The Chicken or the Egg?
Hen Health and Food Safety on California's Pastured Poultry Farms

By

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ABSTRACT

Pasture-raised poultry comprises a small portion of the commercial egg industry in North America, but this alternative rearing system is increasingly popular. Rearing poultry outdoors is considered to be high risk due to pathogen and predation hazards, yet pastured systems continue to grow. The limited research on these systems presents an opportunity to improve understanding of husbandry practices, farmer incentives, and disease prevalence on pasture-raised poultry farms. This study analyzes the spatial, environmental, and epidemiological characteristics of pastured poultry egg production in California, based on a survey sent to 82 commercial pastured poultry farms in California. While the survey response was only 13% (11/82), it was enhanced with detailed informal interviews and farm visits. On average, farms utilized 12% of their total farmland for pastured poultry operations, which often coexisted with other livestock (45%), crops that touch the ground (e.g., squash) (27%), and crops that do not touch the ground (e.g., tree fruits) (45%). Common obstacles to pastured poultry farming included feed cost and high mortality as a result of predation. Six of the 11 farms reported annual flock loss over 10%. *Salmonella* Pullorum (SP) whole blood agglutination and *Salmonella* Enteritidis (SE) environmental drag swab tests were conducted to better understand disease prevalence, food safety risks, and potential environmental risk factors. Drag swab results showed the presence of SE in the environment of one of the 11 farms (9%). Agglutination tests for SP showed the presence of antibodies in six of the seven non-SE vaccinated farms, with an average on-farm prevalence of 26% of the laying hens affected. Logistic regression was used to determine husbandry and environmental risk indicators for *Salmonella spp.* exposure in non-vaccinated flocks, using the SP agglutination data as the dependent variable and survey questions as the independent variables. Statistically significant ($p < 0.05$) risk factors included flock size and wire floors, providing insight into the relationship between pathogens and husbandry practices on pastured poultry farms. These results suggest that despite the increasing popularity of pasture-raised poultry, epidemiological obstacles related to management and environment warrant further study.

1. INTRODUCTION

Pasture-raised poultry production has become increasingly popular in the United States over the last 20 years, and today contribute to 5% of U.S. egg production (Colles et al., 2008; Kijlstra et al., 2009; Mench et al., 2011). Consumers and farmers alike have expressed concern over food safety, hen health, and animal welfare conditions in conventional production systems (Harper and Makatouni, 2002; Yeung and Morris, 2001), opening a niche market for alternative poultry rearing. Heightened consumer awareness has enabled farmers to sell premium priced eggs from outdoor layer hens, despite environmental risks such as predation and disease exposure (Jones et al., 2003; Sossidou et al., 2011; van Bommel and Spicer, 2011). Pasture-raised poultry is an extension of free-range systems, and refers to the husbandry practice in which poultry flocks have access to pasture during the day, and are housed in a mobile structure or "eggmobile" at night (Sossidou et al., 2011). In California, many fruit and vegetable farmers have diversified their operations to include small-scale[1] pasture-raised poultry as a supplementary enterprise for farmer's markets and Community Supported Agriculture (Stevenson and Schuster, 2003; Stevenson, 2001). Eggs from pastured chickens can fetch up to $9.99 (USD) per dozen in California, compared to $3.61 (USD) per dozen for conventionally raised[2] eggs (CUESA, 2011; Good Eggs, 2015; USDA ERS, 2015). Pastured producers also tend to have relatively small flocks (300 to 1,500 hens) that fall below federal and state regulatory thresholds, resulting in a knowledge gap about food safety parameters and basic production

[1] According to Stevenson and Schuster (2003), 'small-scale' farms are those with less than 3,000 hens, as this group of pastured poultry farms falls below the regulatory threshold for disease monitoring by the FDA and CDFA. Large-scale pastured poultry farms are considered to be those between 3,000 and 50,000 hens.
[2] The term 'conventional' is used to describe industrial and highly mechanized poultry farms that use aviary, colony cage, or battery cage systems to produce eggs.

strategies. This study addresses the lack of research on pastured layer systems by characterizing food safety and hen health issues common to pastured poultry farms in California.

Pastured poultry's popularity can be attributed, in part, to increased demand for cage-free and alternative eggs (Mench et al., 2011). Transparency of the conditions in caged layer facilities has had broad ramifications, both on farms and in state legislation. The California egg industry faced a dramatic overhaul after California voters passed Proposition 2 in 2008 (i.e., Prevention of Farm Animal Cruelty Act). Subsequent food safety regulations implemented in January of 2015 required producers to approximately double the cage size for egg layers. These changes resulted in a dramatic decrease in the number of commercial layer birds from approximately 18 million in 2014 to 11 million in 2015 ((USDA ERS, 2011)). Challenges for the conventional egg industry helped strengthen the presence of alternative poultry systems. Specifically, these changes created new opportunities for different production systems, including aviary and free-range systems, that were expected to increase egg costs by as much as 40% per dozen (Sumner et al., 2011).

As the tenth highest egg producing state in the U.S., informal evidence from farmer's markets and community grocers suggests that California's pastured poultry producers have responded rapidly to consumer demands for eggs from "safe" and "humanely raised" chickens raised in alternative systems. Cartons of eggs from pasture-raised chickens now sit alongside conventional cartons at many large scale supermarkets. Yet, there is a lack of regulation and research on pastured poultry in comparison with the large number of studies in conventional caged operations, particularly on animal welfare, production costs, and food safety (e.g., Garber et al., 2003, Gast and Holt, 1998, and Henzler et al., 1993). Pastured poultry production is regionally unique with respect to predator exposure, pasture rotation cycles, climate, and avian diseases (Sossidou et al., 2011; Xu et al., 2014), making it more difficult to apply generalized rules to all farms than for the more homogeneous conditions of conventional caged production systems. Pastured birds are more influenced by the natural environment than indoor flocks, and therefore it may not appropriate to extrapolate and generalize data from pastured poultry studies to different geographical areas. This spatial variation complicates research and regulation.

1.1 PROBLEM

The United States Department of Agriculture (USDA) does not have a regulatory definition for pastured poultry systems, but does stipulate that "free-range or free-roaming hens" must have access to the outdoors (USDA ERS, 2015). Many non-government stakeholders and academics have attempted to refine the pasture-raised poultry definition with external certification programs such as Certified Humane (CH) and Animal Welfare Approved (AWA) (AWA, 2015; HFAC, 2014). CH and AWA each have extensive standards for pasture-raised poultry, but both include requirements for continuous outdoor access and preventative health plans (AWA, 2015; HFAC, 2014). Certifications also require that pasture-raised flocks have access to a movable house for "shelter, feeding, nesting, dust bathing, and roosting with constant daytime outdoor access to fresh-growing palatable vegetation" (Sossidou et al., 2011). While these guidelines provide a foundation for understanding pastured poultry, geographic and environmental variation among farms limit its utility and implementation (e.g., the 2012-2015 California drought restricted access to fresh-growing vegetation).

Regulatory gaps for the pastured poultry industry present epidemiological problems as flock sizes increase from less than 3,000 up to 50,000 hens (Stevenson and Schuster, 2003). Pastured husbandry systems have drawn the attention of large egg companies, many of which have sufficient capital to produce pasture-raised chickens commercially in flocks of 4,000 to

50,000 hens. A trend is emerging that is familiar to the U.S. poultry industry: growth beyond small farms to intensive production and contract growers (Boyd and Watts, 1997). Specialized free-range egg layer companies already exist, such as Vital Farms and The Happy Egg Co. Operations are based in Georgia, Arkansas, Missouri, Oklahoma, and Texas, where they contract smaller farms and sell eggs from pastured hens at supermarkets under their label (The Happy Egg Co., 2016; Vital Farms, 2016). However, capitalizing on a market driven by consumers fearful of conventional farming methods is risky (Pollan, 2007; Salatin, 1996), given the potential food safety hazards. In order to better understand the impacts of increasing commercial interest in pastured poultry farming, this research will analyze geographically specific risks to food safety, hen health, and management on pastured poultry farms.

1.2 RESEARCH GOALS

The primary goal of this research is to explore and analyze the geographical and epidemiological characteristics and limitations of pastured poultry farms in California. Data collected in this exploratory study is used to consider potential risk factors that can be problematic for hen health and food safety. Recommendations for further research in this burgeoning egg industry are also made. It should be noted that this study is limited in scope, as only 11 farms participated. Despite the small sample size, this study provides one of the first attempts to characterize these systems and identify the obstacles faced on pastured poultry farms, as well as the potential health and food safety issues that arise from husbandry decisions and environmental variation in California.

