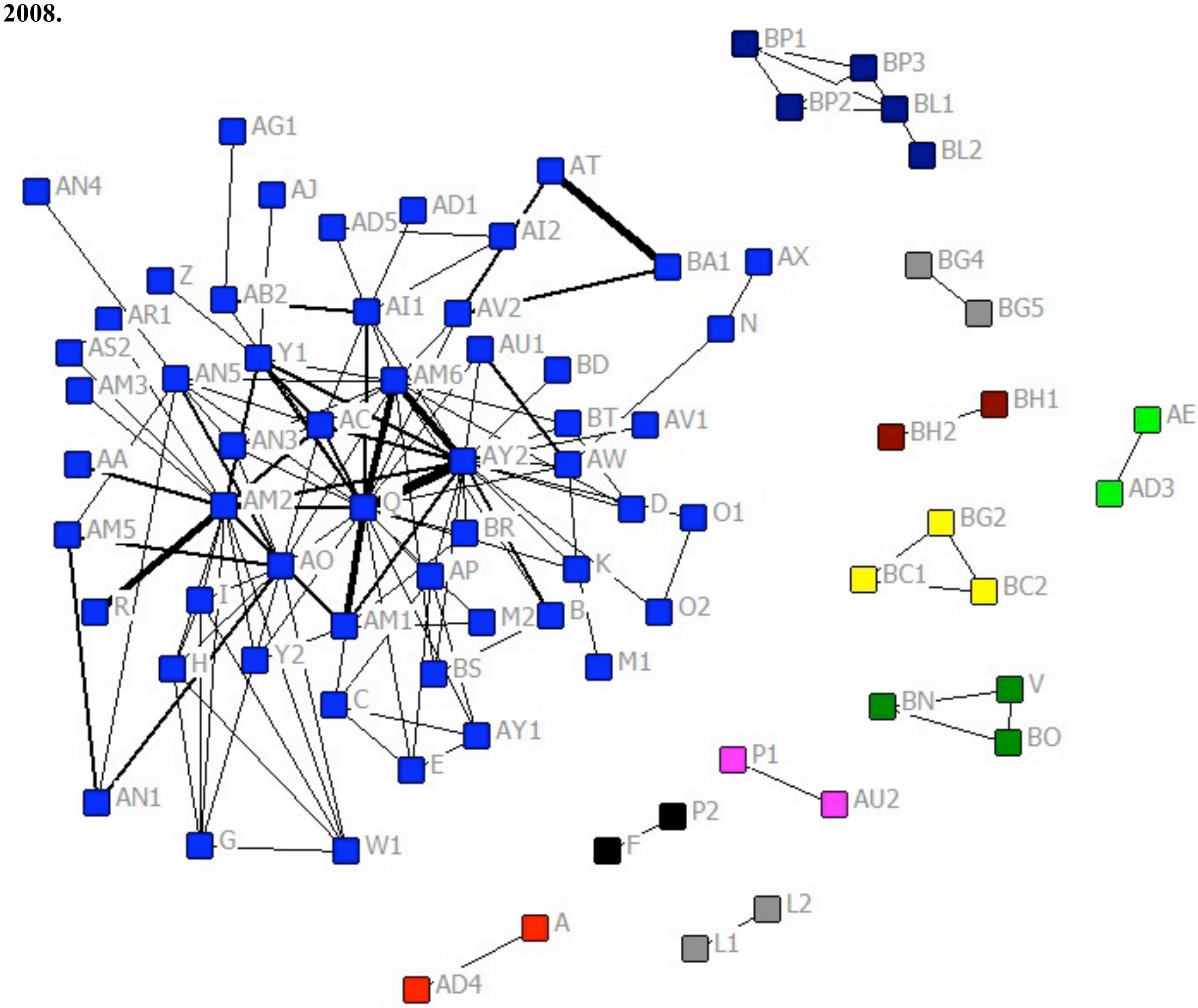


Figure 12. Network Analysis Map of the Backyard Bird Event Network, displaying the Specific Network "cutpoints", essential to the Fluidity of the Network with 108 Total Events, 2008.

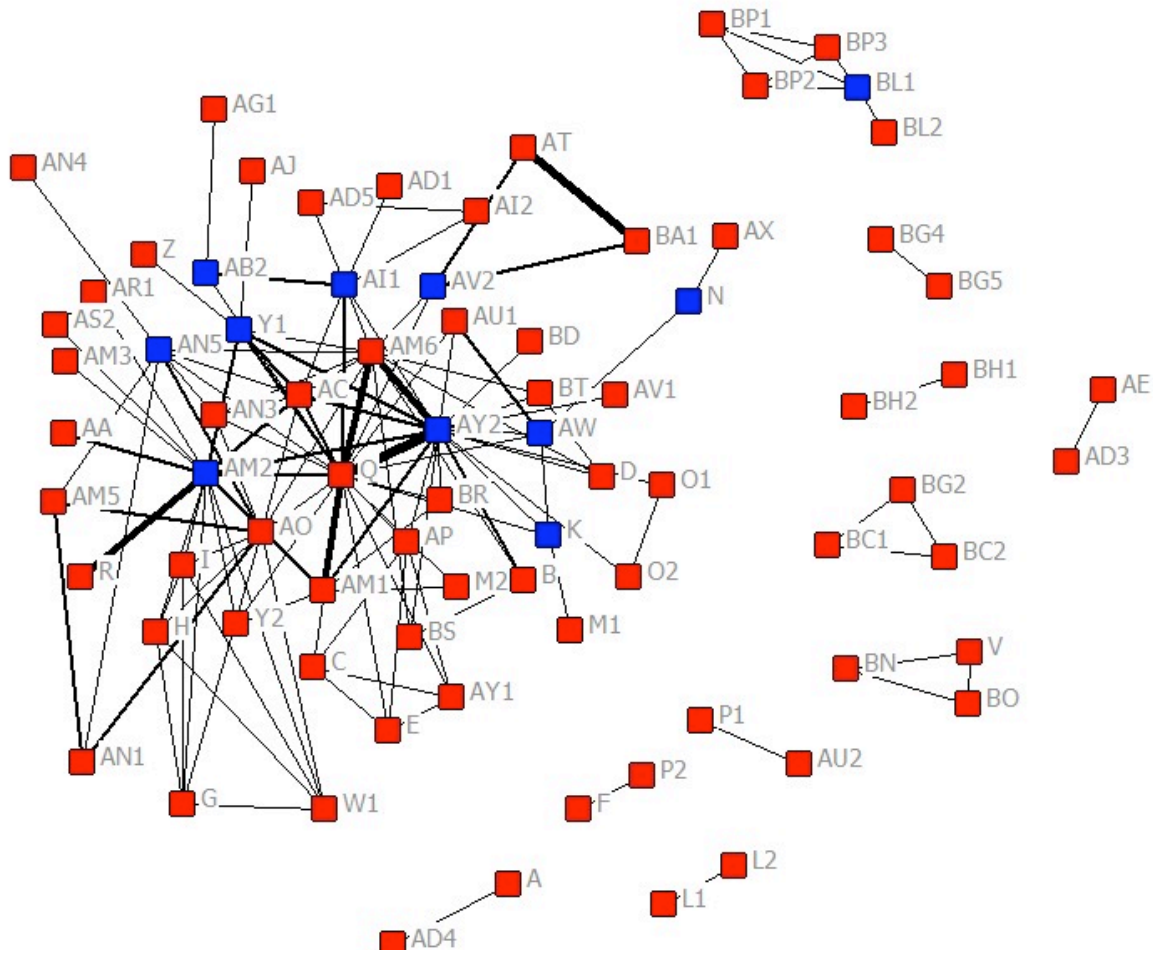


Figure 13. Ego-Networks of Flocks (nodes) 58, 67, 86 in Backyard Bird Flock Network of 140 Total Flocks, 2008.