The primary research question addressed is: To what extent do environmental factors and management decisions on pastured poultry layer farms affect food safety, poultry health, and the increasing popularity of this industry? To answer this question, farmer responses from online survey and field data will be analyzed to determine common obstacles to food safety and poultry health on each farm. An assessment of poultry health will be conducted via *Salmonella* Pullorum (SP) whole blood agglutination and *Salmonella* Enteritidis (SE) environmental drag swab samples, enrichment, and PCR diagnostic tests. These are both important *Salmonella* serotypes that are hazardous both to hen health (SP) and human health (SE). *Salmonella* surveillance is not legally required of farms with small flock sizes (e.g., less than 3,000 hens) (FDA, 2013), and to the author's knowledge this is the first such study of pastured layers in California. While the study does not claim that the participating farms are representative of the pastured poultry industry as a whole, the research provides an exploratory study of production practices and disease prevalence that has not yet been conducted in California.

1.3 ORGANIZATION

Chapter 2 provides an overview of relevant research from three major areas: (1) a brief history of poultry farming in the U.S., (2) consumer influence over egg production, and (3) pastured poultry regulations and food safety. The first section outlines the rapid industrialization of U.S. food production and map the poultry industry's development from home production to vertical integration. The second section discusses how consumer preference for eggs has changed, and ultimately shaped, the shift to alternative poultry production (e.g., organic, local, and free-range systems). The third section describes the regulatory shifts that occurred in response to demand for organic and free-range eggs, and outlines egg regulations from which many small-scale pastured poultry farms are exempt. Chapter 3 describes the materials and methods used to conduct this study, and provides an outline of surveys, interviews, *Salmonella* surveillance tests, and statistical analysis. Chapter 4 presents the results of the study and general characteristics of participating farms. Chapter 5 identifies risk indicators for hen health and food safety based on the data, and discusses the indicators' implications on pastured poultry farming in California. Chapter 6 summarizes the work that has been completed, discusses methodological issues, and proposes future research in this area.

2. LITERATURE REVIEW

2.1 POULTRY FARMING IN THE UNITED STATES

Early 20th Century: The Agro-Food Complex

Poultry farming has deep roots in U.S. history. Before large henhouses and industrial production, chickens were kept in residential backyards and on small farms as sources of readily available protein (Friedman and McMichael, 1989). Eggs were considered a luxury food due to seasonal production, since chickens laid eggs infrequently in winter due to limited daylight and lack of vitamin D (Perkins, 2013). Egg consumption increased in spring and summer with the production cycle, but remained marginal compared to modern-day: in 2012 U.S. consumption equaled 19 pounds of eggs per capita (USDA ERS, 2015). To understand the development of intensive egg production, it is necessary to first analyze the shift from small to large-scale agricultural and livestock production in the United States.

The shift from family farms to large-scale agricultural specialization allowed for new methods of livestock production, particularly in the poultry industry. In the early 20th century, agriculture remained concentrated on diversified small farms in rural communities. These farms employed 41% the U.S. workforce and produced about five different commodities per farm (Dimitri et al., 2005). With new technologies and increased rural infrastructure, crop production moved away from labor intensive family farms and divided agriculture into specialized sectors, which increased both efficiency and production (Dimitri et al., 2005; Friedman and McMichael, 1989). Crop inputs became linked across state lines to facilitate international export, as global markets became important to farms in the "golden age" of U.S. agriculture from 1910 to 1914 (Dimitri et al., 2005). Newly integrated markets required crop production to be restructured and streamlined to meet demand. However, in the 1920s commodity crop exports such as corn and soy began to drop, and by the 1930s the volume of U.S. agricultural exports had fallen by 20% (Dimitri et al., 2005). The decline of global market exports pushed farmers and policymakers to seek new vessels for growing corn and soy stockpiles, particularly livestock (Friedman and McMichael, 1989). By feeding cattle and poultry surplus corn and soy meal, high-value meat products offset the decline in commodity exports. The combination of the discovery and artificial manufacturing of vitamin D and low grain prices enabled year-round egg production by 1926, and paved the way for further technological developments in commercial egg production (Boyd and Watts, 1997; Roenigk, 1991). To support increased production in meat and eggs and stabilize the commodity farming industry, politicians promoted increased consumption, particularly during World War I and II. In 1928, U.S. president Herbert Hoover promised that Americans would have "a chicken in every pot," even though average U.S. chicken consumption was only 0.23 kilograms per capita per year (Boyd and Watts, 1997; Hoover, 1928). By World War II, U.S. poultry consumption rapidly increased to 2.27 kilograms per capita in 1945, and to 31.75 kilograms per capita in 1995 (Boyd and Watts, 1997; Friedman and McMichael, 1989).

While poultry meat consumption increased during the early 20th century, many egg farms remained backyard systems. Eggs were produced and consumed at home, with excess eggs sold to neighbors or local markets (Hastings, 1909). Before poultry meat was produced at a commercial scale, chickens were slaughtered as a byproduct of backyard egg production (AEB, 2015). At this time, families consumed two main types of poultry: older laying hens past their prime, and young roosters (AEB, 2015; Boyd and Watts, 1997; Hastings, 1909). As the production of chickens for meat production ("broilers") became more popular in the 1930s, farmers moved to selectively breed and produce both broilers and egg laying hens commercially to meet growing consumer demand (AEB, 2015). Thus, the single purpose chicken was born—a bird raised for meat *or* eggs, rather than both.

Egg-laying hens remained outdoors through the 1930s, but after that flock sizes increased rapidly (AEB, 2015). Numerous obstacles remained, despite selective breeding for healthy birds. Outdoor hazards included inclement weather, predation, parasites, and disease (AEB, 2015). *Salmonella* Pullorum was a pervasive disease that could decimate an entire flock, and stimulated the creation of the National Poultry Improvement Plan (NPIP) in the late 1930s. NPIP regulated and coordinated statewide programs focused on eliminating Pullorum. While other advancements (e.g., vitamin D production) were made in poultry medicine, mortality rates remained high at 40% annually, persuading farmers to move the egg industry indoors (AEB, 2015). Indoor egg production allowed for control of environmental conditions: parasites and disease were mitigated without wildlife contact, feeding practices were controlled and standardized, and temperatures were less extreme. Mortality rates decreased to 18% in the late 1930s, but layer houses remained unsanitary. Other issues like excessive henpecking from close proximity and disease transmission were rampant in indoor layer flocks.

As demand for eggs increased, researchers and veterinarians sought cleaner and more efficient henhouses. In the 1940s, further enrichments reduced mortality rates and increased egg production. Fans were added for ventilation, hens were raised off the floor via wire platforms, and improved availability of food and water allowed for higher feed conversion efficiency (AEB, 2015). Battery cages were introduced in California in the late 1940s, which reduced mortality rates to 5% and increased egg production to 250 eggs per hen per year (AEB, 2015). Housing hens in battery cages separated birds from their feces, decreasing parasite transmission and improving the cleanliness of eggs (Mench et al., 2011). Caged systems also allowed for automated feed, water, and egg collection, as well as control over unpredictable variables, such as horizontal disease transmission, that might affect hen health or performance (Mench et al., 2011). A new ideology took hold of livestock production: integration (Boyd and Watts, 1997).

Egg producers followed the broiler industry in their adoption of vertical integration, which separated and synchronized the means of production for quality control and efficiency (Martinez, 2002; Stumo, 2005). Beginning in the 1950s, vertical integration allowed feed companies and processors to contract farmers, giving the contractor more control over egg production (Boyd and Watts, 1997; Martinez, 2002; Stumo, 2005). Contractors provided laying hens, feed, and other supplies, while the farmer supplied labor and facilities (Martinez, 2002). These contracts gave farmers flat fees or payments related to production efficiency rather than market value, and reduced the price a farmer could secure for eggs (Martinez, 2002). In addition, eggs produced under contracts belonged to the contractor, and farmers were paid performance incentives to increase efficiency (Martinez, 2002). As production increased, the egg industry also used the media to promote consumption, introducing "designer eggs" or those enriched with extra vitamins and Omega-3 fatty acids (McIntosh, 2000). Egg powerhouses emerged and today are the top ten egg production states include Iowa, Ohio, Indiana, Pennsylvania, Texas, Georgia, North Carolina, Arkansas, Michigan, and California (AEB, 2015).

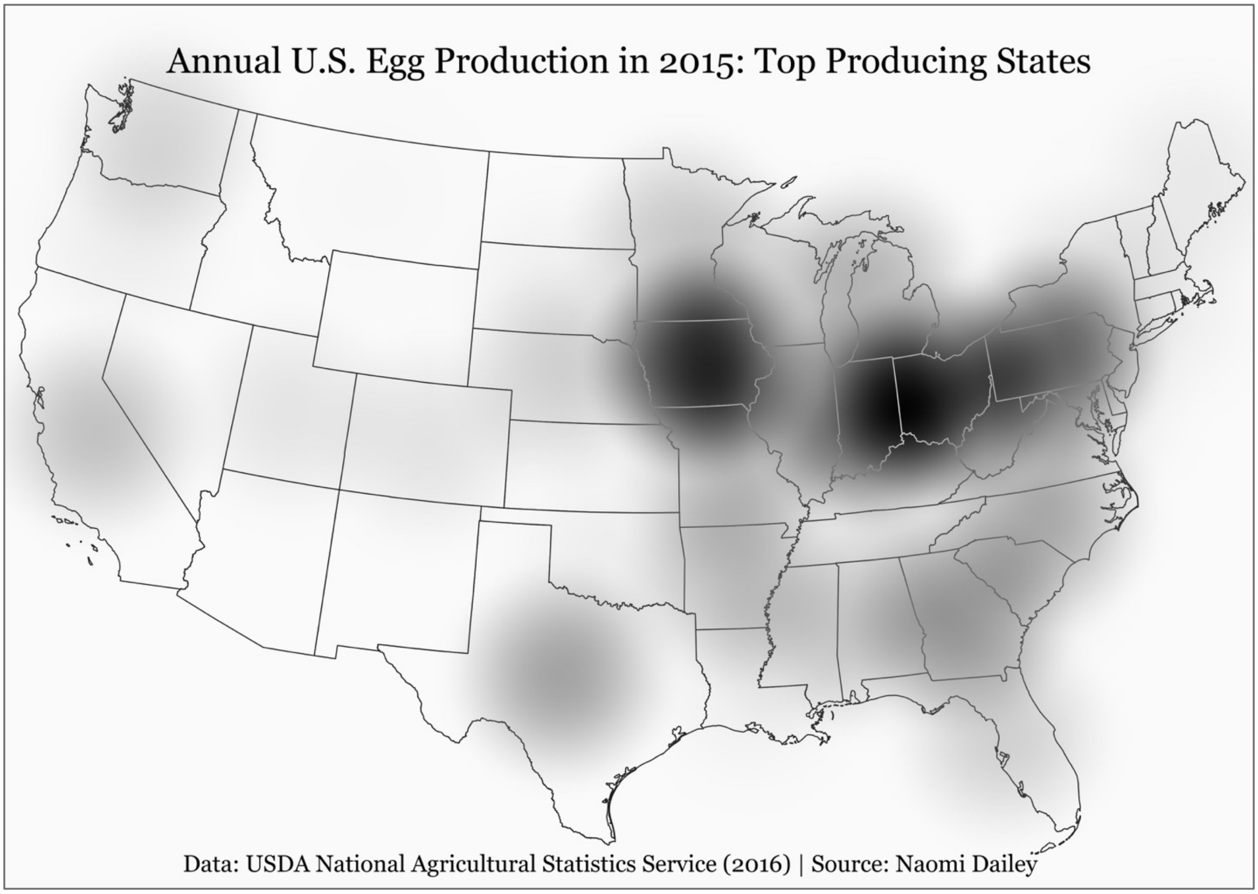

Figure 1. Density map of U.S. egg production from 2015. Darker areas produce more table eggs (in millions). Top ten egg producing states include: Iowa, Ohio, Indiana, Pennsylvania, Texas, Georgia, North Carolina, Arkansas, Michigan, and California (USDA NASS, 2016; AEB, 2015).

Late 20th Century: Organic Myths and Paradigm Shifts

Egg consumption in the US stagnated between 1940 to 1960. A scientific study claimed that eggs contained high levels of cholesterol and should be consumed with caution (Stadelman, 1999). Combined with a *Salmonella* scare in table eggs, annual egg consumption dropped from 400 eggs in the late 1940s to 235 eggs per capita in the mid 1990s (Stadelman, 1999). During this period, health experts sent mixed messages about egg consumption, ranging from “Eggs are as important in the diet as milk” to “Cut back on cholesterol: eat fewer eggs” (McIntosh, 2000). In the 1960s, Ruth Harrison’s *Animal Machines* (Harrison, 1964) shone a spotlight on U.S. livestock production, exposing intensive caged poultry and veal farming along with their associated animal welfare concerns. The Brambell Report (Brambell, 1965) further highlighted the importance of quality of life in poultry houses, and influenced European public opinion of the egg industry (McIntosh, 2000; Mench et al., 2011). As animal welfare became a public concern, the E.U. made one of the first developments in alternative poultry housing (Mench et al., 2011). The European Convention for the Protection of Animals Kept for Farming Purposes (1978) called for producers to "protect farm animals against any unnecessary suffering or injury caused by their housing, the feed they are given or the care they receive." This resulted in changes to poultry legislation in the E.U., particularly in housing systems for layers (Mench et al., 2011). Concern over animal welfare also increased in the U.S., but regulatory change was slower than in the E.U. (Mench et al., 2011). Instead, food scares and ethical concerns initiated a reevaluation of the U.S. agro-food complex, and pushed some consumers toward alternative forms of agriculture in the 1970s and 1980s.

The organic food movement provided the foundation for alternative poultry rearing systems. In 1972, many small organic organizations combined to form the International Federation of Organic Agriculture Movements (IFOAM). In 1973, a group of 54 farmers in California formed the California Certified Organic Farmers (CCOF) organization with the purpose of defining organic standards and certifying growers (CCOF, 2012). While alternative poultry husbandry was not necessarily an offshoot of the organic movement, it was an integral part of the interest among some consumers to shift from buying products from "industrial" farms at the supermarket to buying products from small family farms at local markets. Wendell Berry's (1977) ephemeral and idyllic landscapes in *The Unsettling of America: Culture and Agriculture* embodied this philosophy. Berry sought to combine integrated cropping systems with livestock, harkening back to the family farms of the early 1900s. Despite alternative agriculture's support, pastured poultry husbandry today remains on a precarious boundary between organic food movements and the conventional egg industry. While small-scale poultry farms comprise a small portion of national egg production, they remain important as both animal welfare "sanctuaries" or detrimental disease vectors to commercial poultry operations. On the one hand, alternative agriculture movements have idolized small family farms and opposed corporate production that was detrimental to the environment, without turning a critical eye to alternative poultry rearing systems. On the other hand, demand for pastured and free-range poultry has made it appealing to the commercial egg industry today, which views it as a profitable offshoot of cage-free egg production (Guthman, 2004). Pastured poultry farmers face a crossroads: commit to the family farm ideal and focus on local markets, or scale up production for increased profit.

Many early pastured poultry farmers in the 1990s maintained small production practices for years, selling primarily at farmer's markets. Some consumers gravitated toward alternatively produced eggs, as many conventional egg producers have been cited as the source of food safety outbreaks and worker health concerns (Barua et al., 2013; Cox et al., 1983; Rojas et al., 2013). With the exception of some states, conventional poultry operations continue to use conventional cages to maximize stocking density, resulting in significant amounts of poultry manure, mortalities, and ammonia (Edwards and Daniel, 1992; Koerkamp and Elzing, 1996). Ammonia emissions and runoff from these farms can contribute to contamination of open water and to nitrate leaching into groundwater (Moore et al., 1998; Wiegand et al., 2011). It is often argued that pasture-raised poultry systems do not have such problems, and maintain a better quality of life for egg laying hens (Hilimire, 2011; Soussidou et al., 2011). However, many of these claims are unfounded due to the lack of research on pasture-raised poultry, leaving a knowledge gap regarding poultry health issues, environmental hazards, and food safety.