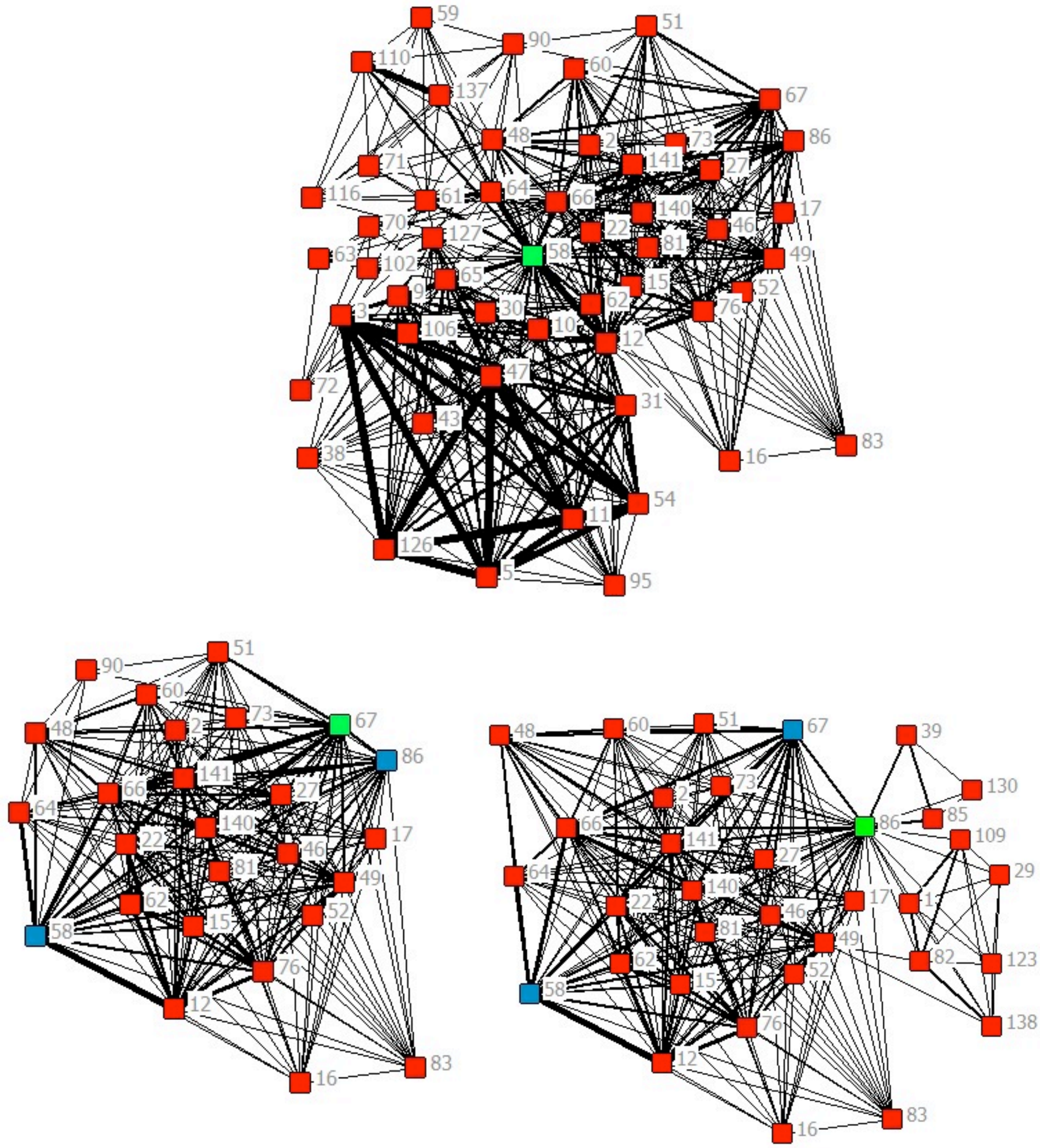


Figure 14. Ego-Networks of Events (Nodes) Q, AY2, AM2 in Backyard Bird Event Network of 108 Total Events, 2008.

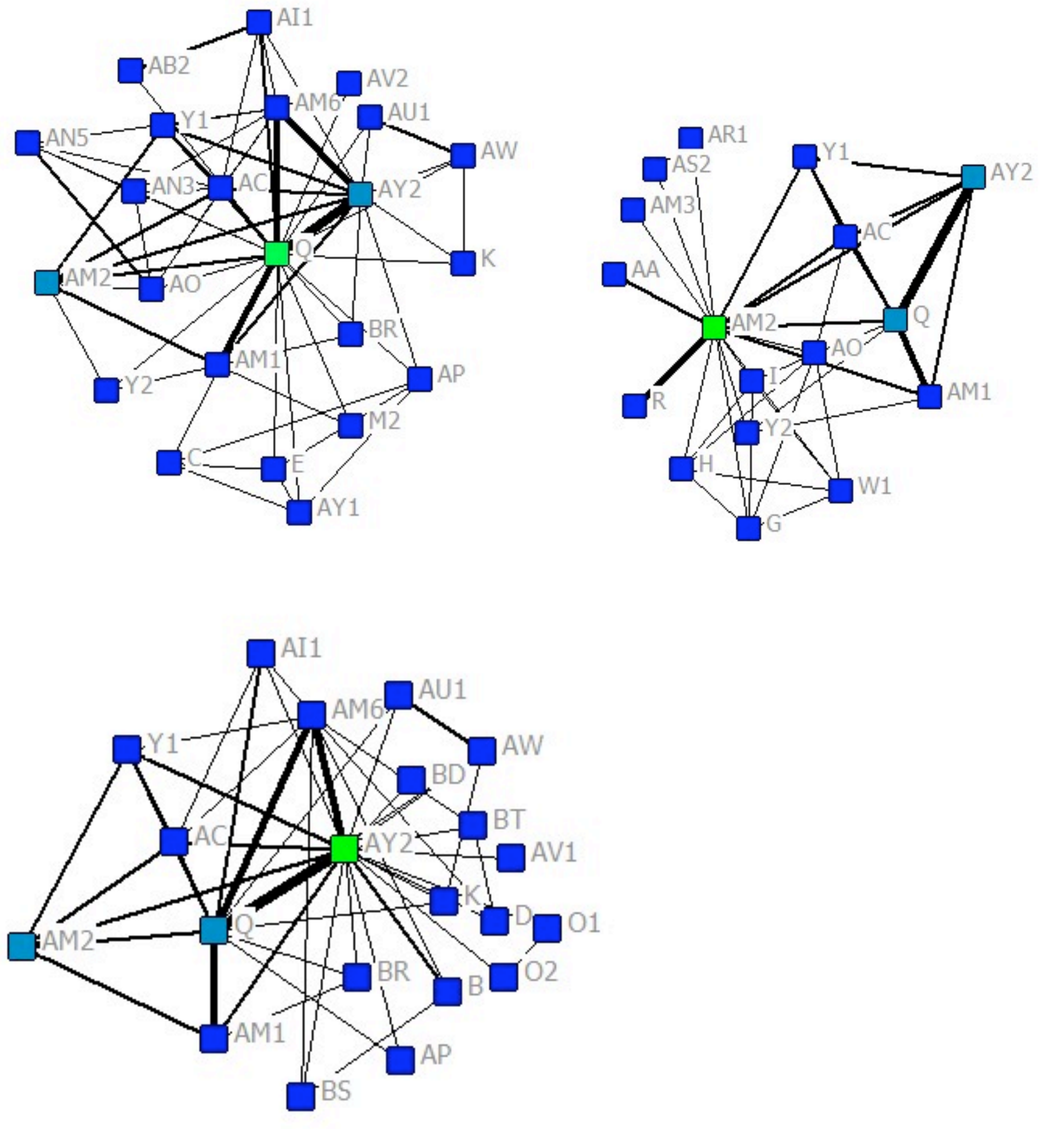


Figure 15. Distribution of the Degree Values of the Flocks in the Backyard Bird Flock Network of 140 Flocks, 2008.

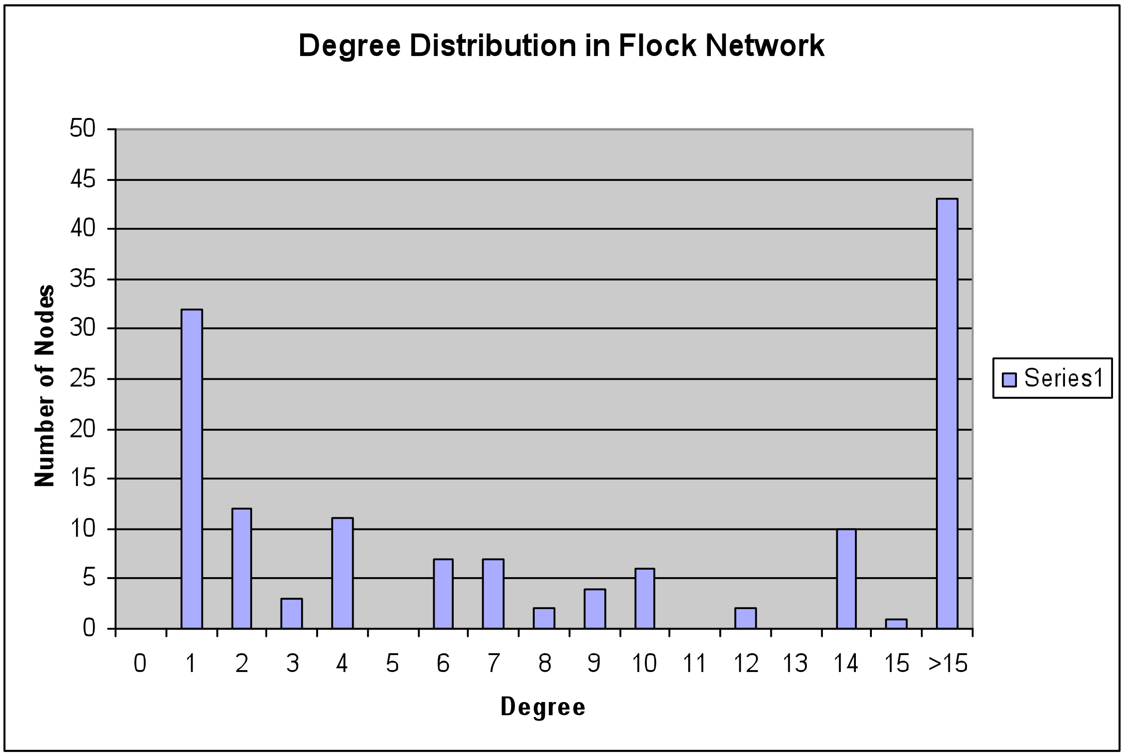


Figure 16. Distribution of the Degree Values of the Events in the Backyard Bird Event Network of 108 Events, 2008.

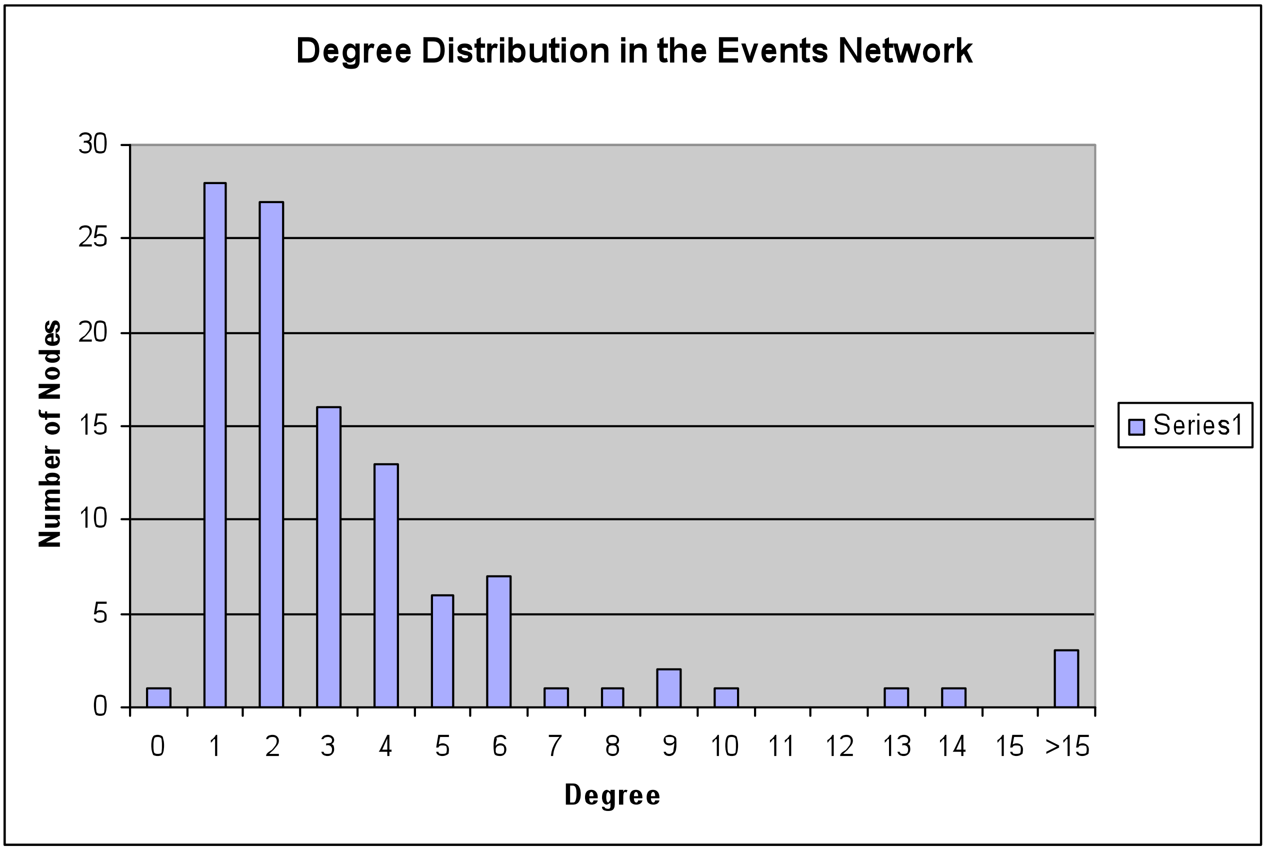


Figure 17. Map of Sample Geodesic Paths between Flocks in the Backyard Bird Flock Network of 140 Total Flocks, 2008.