Proponents of alternative husbandry argue that pastured poultry is a viable, resilient, and sustainable alternative to conventional operations (O'Bryan et al., 2014; Trimble et al., 2012). Yet, these claims fail to address concerns over nitrogen runoff, ammonia in mobile chicken coops, disease transmission, and food safety. Current research is limited to descriptive studies: egg-laying hens are rotated every couple of days throughout a pasture using mobile coops, often in conjunction with portable electric fencing and other livestock (Elson, 2011; Sossidou et al., 2011). Farmers claim that moving the hens to new grass improves fertilization of the pasture and reduces problems associated with poultry waste disposal (Hilimire, 2012). Others argue that rotation systems provide hens with additional protein (e.g., insect larvae and beetles) that is otherwise supplemented through expensive modified grain feeds (Henry, 2002; Mattocks, 2002; Ponte et al., 2008). Eggs from pastured hens can have twice as much vitamin E and omega-3 fatty acids as eggs from caged hens, granting farmers access to niche health markets (Elson, 2011; Karsten et al., 2010). Whether the access to these markets implies economic benefit remains vague: eggs from pastured hens can sell for up to $9.99 (USD) a dozen, but the increased cost of land and feed can reduce profit margins compared to conventional eggs (CUESA, 2011; Thornton and Herrero, 2001). Pastured poultry production also requires more land and labor, which can increase barriers to entry and challenges the arguments in favor of changing the conventional egg industry.

2.2 CONSUMER INFLUENCE OVER EGG PRODUCTION

Alternative Poultry and Agrarian Political Ecology

The history of egg layer farming in the U.S. closely parallels the shifts in consumer preference. As the public became less wary of eggs in the 1990s and early 2000s, organic and alternative farms began to include egg layers in their operations for economic benefit. Joel Salatin, the Virginian farmer of Polyface Farms known for his appearance in *The Omnivore's Dilemma* (Pollan, 2007) and *Food Inc.* (Kenner, 2008), helped initiate this change. Salatin is known as the pioneer of pastured poultry. His integrated approach rotates laying hens in an eggmobile, typically following herds of cattle on pasture. In a study of small pastured poultry farms in California, Salatin's books (*Pastured Poultry Profit$*, 1996) and media influence were cited as one of the main motivators (39%) for farmers to incorporate pastured poultry in their systems (Hilimire, 2012). The other main driver was farmer desire to produce eggs in a more sustainable manner (39%) (Hilimire, 2012). Yet, Salatin's influence is not the only driver of pastured poultry adoption. Consumer perception of farming and food sustainability has also shaped alternative egg production.

Alternative systems championed by farmers are indicators of larger trends in changing consumer preference for eggs. Consumers often prefer organic to conventional foods, and are willing to pay a higher price for so-called "enhanced" rearing conditions, namely pasture-raised and locally produced eggs (Gracia et al., 2014). However, consumers are also inconsistent in their interpretations of "organic" or "sustainable" production systems (Yiridoe et al., 2005), assuming that eggs from pasture-raised hens are objectively better than eggs from indoor caged hens. Many consumers are driven to purchase sustainably produced eggs because of *perceived* animal welfare improvements, environmental protection, freshness and taste, and food safety (Midmore et al., 2005). Consumers have also become interested in labelling schemes that go "beyond organic" as trust in government regulation wanes (Guthman, 2004; Howard and Allen, 2006). The question remains: why has this shift in preference occurred, despite lack of knowledge on the conditions behind the label?

Political ecology (PE) provides a theoretical framework with which to understand the relationship between consumer preference and farmer production. As an offshoot of environmental geography, PE is an approach that combines political economy with ecology, and "encompasses the constantly shifting dialectic between society and land-based resources" (Blaikie and Brookfield, 1987: 17). The shift toward pasture-raised poultry is not devoid of economic and political ties, and consumer preference for alternatively produced eggs must be analyzed with a critical lens. Changing market demands indicate a deeper commitment to the organic movement outlined above, coupled with fabricated perceptions of the small family farms producing these eggs. Terms such as "natural" and "pasture" work as rhetorical devices, stimulating images of green rolling hills and healthy hens (Guthman, 2004; Howard and Allen, 2006). Consumers reconstruct an ideal nature in which pasture-raised hens are treated in an ethical and humane manner, and eggs are objectively better (Guthman, 2004). The act of reconstructing nature is a critical concept in PE (Cronon, 1992). Constructing, undoing, and reconstituting spatial and social aspects of nature can alter perceptions of a place via renaming and fabrication (Peluso and Vandergeest, 2011). Consumer perceptions of what is natural can be altered depending on the frame of the viewer and the dominant narrative (Cronon, 1992). An egg carton with images of hens practicing natural behaviors on pasture reforms a consumer's concept of the farm. Spaces transform under the assumption that all pastured poultry farms employ natural and sustainable techniques.

Dominant narratives of nature already changed consumer perception in the history of U.S. poultry production. Both media and scientific literature convinced citizens of the food safety risks in outdoor poultry in the 1940s, and again convinced the public of the high cholesterol myth in the 1960s (McIntosh, 2000). These narratives had far reaching ramifications, including moving egg production indoors and decreasing egg consumption nationwide. Wendell Berry's (1977) book *The Unsettling of America: Culture & Agriculture* provides an example of reformed nature via narrative. Berry (1977) moralizes farming as a spiritual discipline with a calling toward environmental sustainability, a message that resonated with many of his readers. In a similar vein, recent popular media turned a critical gaze to the food industry and commercial farms, particularly meat, egg and dairy producers (e.g., *The Omnivore's Dilemma* by Michael Pollan, *Food Politics* by Marion Nestle, and *Eating Animals* by Jonathan Safran Foer). Pollan (2007) harkens back to a time when chickens wandered through pastures in search of beetles, idolizing Salatin and similar farms in their loyalty to the early 20th century methods of farming. In the same way that these works demonize large-scale production of food, so too they idealize the small family farm. Each of these works has played a significant role in shifting public perceptions of the family farm, remaking it as a bucolic space untouched by the the industrial agro-food complex.

Situating pastured poultry farming in PE discourse provides a better understanding of the real ecological and epidemiological struggles faced by farmers. In California especially, there is a food culture that has shaped farmers' response to consumer preference. California has been both the center of agricultural counterculture and the root of the "yuppie explosion" that helped make pastured poultry so popular (Guthman, 2004). Guthman highlights that "there is no simple commodity production, i.e., the ideal-typical family farm, to speak of in California…Virtually all California farmers are capitalist producers, either employing wage labor directly or contracting out for labor" (2004: 305). In addition to the capitalist framework that pastured poultry production necessarily imbues, its farms are also not exempt from food scares and disease prevalence (Bailey and Cosby, 2005; Melendez et al., 2010; Siemon et al., 2007; Trimble et al., 2013; Wallner-Pendleton et al., 2014). It is important to recognize the limits of the ideal family farm, and situate pastured poultry farms in the realities of capital accumulation and food safety challenges.

2.3 PASTURED POULTRY REGULATION AND FOOD SAFETY

State and Federal Legislation and Regulations

Many Californian consumers have supported alternative agriculture for decades, but the state is also known its for large-scale industrial production of crops, meat, dairy, and eggs (CDFA, 2015). As the home of the mechanical tomato harvester and arbiter of feed lot dairies (de la Peña, 2013; Guthman, 2004), it is not surprising that the family farm rhetoric stands in such stark contrast. These two very different concepts of agriculture coexist and cross-pollinate within California, and have affected each other in terms of state and federal legislation. In the 2008 general election, the Prevention of Farm Animal Cruelty Act (Proposition 2) was passed with 63% of votes in favor and 37% against (Lulka, 2011). The keystone of the proposition prohibited the confinement of chickens in a manner that prevented them from lying down, turning around freely, standing up, and fully extending their limbs (California Attorney General, 2008). For chickens, this meant that cages were either enlarged by cutting the wires between two conventional cages and halving the number of birds, or were eliminated entirely by converting to cage-free production, despite higher risks of disease transmission (Sims, 2008). Proposition 2 is a prime example of legislative change based on California's evolving consumer preference, and indicates the shifts occurring in environmental monitoring and regulation for alternative poultry production systems.

State and federal regulation over pasture-raised poultry have slowly begun to meet the rapid growth of the industry. In 2013, the Food and Drug Administration (FDA) issued a guidance document that includes disease surveillance recommendations for pastured layer farms above 3,000 hens: Title 21 CFR 118, also known as the “Egg Safety Rule” (FDA, 2013). In addition, the California Department of Food and Agriculture (CDFA) implemented the Shell Egg Food Safety Rule (SEFS) in 2015 that also requires further *Salmonella* Enteritidis (SE) surveillance and vaccinations. For both the FDA and CDFA rules, producers with less than 3,000 hens are exempt. Since many pastured poultry farms typically have less than 3,000 hens, and pastured poultry farming is a relatively new husbandry practice for commercial egg production in the U.S., little is known about basic husbandry, management approaches, and the prevalence of paratyphoid SE and host-adapted *Salmonella spp*. on these farms. While some studies of pastured broilers have been conducted in other parts of the U.S. (Melendez et al., 2010; Siemon et al., 2007; Trimble et al., 2013), to date this is the first such study of pastured layers in California.

Food Safety Studies on Pastured Poultry

Research on disease prevalence and food safety in pasture-raised poultry systems remains limited in scope. Changing poultry rearing systems and production practices can influence the safety and quality of eggs produced, particularly when hens have access to the outdoors (Holt et al., 2011). Keeping poultry flocks indoors reduces their exposure to predators and pathogens, as well as mitigating climate extremes and monitoring feed and water intake (Holt et al., 2011; Sims, 2008). When raised with access to the outdoors, particularly with breeds that are not well-suited to outdoor lifestyles, additional stress that exacerbate the prevalence of *Salmonella*, especially from thermal extremes, rehousing, and predation (Holt et al., 2011; Kinde et al., 1996; Wallner-Pendleton et al., 2014).

Salmonella control programs, such as the California Egg Quality Assurance Plan (CEQAP), are often costly to implement on pastured poultry farms with mobile coops (Kinde et al., 2005) and require management practices such as environmental monitoring for SE, flock vaccination, biosecurity, and rodent control that can help reduce the incidence of *Salmonella* (Kinde et al., 2005; Wallner-Pendleton et al., 2014). While producers rearing egg layers indoors often monitor their flocks for bird health and food safety purposes (Kinde et al., 2005; Schaar et al., 1997), many pastured poultry producers do not participate in industry standard quality assurance programs like CEQAP. Numerous studies focus on *Salmonella* prevalence in pasture-raised broilers (Bailey and Cosby, 2005; Melendez et al., 2010; Siemon et al., 2007; Trimble et al., 2013), but since *Salmonella* prevalence varies widely between free-range farms, it is difficult to compare free-range or pasture-raised poultry with what is known about *Salmonella* in conventional indoor-raised poultry (Bailey and Cosby, 2005; Siemon et al., 2007). Consequently, research on *Salmonella* prevalence in pasture-raised flocks remains very limited.

While research of pasture-raised poultry remains sparse, there is a need for applied regulatory frameworks for farmers to monitor food safety and hen health. Cooperative Extension documents have been written to fill this gap and are published online, such as the University of Vermont's report "Scaling up Egg Production: Management, Markets, Regulation, and Finances" (Cannella and Smith, 2015). The National Center for Appropriate Technology (NCAT) published extensive online documentation regarding sustainable and alternative poultry rearing systems, including reports on health and welfare, marketing, and pasture rotations (NCAT, 2015). Pasture-raised layer educational farms have also begun to emerge, including Shone Farms at Santa Rosa Junior College and the UC Davis Pastured Poultry Farm. These farms bring together researchers and faculty from a variety of disciplines, with the goal of acting as research and education hubs for pastured poultry egg producers. Often their programs include training on biosecurity and disease monitoring, but training is voluntary by nature and difficult for farmers to access in isolated parts of the state. In order to assist pastured poultry farmers in monitoring disease prevalence and hen health, exploratory research on management and environmental factors on these farms is needed.

3. MATERIALS AND METHODS

Recruitment

During the spring and summer of 2015, a total of 82 pastured poultry farms were identified via contacts from the January 2015 Ecological Farming Conference in Asilomar, California, and from the National Center for Appropriate Technology's (NCAT) program for pasture-raised layer farms. Pasture-raised broiler farms were excluded from the list. The farms were invited to participate in the study by phone or email; 11 farms (13%) participated in the final study (Figure 2). An online survey, on-site field surveys, and informal interviews were conducted at each farm (Appendix). In addition, *Salmonella* Enteritidis and *Salmonella* Pullorum surveillance tests were conducted via environmental drag swabs and whole blood agglutination tests.

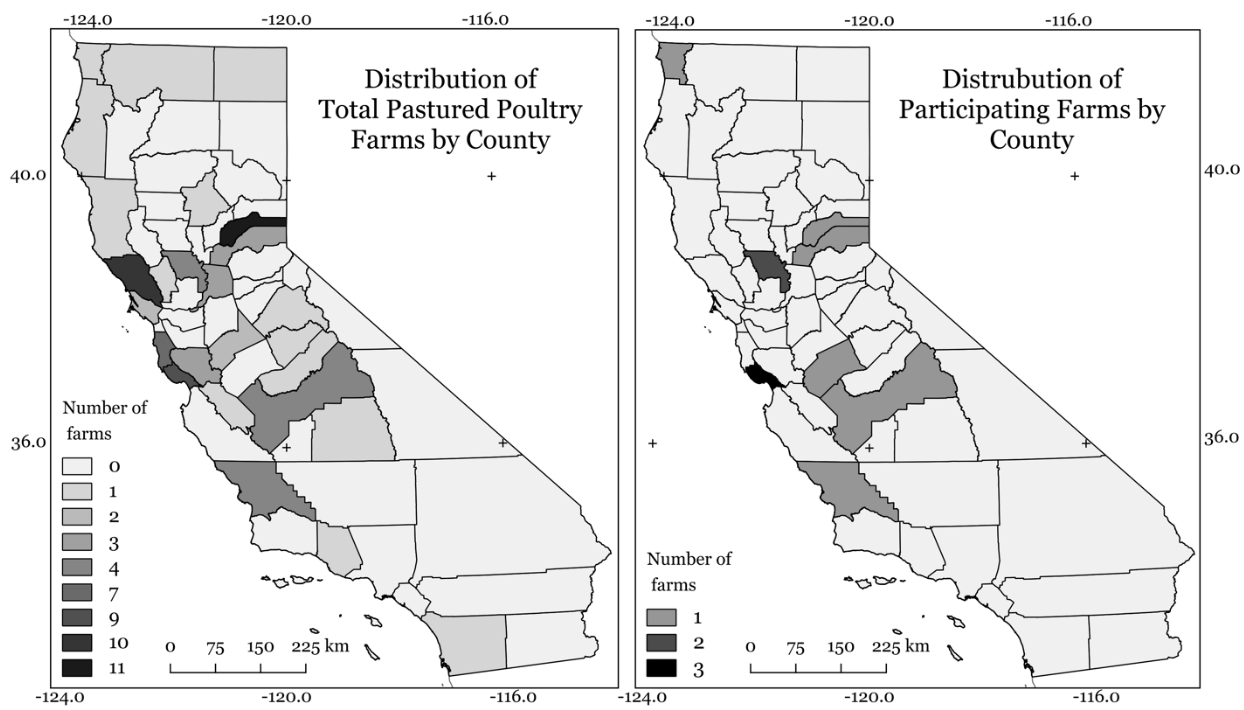

Figure 2. Geographic distribution of pastured poultry farms in California: all 82 farms that were contacted (left) and the 11 farms that participated in the online survey, field data collection, and Salmonella *surveillance (right). Source: Naomi Dailey.*

Online Survey Questionnaire

An online 69 question survey questionnaire was administered to the 11 participating farms (Appendix). The survey focused on collecting data associated with flock history, flock health and disease prevention, biosecurity practices, mortality management, predation, vaccination programs, egg processing and pricing, land cover, irrigation and fertilization, certification, and data collection (Table 2). Questions were determined based on preliminary surveys with local backyard poultry owners, and based on advice from animal behavior specialists from University of California Cooperative Extension (UCCE). The survey consisted of primarily multiple choice or rating questions, with the opportunity to expand answers further in comment boxes. It was pretested with backyard poultry owners in Davis and UCCE animal behavior and poultry welfare specialists. The online survey link was sent to participating farms, with phone or email reminders sent two to four weeks later. A paper copy of the survey was brought to one non-responding farm to complete in person.

On-site Data Collection

After online surveys were completed, on-site field surveys and informal interviews were conducted at each farm (Appendix). Field data collected included: a description of mobile coop structures, dimensions, building materials, type of equipment, ventilation, and stocking density per rotation plot. Next, descriptions of the watering system (well, spring, municipal), drinkers, feeders, nest boxes, and perches were recorded. Land cover type (e.g., cropland, pasture, bare soil) was recorded, and included both touch (i.e. crops where the edible portion touches the ground) and no-touch crops, as well as California native grasses. Specific information about flock age, flock behavior, and livestock was also identified. Average temperature and humidity measurements were recorded for the field sampling dates using the Weather Underground website (www.wunderground.com). Soil characteristics specific to each farm's location were also analyzed in relation to SP prevalence. Soil order was recorded for each farm using the University of California's interactive soil map (http://www.casoilresource.lawr.ucdavis.edu/gmap/).