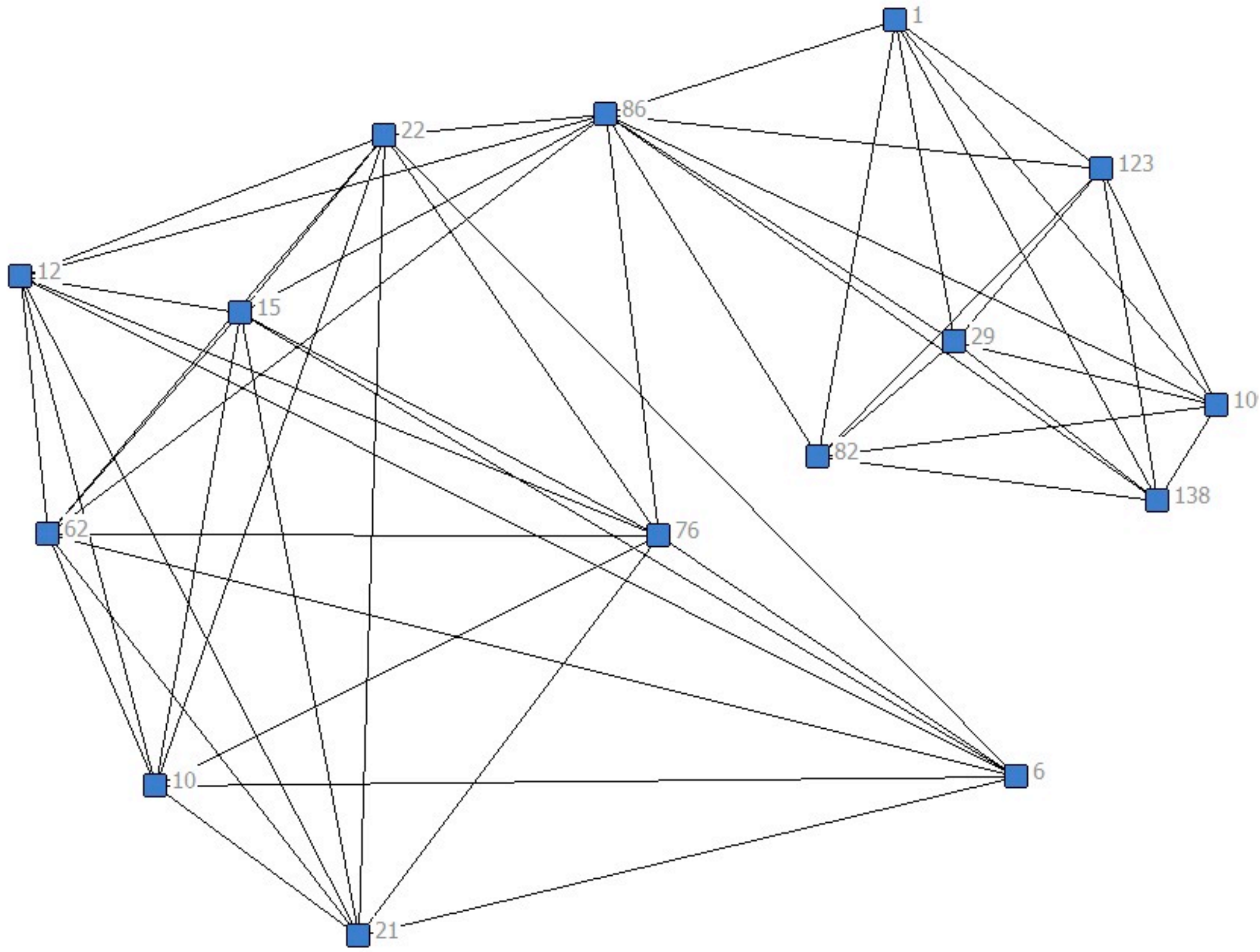


Figure 18. Map of Sample Geodesic Paths between Events in the Backyard Bird Event Network of 108 Total Events, 2008.

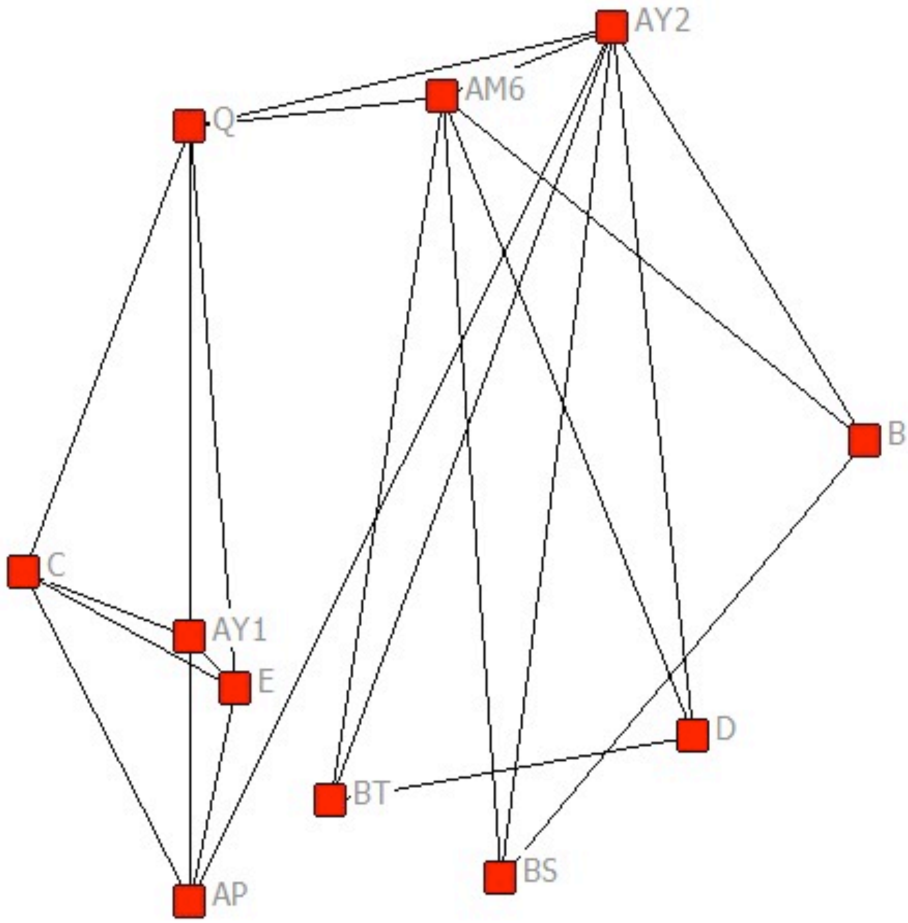
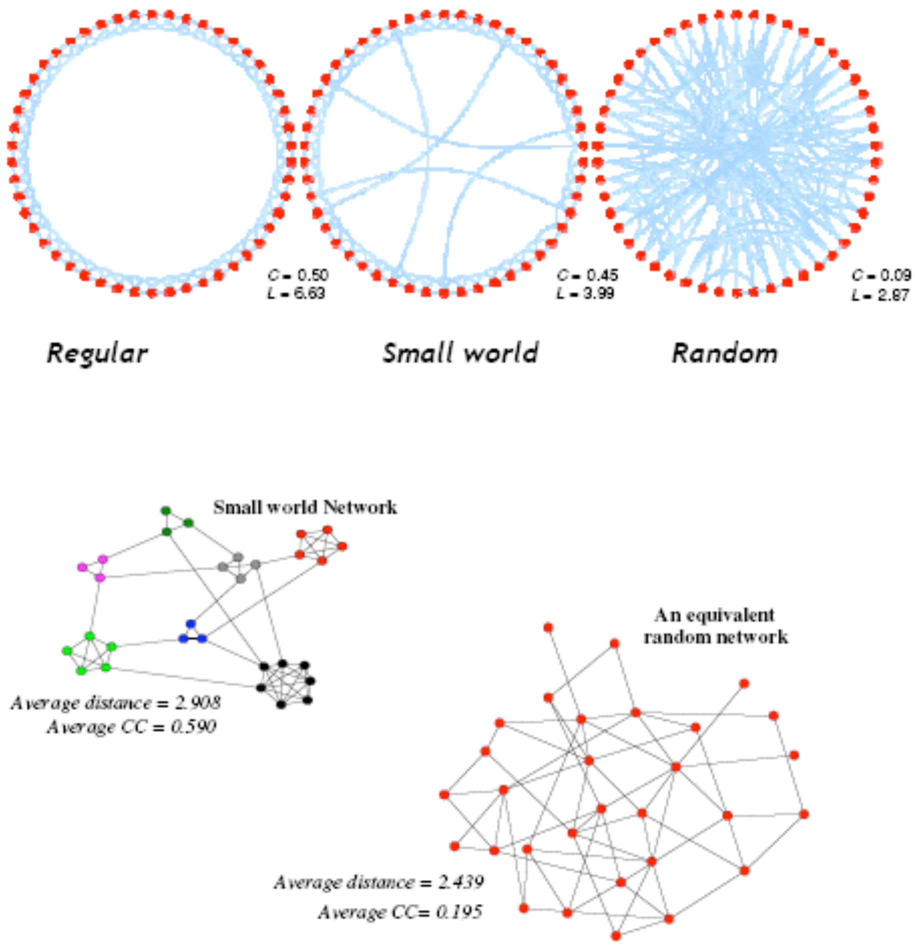


Figure 19. Examples of a Small World Network versus other Potential Network Types (Network Analysis Workshop, 2006).



Appendix A

Questionnaire

Backyard Poultry Survey

Code #___________

For each multiple choice question, please circle the letter that best describes you or your flock. For all others, please provide the information specified by each question.

1. Are you over 18 years of age?

A. Yes
B. No

Part 1- Flock Characterization

2. How many *birds* of the following types have you kept on your premises in the past 12 months?

A.Chickens-egg layer breeds.................................... ________
B.Chickens-meat breeds……….......................... ________
C. Chickens –show, exhibition, companion, etc.... ________
D. Turkeys....................………….......................... ________
E. Waterfowl (ducks, geese, swans, etc)............... ________
F. Game birds (pheasant, Quail, Chukar).............. ________
G. Guinea Fowl……………………………….... ________
H. Peafowl……………………......................... ________
I. Pigeons, Doves……………………................ ________
J. Indoor pet birds (non-poultry)………............... ________
L. Other birds (specify).. ________

3. What is the *primary* purpose for your flock? Please circle ALL that apply.

A. Food (meat or eggs) for family

B. Selling food products to outside sources

C. Hobby/ Companion/ Pet

D. Show/ Exhibition

E. 4-H or FFA

F. Breeding to sell

4. What *type(s)* of flock products do you sell or give away? Please circle ALL that apply.

A. Meat/ whole slaughtered birds

B. Eggs

C. Live birds destined for slaughter

D. Game birds

E. Breeder birds or show birds

F. Feathers/ pelts

G. I do not sell or give away my products

H. Other (list)__________________

5. Do you slaughter birds on or near your premises?

A. Yes

B. No

6. What housing management style best describes your flock?

A. Inside, confined to coop/barn/house (no outdoor access)

B. Inside coop/barn/house with outdoor access but unable to leave property (ie: coop with attached flight pen)

C. Inside coop/barn/house with outdoor access but able to leave property (ie: outdoor birds that return to coup in evening)

D. Outdoors only, but confined to property (ie: flight pen only)

E. Outdoors only and able to leave property (ie: no confinement or housing used)

F. Other (please specify) _____________

7. Do you allow adult birds from your flock inside your house (exclude non-poultry, pet birds)?

A. Yes

B. No

8. Do you live on the premises where your birds are kept?

A. Yes

B. No

Part 2-Bird Movement

9. In the past *12 months*, have birds from your flock left your premises and traveled to any of the following places?
If so, please record the corresponding letter, how many times, and the names of the properties/facilities, and nearest town or zipcode. ***If not, please leave blank and skip to question 11.***

A. Live Bird Market
B. Another premises with birds
C. Farm or Feed store
D. Swap meet or Flea/Farmer's market
E. Fair/Show
F. Auction
G. Directly to Slaughter
H. Into the wild
J. Other_______

	Place (letter)	# of times	Property/facility and/or Nearest town (s)/Zip codes
Example	C	2	Brighton Farm & Feed, Brighton CO 80601
Example	C	1	Poudre Pet & Feed, Fort Collins CO 80524

10. **From the list in question 9, did any of the birds *return to your premises* after visiting specified places?**
If YES, please record the corresponding letters to each event listed above where birds returned from (ie: F = Auction) and the approximate number of birds that returned.
Example: Yes: C= Poudre Pet and Feed. 6 chickens

A. Yes ____

B. No

11. **Do you keep separate/quarantine the returning birds from those at home? If YES, for how many days?**
A. Yes ____________days
B. No

12. **In the *past 12 months*, have you purchased or obtained birds or hatching eggs from the following places? If so, please state the corresponding letter, type of bird, number of birds and the name of the location or facility with zip code (ie: Murray McMurray). If not, please leave blank.**

A. Bird wholesaler or dealer
B. Another premises with birds
C. Farm or Feed Store
D. Swap meet or Flea/Farmer's market
E. Fair or Show
F. Auction
G. Other ____________

	Place (letter)	Type	# of Birds	Location (city, state) or Facility
Example	A	Turkey	20	Murry McMurry, Webster IA 50595
	______	______	______	________________________________
	______	______	______	________________________________
	______	______	______	________________________________
	______	______	______	________________________________
	______	______	______	________________________________
	______	______	______	________________________________
	______	______	______	________________________________
	______	______	______	________________________________
	______	______	______	________________________________

Part 3-Human Interaction

13. In the past 12 months, how many people (including yourself) have had contact with your flock?
Please state the corresponding age group of each person as child, teen, or adult and circle the frequency of contact.

Total # of people _________

Age Group	Frequency				
______	Daily	Weekly	Monthly	Rarely	Never
______	Daily	Weekly	Monthly	Rarely	Never
______	Daily	Weekly	Monthly	Rarely	Never
______	Daily	Weekly	Monthly	Rarely	Never
______	Daily	Weekly	Monthly	Rarely	Never
______	Daily	Weekly	Monthly	Rarely	Never
______	Daily	Weekly	Monthly	Rarely	Never

14. In an average WEEK, how many people have contact with your flock that also have contact with other flocks?

Please record the number of people from each category that have contact with other flocks besides your own (ie: have birds at their home or work at premises with other flocks) and the location of the flocks (town/zip code). ***If none, please put zero, if not known please write D/K***

	# of People	# of People with other birds	Location of birds (town/zipcode)
A. Family members…………………	________	________	________
B. Friends or neighbors……………..	________	________	________
C. Paid or unpaid workers………….	________	________	________
D. Customers………………….	________	________	________
E. Other__________..................			

15. During an average MONTH or YEAR, how many times do the following people visit your operation? *If never, please put zero.*

	# of visits per month	# of visits per year
A. Private veterinarians........................	________	________
B. State/ Federal/ University veterinarian or animal health worker...	________	________
C. Feed delivery person, nutritionist or feed company representative.................................	________	________
D. Customer purchasing bird(s), meat, eggs, or other bird products............	________	________
E. Bird wholesaler, buyer or dealer..	________	________
F. Inspector (county health inspector) or official there to certify bird(s).....	________	________
G. Non-business visitors (school groups, friends, or neighbors).......................................	________	________

Part 4- Biosecurity

16. Do you separate any new birds you obtain before they are introduced into your established flock? If yes, for how long?

A. Yes _______________ (days)
B. No

17. How many times in the past 12 months have you shared equipment (include lent, borrowed or co-owned) with another flock owner?

A. Zero
B. 1-3 times
C. 4-12 times
D. Over 12 times

18. How often do the people who have contact with your flock do the following? Please circle frequency

	Frequency			
A. Use a disinfectant footbath before/after contact............................	**Always**	**Usually**	**Sometimes**	**Never**
B. Change into clean clothes/coveralls before contact.....................................	**Always**	**Usually**	**Sometimes**	**Never**
C. Change into specified "flock shoes" before contact.	**Always**	**Usually**	**Sometimes**	**Never**
D. Change into clean boots or use shoe covers before contact..........................	**Always**	**Usually**	**Sometimes**	**Never**
E. Shower after contact..........................	**Always**	**Usually**	**Sometimes**	**Never**
F. Scrub & disinfect shoes before entry to flock...	**Always**	**Usually**	**Sometimes**	**Never**
G. Scrub & disinfect shoes after leaving flock..	**Always**	**Usually**	**Sometimes**	**Never**
H. Wash hands before handling birds.....	**Always**	**Usually**	**Sometimes**	**Never**
I. Wash hand after handling birds.........	**Always**	**Usually**	**Sometimes**	**Never**
J. Park away from the bird area............	**Always**	**Usually**	**Sometimes**	**Never**

19. Do you have any of the following within a tenth of a mile from your flock premises? Please circle all that apply.

A. Pond
B. Lake
C. Stream
D. River
E. Irrigation Ditch

20. **Do you sell or give flock litter/compost/manure to any of the following? Please circle yes or no. <u>If yes, how many times in the past 12 months?</u>**

			# of times
A. Friends........................	**Yes**	**No**	______
B. Business/Company......	**Yes**	**No**	______
C. Sold as product...........	**Yes**	**No**	______

21. How often do you see the following animals or evidence of them in the flock area or feed storage area? (<u>Include animals that approach your flock fence</u>) Please circle frequency.