Salmonella Pullorum Whole Blood Agglutination Test

Each participating farm was visited between June and August of 2015. Blood samples were collected using appropriate biosecurity protocols to prevent disease transmission. Additionally, there was a delay of three to five days between farm visits to prevent cross-contamination. The number of hens needed for a representative sample was determined using the EpiTools Services (AusVet Animal Health Services, 2015, http://www.epitools.ausvet.com.au). SP is considered very rare in conventional commercial poultry in North America (Gast, 1997), but has an unknown prevalence in non-conventional commercial production, including pastured poultry production. Therefore, the relatively conservative assumed true SP prevalence was estimated to be 0.5% (Waltman and Horne, 1993). The assumed test sensitivity and specificity, confidence level, and precision for the SP whole-blood plate agglutination test (Charles River Laboratories, Material No. 10100762, Charles River Laboratories, Wilmington, MA) was 0.99, 0.70, 0.90 and 0.2 respectively. Sample sizes ranged from four to 28 hens at each farm, depending on flock size. Of the sampled farms, ten had less than 3,000 birds and were therefore not subject to state or federally mandated SE monitoring and vaccination requirements.

At each farm, a positive control sample was established to ensure the antigen's viability for each blood sample. Approximately 0.05 mL of the positive control was placed on a glass slide and mixed with 0.05 mL of the LAH Pullorum antigen. The slide was agitated for two minutes, and if precipitate formed, the antigen was considered viable for blood sampling. A 0.1 mL blood sample was taken from the left wing of each hen using a sterile 21-gauge needle and syringe, to prevent resampling the same individual. The blood sample was mixed with 0.05 mL of LAH Pullorum antigen on a glass slide and agitated for two minutes for visual measurement of blue precipitate (positive).

Salmonella Enteritidis Test

Specimens tested for environmental SE were collected according to the protocol outlined in Title 21 CFR 118 of the FDA Egg Safety Rule (FDA, 2013). Testing areas included the mobile coop's floors, nest boxes, and the outside ground underneath the coops. The specimens were labeled and sealed in Whirl Pak© bags, and immediately placed in insulated boxes over ice until delivery to the laboratory for *Salmonella* enrichment and PCR by the California Animal Health and Food Safety Laboratory (CAHFS) lab in Turlock, CA. Each mobile coop unit was sampled and recorded as a separate entity. The environmental drag swabs were delivered to the CAHFS lab within eight hours of collection.

Statistical Analysis

Survey and sample data from all farms (n = 11) were included in the analysis. In the regression models and odds ratio (OR) calculations, only farms without *Salmonella sp.* vaccinations were included (n = 7), due to confounding results with vaccinated birds. Because not all survey questions were answered by each participant, the denominator used in the calculation was the total number of responses collected for each question. Data was entered and refined using Microsoft Excel (2015, Microsoft Corp, Redmond, WA), and was further coded and analyzed using R 3.2.2 (2013, R Foundation for Statistical Computing, Vienna, Austria). Statistical tables were produced using R 3.2.2 and LaTeXiT 2.7.5 (Chatelier et al., 2014), and maps were produced using QGIS 2.10.1 (QGIS Project, 2016). Because we had a small sample, associations between categorical variables were determined using nonparametric statistical tests in R and Minitab (Minitab 16, State College, PA). Odds ratios, *p*-values, and 95% confidence intervals were constructed for each variable. For all tests, significance was defined as $p < 0.05$. Note that the American Statistical Association recently called for a cessation of the use of *p*-values, but they have been provided here simply for convention (Wasserstein, 2016).

4. RESULTS

Field and Online Survey Data

All of the farms rotated layers on pasture, spent crops, or orchards during the day and/or night. Every farm had mixed species of livestock, touch and no-touch crops. Common livestock included geese, turkeys, cattle, sheep, and goats. Each farm used cage-free mobile chicken coops rotated among variably sized rotation plots that provided shelter for egg laying, roosting, and feed and water (Table 1). The mobile coops were predominantly built on trailer frames with metal or wooden roofs, a combination of wood and wire walls, and solid or wire (permeable) flooring. Coops were rotated using different schedules for each farm, ranging from once per week to once every three months. Time of rotation depended on the levels of denuded vegetation and/or farmer preference. Each coop was sized to hold 10 to 500 hens, depending on flock size and the type of structure used (i.e., homemade vs. factory-made fifth wheel trailer). Other common structural characteristics can be found in Table 1.

Table 1. Field survey data results (selection).

Statistic	N	Mean	St. Dev.	Min	Median	Max
Coop area (m^2)	11	32.3	63.6	3.0	14.9	223.0
Number of coops	11	3	2	1	3	6
Birds per coop (no.)	11	525	1,057	12	200	3,666
Coop stocking density (m^2/bird)	11	0.07	0.1	0.01	0.04	0.4
Pasture stocking density (m^2/bird)	11	4.2	4.4	1.1	3.3	16.2
Waterers (no.)	11	7	9	1	3	30
Feeders (no.)	11	8	8	1	6	30
Nest boxes (no.)	11	416	1,061	4	103	3,600
Nest box area (m^3)	11	0.05	0.04	0.02	0.03	0.2
Nest box height from floor (m)	11	0.3	0.2	0	0.4	0.6
Birds per nest box (no.)	11	8.0	6.4	1.9	6.1	25.0
Roosts (no.)	11	37.9	48.0	1	24	168
Roost length (m)	11	5.5	4.9	1.8	3.7	18.3
Roost space per bird (m)	11	0.6	0.5	0.2	0.5	1.7
Roost height from floor (m)	11	0.4	0.1	0.1	0.4	0.7
Average temperature (F)	11	76.5	11.0	60	81	89
Average humidity (%)	11	54.0	24.5	22	47	80

Participating farms were variably sized, ranging from 0.3 to 2,596 total acres (Table 2). An outlier is in part responsible for the wide variation: a large dairy and pastured poultry farm with over 3,000 hens. While this farm was much larger than the rest of the sample, it was included in the study to better understand husbandry and environmental variation depending on production scale. Farms allotted a range of 0.3 to 300 total acres for rearing pastured poultry, and divided this acreage into individual rotation plots of 0.1 to 18 acres, separated via temporary fencing. Rotation plots were separated from other livestock or crops via portable electric or temporary fencing. Eight of the 11 farms (74%) rotated their hens with other livestock or crops, presenting an opportunity for further food safety studies. Seven of the 11 farms (64%) also fertilized the rotation plots using cattle manure, poultry manure, horse manure, decomposed fish, or compost. The mixture of manure from different species presents a potential disease risk, particularly if poultry manure was collected from flocks of different ages or location (Mollenhorst et al., 2005).

Table 2. Online survey data results (selection).

Statistic	N	Mean	St. Dev.	Min	Median	Max
Total acres	11	370	788	0.3	35	2,596
Total acres used for poultry	11	46	88	0.3	15	300
Rotation plot (acre)	11	2.4	5.4	0.004	0.5	18
Annual irrigation water (acre-feet)	8	1.1	1	0	0.9	3
Number of hens	11	2,670	6,469	12	600	22,000
Number of pullets	11	1,084	2,978	0	30	10,000
Cost per dozen eggs (USD)	11	6.7	2.5	0	7	9
Feed used per month (tons)	10	11	26	0.02	2	84.0

The most common source of mortality across all farms was predation (91%), followed by old flock age (18%). Predators observed most frequently (reported daily or weekly) included hawks, coyotes, raccoons, owls, and rodents. Common predator prevention measures included fencing (100%), dogs (63%), covered chicken tractors (63%), and roosters (45%). Rodents and their feces have been commonly cited as vectors for *Salmonella* (Gast, 2007; Mollenhorst et al., 2005; Wallner-Pendleton et al., 2014), but only three farms reported seeing rodents on a daily or weekly basis. Only half of the farms used some form of rodent control, most commonly cats (27%) or snap traps (18%). All farms reported some flock loss, with six of the 11 farms (55%) estimating between 10-40% mortality of their flocks per year. These measures were all self-reported, taken from the online survey.