			Frequency		
A. Wild ducks........................	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
B. Wild geese........................	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
C. Other wild birds................	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
D. Rodents.............................	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
E. Wild animals (deer, fox, raccoon, etc.)....................	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
F. Domestic birds that do not belong to premises...........	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
G. Cattle/sheep/goats...........	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
H. Pigs..................................	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
I. Owner's (your) dogs or cats....................................	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
J. Neighbor's dogs or cats.....	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**
K. Other _____________.......	**Daily**	**Weekly**	**Monthly**	**Rarely**	**Never**

Part 5- Flock Health

22. Have any of the birds in your flock experienced any of the following health problems in the past 12 months? Please circle yes or no. <u>If yes, please state the number of events in the past 12 months.</u> (Change included deleting option to correlate health event to particular season of the year)

		# of events in past 12 Months
A. Diarrhea..........................	**Yes No**	______
B. Respiratory (nasal/eye discharge, cough/sneeze, swollen sinuses).............	**Yes No**	______
C. Neurological (lack of coordination, weakness)..	**Yes No**	______
D. Weight loss.....................	**Yes No**	______
E. Feed refusal/depression (droopy birds)..................	**Yes No**	______
F. Sudden decreased production not related to molting (reduced egg laying, hatching rate, no weight gain).....................	**Yes No**	______
G. Unexplained death loss...	**Yes No**	______
H. Lameness........................	**Yes No**	______
I. External parasites............	**Yes No**	______
J. Internal parasites.............	**Yes No**	______
L. Other __________............	**Yes No**	______

23. How many birds from your flock have died (do not include slaughtered birds for consumption) in the past 12 months? <u>If zero please skip to question 24</u>

# of birds_______

24. In the past 12 months, have you experienced any of the following mortality events (bird losses) in your flock? Please circle all that apply and specify the *cause of death* if known and the number of *times* it has occurred.

	Cause of Death	# of times
A. Less than 10% mortality in 1 week	________________	______
B. Approximately 10% mortality in 1 week	________________	______
C. Approximately 10-50% mortality in 1 week	________________	______
D. Greater than 50% mortality in 1 week	________________	______

25. What is your *primary* method of disposing of dead birds? Please circle only 1.

A. Renderer pick-up
B. Carcass taken to renderer
C. Incinerate
D. Bury on premises
E. Compost
F. Taken to landfill
G. Put in trash (picked up)
H. Fed to other animals
I. Added to manure pile
J. Other method ____________

26. Have any birds in your flock been administered medications in the past 12 months? (Do not include antibiotics found in common feed)

A. Yes
B. No
C. Don't know

27. Do you vaccinate any of the birds in your flock? <u>If yes, please specify the disease(s) you vaccinate for.</u>

A. Yes ___________
B. No
C. Don't know

APPENDIX B: TABLES

Appendix B1. Frequency Distribution of Use of Flock Products for Colorado Backyard Flocks, 2008.

Flock Product Purpose		Yes	No	Total
Meat/whole slaughtered birds	n	54	263	317
	%	17.03	82.97	
	CI	(0.13,0.21)	(0.79,0.87)	
Eggs	n	251	66	317
	%	79.18	20.82	
	CI	(0.75,0.84)	(0.16,0.25)	
Live birds destined for slaughter	n	28	289	317
	%	8.83	91.17	
	CI	(0.06,0.12)	(0.88,0.94)	
Game birds	n	9	308	317
	%	2.84	97.16	
	CI	(0.01,0.05)	(0.95,0.99)	
Breeder birds or show birds	n	54	263	317
	%	17.03	82.97	
	CI	(0.13,0.21)	(0.79,0.87)	
Feathers/pelts	n	15	302	317
	%	4.73	95.27	
	CI	(0.02,0.07)	(0.93,0.98)	
Do not sell or give away products	n	34	283	317
	%	10.73	89.27	
	CI	(0.07,0.14)	(0.89,0.93)	
Other	n	14	303	317
	%	4.42	95.58	
	CI	(0.02,0.07)	(0.93,0.98)	

*Percentages do not add up to 100% as respondents were able to answer yes to multiple options.

Appendix B2. Frequency Distribution of Quarantine Practices Returning from Movement Event among Colorado Backyard Flocks in 2008

Quarantine		
Yes	n % CI	39 12.30 (0.09,0.16)
No	n % CI	80 25.20 (0.20,0.30)
NA	n % CI	198 62.50 (0.57,0.68)
Total	n	317

Appendix B3. Frequency Distribution of Birds Purchased among Colorado's Backyard Flocks in 2008

Bird Purchases		
Yes	n % CI	218 69.4 (0.64,0.74)
No	n % CI	96 30.6 (0.25,0.36)
Total	n	314

Appendix B4. Frequency Distribution of Purchasing Events by Bird Type among Colorado Backyard Flocks in 2008.

Bird Type Purchased	Purchasing Events	
Chicken – all breeds	n % CI	290 69.38 (0.65,0.74)
Waterfowl (ducks, geese)	n % CI	51 12.2 (0.09,0.15)
Game birds (quail, guinea fowl)	n % CI	18 4.31 (0.02,0.06)
Turkeys	n % CI	44 10.53 (0.08,0.13)
Peafowl	n % CI	5 1.20 (0.00,0.02)
Pigeons/Doves	n % CI	10 2.39 (0.01,0.04)
Total	n	418

*Participants were able to list multiple bird types purchased

Appendix B5. Frequency Distribution of Monthly Visits to Colorado Backyard Flocks by Specific Flock Visitors in 2008

Visitor	Monthly Visits	0	1	2	3	4	5	6	7	8	9	10	>10
Private Veter-inarian	**n % CI**	276 87.07 (0.83,0.91)	14 4.42 (0.02,0.07)	16 5.05 (0.03,0.07)	2 3 (0.00,0.15)	0 0.00 --	3 0.95	2 0.63 (0.00,0.15)	1 0.32 (0.00,0.01)	0 0.00 --	0 0.00 --	0 0.00 --	3 0.95 (0.00,0.02)
State/ Fed/ Univ Vet or Health Worker	**n % CI**	293 92.43 (0.90,0.95)	16 5.05 (0.03,0.07)	5 1.58 (0.00,0.03)	1 0.32 (0.00,0.01)	0 0.00 --	0 0.00 --	1 0.32 (0.00,0.01)	0 0.00 --	0 0.00 --	0 0.00 -	0 0.00 --	1 0.32 (0.00,0.01)
Feed deliv-ery person, nutritio nist	**n % CI**	313 98.74 (0.98,0.99)	2 0.63 (0.00,0.15)	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	1 0.32 (0.00,0.01)
Custom -er purcha s-ing bird product	**n % CI**	248 78.23 (0.74,0.83)	7 2.21 (0.01,0.04)	8 2.52 (0.01,0.04)	3 0.95 (0.00,0.02)	1 0.32 (0.00,0.01)	2 0.63 (0.00, 0.15)	6 1.89 (0.00,0.03)	0 0.00 --	1 0.32 (0.00,0.01)	0 0.00 --	3 0.95 (0.00, 0.02)	38 11.99 (0.08,0.16)
Bird whole-saler or buyer	**n % CI**	312 98.42 (0.97,0.99)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	0 0.00	0 0.00	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --
Official to cert birds	**n % CI**	313 98.7 (0.98,0.99)	4 1.2 (0.00,0.02)	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --
Non-busines visitors	**n % CI**	158 49.84 (0.44,0.55)	7 2.21 (0.01,0.04)	16 5.05 (0.03,0.07)	11 3.47 (0.01,0.05)	8 2.52 (0.01,0.04)	4 1.26 (0.00, 0.02)	17 5.36 (0.03,0.08)	1 0.32 (0.00,0.01)	7 2.21 (0.01,0.04)	1 0.32 (0.00, 0.01)	4 1.26 (0.00,0. 02)	83 26.18 (0.21,0.31)