Salmonella Surveillance

All of the participating farms were sampled for both SP (i.e., individual birds) and SE (i.e., environmental drag swabs) (Table 3). A total of 80 environmental drag swabs were collected across the participating farms. The main disease prevention measures reported by farmers in the online survey were vaccinations (55%), limiting wildlife contact (36%), and culling hens that appeared sick (27%). General vaccinations for Marek's and Newcastle disease virus had been applied on five of the 11 farms (46%), and four of the 11 farms (36%) vaccinated against SE with a combination of live and killed vaccines consistent with the California Shell Egg Food Safety Rule (Table 3) (Zhang-Barber et al., 1999). There was no apparent relationship between vaccination status and the size of the flock. Of the four farms that vaccinated against SE, one had above 3,000 hens and three had below 3,000 hens. Additionally, three of the four vaccinated farms had conducted SE surveillance using environmental drag swabs prior to this study. No SE was found in these prior reports.

Table 3. Salmonella Enteritidis (SE) and Salmonella Pullorum (SP) prevalence.

Farm	Hens (total no.)	SE vaccination status	SE status	SP prevalence
A	300	No	Negative	19.2%
B	2,900	Yes	Positive*	100%
C	900	No	Negative	36.4%
D	75	Yes	Negative	100%
E	800	No	Negative	32.1%
F	1,600	Yes	Negative	20.0%
G	12	No	Negative	22.2%
H	30	No	Negative	0%
I	22,000	Yes	Negative	100%
J	150	No	Negative	29.2%
K	600	No	Negative	15.0%

* Environmental drag swab tested positive for SE.

Note: SE vaccination status indicates whether or not flocks received 2 live ST and 1 killed SE vaccine.

SP agglutination tests were positive on ten of the 11 farms with a mean overall flock prevalence of 26% (Table 3). After removing vaccinated flocks from this calculation, SP positive agglutination tests were detected on six of the seven unvaccinated farms, with a mean overall flock prevalence of 23%. The whole-blood agglutination test is highly sensitive and has a high likelihood of false positives, particularly when tested on SE vaccinated flocks (Gast, 1997). Due to the high sensitivity and low specificity of the whole-blood agglutination test, it is widely considered to only be a screening test (Gast, 1997). Confirmation that flocks are infected is done by bacteriological culturing or PCR of tissue samples (Gast, 1997). In a previous study, over 13 different serotypes (including SP) were isolated from chickens that tested positive by SP whole blood agglutination, reflecting the poor specificity of this test (Waltman and Horne, 1993). Therefore, the high prevalence of positive SP blood agglutination tests in this study reflect a relatively high load of general *Salmonella* environmental exposure to *Salmonella spp.* in the positive flocks. SE was only detected on one of the 11 farms (Table 3). Interestingly, this flock was reported to have been vaccinated against SE with a vaccination combination of two live ST and one killed SE. The test conducted on the environmental drag swab sample was processed with enrichment followed by PCR at the CAHFS-Turlock laboratory, according to the FDA's Bacteriological Analytical Manual (BAM) (Center for Food Safety and Applied Nutrition, 1998). Only one of the 11 farms reported that their flock had been "sick" in the last 12 months.

Statistical Analysis

In order to situate the *Salmonella* surveillance results within the broader context of management and environmental variation, numerous potential risk indicators for *Salmonella* were identified on each farm (Wallner-Pendleton et al., 2014). The indicators included husbandry and environmental characteristics that had either been suggested in the literature (Gast, 2007; Wallner-Pendleton et al., 2014) or had a significant effect ($p < 0.05$) on *Salmonella* prevalence on pastured poultry farms. Separate models were calculated for each indicator, which included flock size, flock density, wire floors, waterfowl presence, standing water, temperature, humidity, and soil type (Table 4). These variables were analyzed against the dependent variable: mean on-farm *Salmonella* Pullorum prevalence (25.6%). It should be noted that the sample size for the risk indicator calculations was very low ($n = 7$), because four farms with vaccinated flocks were removed from the analysis, which also included the outlier farm with 22,000 hens. Thus, these results should be considered exploratory. Despite the small sample size, the associated OR values provide interesting trends that could be explored in future studies. Indicators for SP prevalence were analyzed via logistic regression, and significant indicators are displayed in Figure 3.

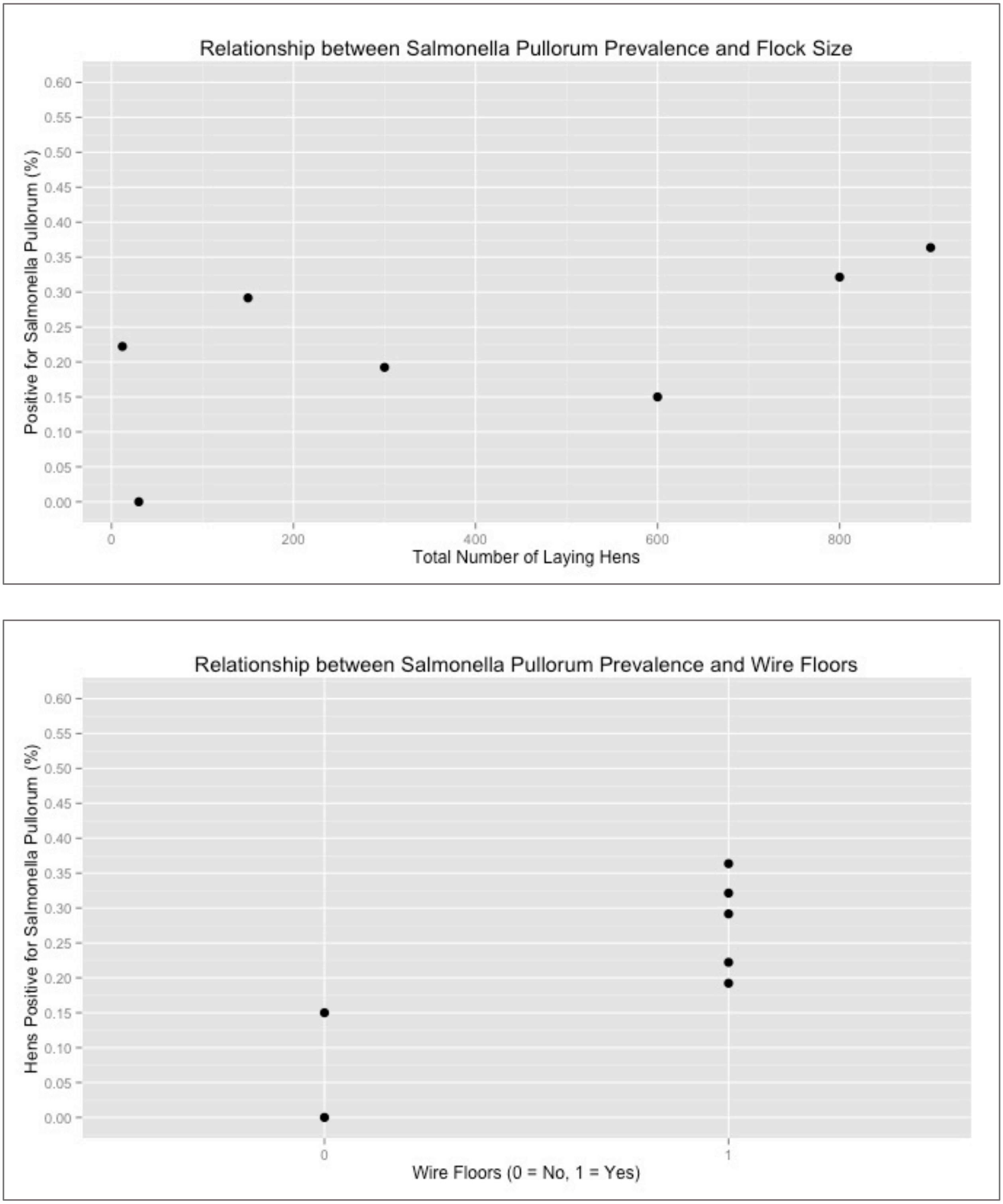

Figure 3. Relationships between Salmonella Pullorum prevalence and statistically significant independent variables: flock size (top) and wire flooring (bottom).

5. DISCUSSION

The results of this study provide insight into disease prevalence affecting hen health and food safety at pastured poultry layer farms in California. Relative importance of the husbandry and environmental indicators to *Salmonella* prevalence are discussed below.

Table 4. Statistically significant and other Salmonella Pullorum indicators identified by logistic regression. Higher odds ratio values indicate higher Salmonella Pullorum prevalence.

Indicator	Odds Ratio	P-value	CI: 2.5%	CI: 97.5%
Flock size	2.65	0.04	1.06	6.59
Flock density	1.84	0.07	0.77	3.64
Standing water	2.26	0.07	0.03	133.62
Wire floors	4.64	0.02	1.33	16.19
Temperature	1.00	0.82	0.99	1.01
Humidity	0.99	0.64	0.99	1.00
Soil type: Entisols	1.17	0.34	0.88	1.57
Soil type: Mollisols	0.98	0.88	0.80	1.21

Note: Significant indicators are boldface. P-values above 0.05 were considered statistically insignificant.