Appendix B6. Frequency Distribution of Yearly Visits to Colorado Backyard Flocks by Specific Flock Visitors in 2008

Visitor	Yearly Visits	0	1	2	3	4	5	6	7	8	9	10	>10
Private Veterin-arian	n % CI	312 98.42 (0.97,0.99)	5 1.58 (0.00,0.03)	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --
State/ Fed/ Univ Vet or Animal Health Worker	n % CI	316 99.68 (0.99,1.00)	1 0.32 (0.00,0.01)	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --
Feed deliv-ery person nutrit-ionist	n % CI	316 99.68 (0.99,1.00)	1 0.32 (0.00,0.01)	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --
Custo-mer for bird product	n % CI	269 84.86 (0.81,0.89)	23 7.26 (0.04,0.10)	5 1.58 (0.00,0.03)	3 0.95 (0.00,0.02)	7 2.21 (0.01,0.04)	2 0.63 (0.00,0.15)	1 0.32 (0.00,0.01)	0 0.00 --	1 0.32 (0.00,0.01)	0 0.00 --	2 3 (0.00,0.15)	4 1.2 (0.00,0.02)
Bird whole-saler or buyer	n % CI	315 99.37 (0.98,1.00)	1 0.32 (0.00,0.01)	0 0.00 --	0 0.00 --	0 0.00 --	1 0.32 (0.00,0.01)	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --
Official to cert birds	n % CI	317 100 ---	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --	0 0.00 --
Non-busines visitors	n % CI	210 66.25 (0.61,0.71)	36 11.36 (0.08,0.15)	34 10.73 (0.07,0.14)	7 2.21 (0.01,0.04)	15 4.73 (0.02,0.07)	3 0.95 (0.00,0.02)	0 0.00 --	0 0.00 --	2 0.63 (0.00,0.15)	0 0.00 --	3 0.95 (0.00,0.02)	7 2.21 (0.01,0.04)

Appendix B7. Frequency of Colorado Backyard Flock Owners that Share or Give Away Flock Litter/Compost or Manure, 2008

Sell or Give Flock Litter/Compost/Manure Away		
Yes	**n** **%** **CI**	39 12.30 (0.09.0.16)
No	**n** **%** **CI**	278 87.70 (0.84,0.91)
Total	**n**	317

Appendix B8. Frequency Distribution of Slaughtering Practices in Colorado Backyard Flocks, 2008

Slaughter Birds On or Near Home		
Yes	**n** **%** **CI**	96 30.28 (0.25,0.35)
No	**n** **%** **CI**	221 69.72 (0.65,0.75)
Total	**n**	317

Appendix B9. Frequency Distribution of Quarantining New Birds in the Flock by Backyard Flock Owners, Colorado 2008

Quarantine		
Yes	**n** **%** **CI**	190 59.94 (0.54,0.65)
No	**n** **%** **CI**	127 40.06 (0.35,0.45)
Total	**n**	317

Appendix B10. Frequency Distribution of Biosecurity Practiced by those in Contact with Backyard Flocks in Colorado 2008

Activity	Frequency n % CI						
	Always	Usually	Sometimes	Never	Don't Know	NA	Total
Use a disinfectant Footbath Before/ After Contact	3 0.95 (0.00,0.02)	3 0.95 (0.00,0.02)	13 4.1 (0.02,0.06)	296 93.38 (0.91,0.96)	1 0.32 (0,00,0.01)	1 0.32 (0.00,0.01)	317
Change into Clean Clothes/ Coveralls Before Contact	7 2.22 (0.01,0.04)	8 2.53 (0.01,0.04)	27 8.54 (0.05,0.12)	272 86.08 (0.82,0.90)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	316
Change into Specified "Flock Shoes" Before Contact	28 8.83 (0.06,0.12)	28 8.83 (0.06,0.12)	16 5.05 (0.03,0.07)	243 76.66 (0.72,0.81)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	317
Change into Clean Boots or Shoe Covers Before Contact	14 4.42 (0.020.07)	7 2.21 (0.01,0.04)	22 6.94 (0.04,0.10)	272 85.8 (0.82,0.90)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	317
Shower after Contact	9 2.84 (0.01,0.05)	22 6.94 (0.04,0.10)	57 17.98 (0.14,0.22)	227 71.61 (0.67,0.77)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	317
Scrub & Disinfect Shoes Before Entry	2 0.63 (0.00,0.02)	2 0.63 (0.00,0.02)	10 3.15 (0.01,0.05)	301 94.95 (0.93,0.97)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	317
Scrub & Disinfect Shoes After Leaving Flock	3 0.95 (0.00,0.02)	8 2.52 (0.01,0.04)	22 6.94 (0.04,0.10)	282 88.96 (0.86,0.92)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	317
Wash Hands Before Handling Birds	32 10.09 (0.07,0.13)	54 17.03 (0.13,0.21)	45 14.2 (0.10,0.18)	184 58.04 (0.53,0.63)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	317
Wash Hands After Handling Flock	182 57.41 (0.52,0.63)	67 21.14 (0.17,0.26)	18 5.68 (0.03,0.08)	48 15.14 (0.11,0.19)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	317
Park Away from Bird Area	176 55.52 (0.50,0.61)	42 13.25 (0.10,0.17)	14 4.42 (0.02,0.07)	83 26.18 (0.21,0.31)	1 0.32 (0.00,0.01)	1 0.32 (0.00,0.01)	317

Appendix B11. Frequency Distribution of Flock Carcass Disposal among Colorado Backyard Flocks in 2008.

Method of Carcass Disposal		
Added to Manure Pile	**n** **%** **CI**	2 0.63 (0.00,0.02)
Bury on Premises	**n** **%** **CI**	69 21.84 (0.17,0.26)
Carcass taken to renderer	**n** **%** **CI**	1 0.32 (0.00,0.01)
Compost	**n** **%** **CI**	6 1.90 (0.00,0.03)
Fed to other animals	**n** **%** **CI**	21 6.65 (0.04,0.10)
Incinerate	**n** **%** **CI**	42 13.29 (0.10,0.17)
Put in Trash (picked up)	**n** **%** **CI**	118 37.34 (0.32,0.43)
Renderer pick-up	**n** **%** **CI**	1 0.32 (0.00,0.01)
Taken to Landfill	**n** **%** **CI**	19 6.01 (0.03,0.09)
Other Method	**n** **%** **CI**	35 11.08 (0.08,0.14)
Does not apply	**n** **%** **CI**	2 0.63 (0.00,0.02)
Total:	**n**	316

Appendix B12. Frequency of Total Bird Losses among Colorado Backyard Flocks in 2008

Bird Loss		
Yes	n % CI	197 62.3 (0.57,0.68)
No	n % CI	119 37.7 (0.32,0.43)
Total	n	316

Appendix B13. Frequency of Flock Bird Loss among Colorado Backyard Flocks in 2008

Bird Loss		
0	n % CI	119 37.7 (0.32,0.43)
1	n % CI	47 14.9 (0.11,0.19)
2	n % CI	34 10.8 (0.07,0.14)
3-5	n % CI	53 16.8 (0.13,0.21)
6-10	n % CI	26 8.2 (0.05,0.11)
11-20	n % CI	21 6.6 (0.04,0.10)
>21	n % CI	16 5.1 (0.03,0.07)
Total	n	316

Appendix B14. Frequency Distribution of Colorado Backyard Flock Owners that Administer Medication, 2008

Administered Medications		
Yes	**n** **%** **CI**	49 15.51 (0.11,0.19)
No	**n** **%** **CI**	264 83.54 (0.79,0.88)
Don't Know	**n** **%** **CI**	3 0.95 (0.00,0.02)
Total	**n**	316

Appendix B15. Frequency Distribution of Colorado Backyard Flock Owners that Vaccinate, 2008

Vaccinate Flock		
Yes	**n** **%** **CI**	26 8.23 (0.05,0.11)
No	**n** **%** **CI**	281 88.92 (0.85,0.92)
Don't Know	**n** **%** **CI**	9 2.85 (0.01,0.05)
Total	**n**	316

Appendix B16. Frequency Distribution of Vaccinations given to Backyard Flocks in Colorado in 2008

Vaccine		
Coccidiosis	**n**	6
	%	23.07
	CI	(0.07,0.39)
Avian Influenza	**n**	1
	%	3.85
	CI	(0.00,0.11)
Fowl Pox	**n**	1
	%	3.85
	CI	(0.00,0.11)
Marek's Disease	**n**	12
	%	46.15
	CI	(0.27,0.65)
New Castle Virus	**n**	1
	%	3.85
	CI	(0.00,0.11)
Paramyxovirus	**n**	2
	%	7.69
	CI	(0.00,0.18)
Not Specified	**n**	3
	%	11.54
	CI	(0.00,0.24)
Total	**n**	26

GLOSSARY

Avian Influenza Terms:

1. **HPAI:** highly pathogenic of avian influenza that results in severe and acute clinical disease in poultry. HPAI strains are composed of either H5 or H7 surface proteins. HPAI strains can mutate from LPAI strains (Brown et al. 2008).

2. **LPAI:** low pathogenic avian influenza that leads to asymptomatic or mild clinical diseases in poultry. LPAI strains are composed of any one of the 16 HA surface proteins (Brown et al. 2008).

3. **LPNAI:** low pathogenic notifiable avian influenza strains are a subset within LPAI. The strains are biologically identical to LPAI strains. They are more threatening as they contain either H5 or H7 subtypes and are potentially capable of mutating into a HPAI (Brown et al. 2008).

4. **Zoonotic:** any infectious agent that can be transmitted from wild or domestic animals to humans to cause disease (Cutler et al. 2010).

Network Analysis Terms

1. **1-Mode Network**: network that consists of only one node, the matrix is *nxn*. These are the most common networks in network analysis (Network Analysis Workshop 2006).

2. **2-Mode Network**: network that consists of two separate nodes, the matrix is *nxm* (Network Analysis Workshop 2006).

3. **Affiliation Network**: a 2-mode network (*nxm)* that consists of relations connecting actors (nodes) to events. Includes one set of nodes (n) and one set of events (m) (Network Analysis Workshop 2006).

4. **Average path length**: the shortest path (geodesic) among two nodes averaged over all pairs of nodes in the network (Network Analysis Workshop 2006).

5. **Betweenness:** (measure of centrality) the frequency with which a node (k) falls between pairs of other nodes on the shortest path connecting the nodes. A node with a higher betweenness value is a node that holds a more central position in the network. Betweenness is also helpful in reflecting how much a particular node can control the flow within a network, in that it is the connecting point to a variety of other nodes (Network Analysis Workshop 2006).

6. **Binary Matrix:** matrix with recorded cell values as yes (1) or no (0) (Network Analysis Workshop 2006).

7. **Centralization Index for Degree**: provides a general idea of the departure from a network in which all nodes have the same degree (index = 0). Centralization describes the extent to which the cohesion of an entire network is organized around particularly central nodes. The centralization index is a summary of the centrality scores of each node, determining whether a network is heterogeneous or homogenous (Network Analysis Workshop 2006).

8. **Closeness:** (measure of Centrality). Closeness is defined as the distance between nodes. It assesses the distance from one node to all other nodes. A node with a higher level of closeness is a node that is closer to a large number of other nodes and thus has a higher level of centrality. UCINET produces two measures of closeness: "*farness*" and "*closeness*" (Network Analysis Workshop 2006).

9. **Clustering Coefficient**: among nodes, represents the proportion of neighbors who are also neighbors of one another and determines the overall structure of the network. The clustering coefficient is an important factor in determining the type of network: regular; small world, or random. This designation is dependent upon the clustering coefficient and path length (geodesic distance) (Network Analysis Workshop 2006).

10. **Components**: connected subregions within a network in which all pairs of nodes are directly or indirectly linked (Network Analysis Workshop 2006).

11. **Cutpoints**: "Cutpoints" are key nodes to the connectivity of the network. If a cutpoint is eliminated from a network, the flow of information is disrupted and the number of components in the network increases (Network Analysis Workshop 2006).

12. **Degree:** (measure of centrality). The degree value for a node is the number of links to that particular node or the number of connections to other nodes. A higher degree value is a node with a large number of ties to other nodes and is thus more likely to be an influential or "central" node in the network (Network Analysis Workshop 2006).

13. **Density:** describes the cohesion in the network. It is defined as the number of actual links present in the network out of all possible links. The equation used to determine density is:

$$\textbf{Density}_{\textbf{undirected}} = \frac{\mathbf{2L}}{\mathbf{k(k-1)}}$$

where k = nodes (Network Analysis Workshop 2006).

14. Diameter: of the network defines how "big" the network is. The diameter is the length of the largest geodesic distance between a pair of nodes in the network (Network Analysis Workshop 2006).

15. Directed Network: a network in which information can travel in only one direction along the links between nodes (Network Analysis Workshop 2006).

16. Ego-Network: a smaller network associated with a specific node (known as ego) and the specific links to that ego node. The links incorporated in an ego network are those that run between the ego node and other nodes and those between the other nodes (Network Analysis Workshop 2006).

5. **Farness** is the sum of the shortest distances (geodesics) between a node and all others. A node with the lowest farness value is a more central node. Thus a central node with have a high closeness value and a low farness value (Network Analysis Workshop 2006).

6. Geodesic Distances: the shortest path between 2 nodes. The geodesic represents the closest connection between 2 nodes. The geodesic distance is estimated by an algorithm that finds the number of edges in the shortest path between each pair of nodes (Network Analysis Workshop 2006).

7. Hubs: highly connected nodes central to the network (Network Analysis Workshop 2006).

8. **Links**: the connecting relationships between the nodes (Network Analysis Workshop 2006).

9. **Measures of Centrality**: measures to identify the importance and role of individual nodes in the network by measuring degree, betweenness, and closeness of a node in a network. It relates to the importance of the node in the flow of the network by describing the location of the individual nodes in terms of how central they are to the network. Typically, the more central a node, the more influential and powerful that node is in the defined network (Network Analysis Workshop 2006).

10. **Measures of Cohesion**: measures to determine the level of connectivity in the network. Determined by density, clustering coefficient, average geodesic path length (Network Analysis Workshop 2006).

11. **Network**: collection of "units of interest" that may or may not be linked in some manner that creates a connected network between the units (Network Analysis Workshop 2006).

12. **Nodes**: units of interest in network (Network Analysis Workshop 2006).

13. **Random Network**: a normally distributed plot of degree values and a homogenous network composed of randomly assigned links to nodes with a low clustering coefficient and average geodesic path lengths between nodes (Network Analysis Workshop 2006).

14. **Reachability:** Two nodes are said to be reachable if there is a set of connections between them. If two nodes are reachable from one another, there is a path between the nodes. If two nodes are not reachable, it means they belong to different components of the graph (Network Analysis Workshop 2006).

15. **Scale-Free Network:** in this network, see an absence of a typical degree (typical scale) because the degree distribution follows the power law ($f(x) = y = x^{-\alpha}$) and is highly skewed. The network has a high frequency of low-degree nodes with few links as well as just a few links that are highly connected nodes with many links. These highly connected nodes are called hubs (Network Analysis Workshop 2006).

16. **Small World Network**: high clustering coefficient; low average geodesic path lengths between. In such networks, infectious agents will tend to spread more rapidly, but infect fewer individuals when compared with a random network (Network Analysis Workshop 2006).

17. **Undirected network:** a network in which the links between nodes represent relationships where information can travel in either direction (Network Analysis Workshop 2006).

18. **Valued Matrix**: links in the matrix are quantified. In our study, the links are quantified by the number of times the participants reported movement of their birds to a particular event in the 12 month period; the number of events in common between flocks; the number of flocks in common between events (Network Analysis Workshop 2006).