5.1 HUSBANDRY PARAMETERS

Flock Size and Density

Stocking density has been identified as a potential indicator of *Salmonella* prevalence (Wallner-Pendleton et al., 2014), though the relevance of stocking density as it relates to *Salmonella* prevalence is widely debated (Buijs et al., 2009; Estevez, 2007). Stocking density refers to the number of hens per unit area, and is a common measurement recorded in conventional layer houses (Estevez, 2007). The impacts of flock density on health and food safety in small-scale pastured systems is not well known. Nonorganic caged layer producers outside of California require 0.04 m^2 and 0.05 m^2 per hen for White Leghorns and Brown Egg

Layers, respectively (United Egg Producers, 2016). Recently the USDA proposed a rule (7 CFR Part 205) for pastured poultry that would require 0.09 m^2 per bird in mobile coops, and 0.2 m^2 per bird outdoors (USDA AMS, 2016). Space requirements are currently voluntary for U.S. pastured poultry producers, and largely depend on whether a farmer participates in a certification program. Many independent auditing groups in the U.S. have stringent certification requirements on flock density for pastured poultry operations. Animal Welfare Approved requires a minimum of 0.2 m^2 per bird indoors, and 0.4 m^2 per bird outdoors (AWA, 2015). Comparatively, Certified Humane requires 0.2 m^2 per bird indoors and 0.2 m^2 per bird outdoors (HFAC, 2014).

For the purpose of this study, two types of stocking density were calculated: *pasture* stocking density is the mean size of rotation plots per farm, and *coop* stocking density is the mean floor space in mobile coops. This modified definition reflects the fact that pasture-raised hens have continuous access to the outdoors, and spend time both inside and outside of the mobile coop. The mean pasture stocking density was 4.1 m^2 per hen, with a median pasture stocking density of 2.1 m^2 per hen, across all farms. The mean indoor coop stocking density was 0.1 m^2 per hen, and the median coop stocking density was 0.05 m^2 per hen. While both coop and pasture stocking density were found to be statistically insignificant, flock size was a significant indicator (p = 0.036) with an OR value of 2.65. This indicates that as flock size increased, the likelihood of positive SP agglutination tests also increased. As the coop density increased there was a trend toward increased positive SP prevalence. This could be related to the fact that SP is primarily transmitted vertically (from parent to embryo) as opposed to horizontally (from one individual to another) (Dufour-Zavala, 2008). Considering the debate surrounding stocking density and its effects on animal welfare (Buijs et al., 2009; Estevez, 2007; Hermansen et al., 2004), these results shed light on how alternative housing and farm management may affect poultry health. However, this must be taken as exploratory since the sample size was limited.

Wire Floors

While stocking density has been studied as a risk factor for *Salmonella* in large and medium-scale commercial layer operations, particular characteristics unique to mobile coops in operation on pastured poultry farms were also significant predictors of SP prevalence. Mobile coops were built with heavy gauge wire or wood slats for flooring at seven of the 11 farms (64%). The open access design decision allowed feces to fall through the floor onto the pasture, fertilizing the soil and reducing the need for constant cleaning or bedding replacement. Yet, this structural design also led to a higher concentration of feces directly under the wire flooring—a concern since hens spent much of their time pecking and scratching under the coops. Many mobile coops were also constructed on lifted trailer frames, with a vertical height ranging from 0.2 m to 0.8 m between the ground and base of the trailer—ample room for hens to forage and hide from predators underneath. Free access underneath the open-bottomed trailer exposes hens to feces which may contaminate grass, as well as exposing hens to potentially infected feces droppings. Often farmers purchase poultry litter to apply as fertilizer to their fields (Clark and Gage, 1996; Hermansen et al., 2004; Moore et al., 1995), and using a mobile coop to spread manure reduces this cost for pastured poultry farmers. Hens clustered underneath the coops at ten of the 11 farms (91%) during the day, particularly when there was little cover in the rotation plot (e.g., trees, wooden structures, bushes). However, this variable was not evaluated via logistic regression because all seven of the non-vaccinated farms had clustering present.

Horizontal transmission of *Salmonella* is common when hens are in close quarters (Gast and Holt, 1999) or if they are consuming feed or water contaminated with infected feces (Nakamura et al., 1994; Patterson et al. 2014). Likelihood of horizontal transmission may increase in pastured poultry systems, since hens prefer to cluster and forage underneath coops for added protection from predators (Clark and Gage, 1996). This behavior increases the risk of disease transmission via feces as hens move around directly beneath the permeable flooring. Using a simple logistic regression model, the presence of a wire floor was found to be a significant risk factor for positive SP agglutination tests (OR = 4.76, $p < 0.05$) (Table 4). This variable was the most significant in the study with respect to predicting positive SP agglutination tests. It provides a clear example of how a husbandry design decision (e.g., slotted floors in an eggmobile) and behavior response to predators (e.g., hiding under the eggmobile) lead to a food safety and animal disease challenge (e.g., horizontal SE and SP transmission). Creating additional habitat near the eggmobile for the pastured birds should be a top design consideration, and would help to mitigate this type of disease transmission.

5.2 ENVIRONMENTAL CONDITIONS

Due to the extensive amount of time pasture-raised hens spend outside, environmental conditions including exposure to wildlife, standing water, temperature, humidity, and soil type were also analyzed. While none of these variables were found to be significant, a better understanding of geographic and environmental parameters of pastured poultry farms could lend insight into hen health, food safety, and the industry’s viability as a whole.

Figure 4: Pacific Flyway (U.S. Fish & Wildlife Service)

Waterfowl

In this study, four of the 11 farms (36%) were located in the Pacific Flyway where outdoor poultry flocks have seasonal interaction with migratory birds (Figure 4). In addition, three of the 11 farms (27%) utilized waterfowl (e.g., ducks, geese) as a form of predator protection on the pasture. These regional characteristics are important to poultry health, since wild bird and waterfowl droppings have been cited as reservoirs of enteric pathogens to poultry, including *Salmonella* (Bryan and Doyle, 1995; Craven et al., 2000). Poultry raised outdoors show a higher prevalence of parasites, due in part to constant interactions with wildlife and their habitat (Lund, 2006). Waterfowl in particular present a risk to pastured poultry systems, because pathogens like *Salmonella* and *Campylobacter* can be transmitted easily between species (Hanset et al., 2002; Van Loo et al., 2012). However, little research exists on disease transmission between waterfowl and poultry in pastured systems, particularly with serotypes of *Salmonella*. It was expected that some significance would be found between SP prevalence and interaction with waterfowl, especially on those farms that used waterfowl as predator protection. Despite the reported relationships between wild birds and poultry disease, waterfowl had an insignificant effect on SP prevalence.

Standing Water

Standing water has also been cited as a potential risk factor for *Salmonella* incubation in outdoor flocks (Bailey et al., 2001; Bryan and Doyle, 1995). Standing water is infrequently studied by indoor poultry researchers, as it is environmentally and geographically specific to free-range and pastured poultry. Many of the participating farms used flood irrigation to water their pasture, particularly those in the Sacramento Valley and San Joaquin Valley, where July daytime temperatures range from 90°F to 110°F. Certification programs like CH also require green vegetation for pastured poultry year round, which influences farmers' decisions to irrigate. The extended drought in California forced many farms to reduce overall crop watering and flood irrigation, and at the time of this study, drought conditions were still considered extreme.

Despite this, farmers continued using flood irrigation for crops that did not receive water during the scant rainy season. Hens still had access to pools of standing water on three of the 11 farms (27%), all of which were flood irrigated. Bacterial pathogens persist in water, and can multiply rapidly if the water is exposed to infected feces or feed residues (Bryan and Doyle, 1995). The Central Valley's climate characteristics, coupled with increased flood irrigation from the drought, would create an optimal reservoir for bacterial growth (Doyle and Erickson, 2006). Despite these geographical relationships, it was found that standing water was an insignificant indicator of SP prevalence with a simple logistic regression model ($p < 0.05$). The OR value for standing water as an indicator of SP prevalence was 2.26 ($p < 0.05$). Standing water was also present at the single farm that tested positive for environmental SE; the positive sample was swabbed from one of these pools outside of the coop. This indicates that standing water is still of interest on pastured poultry farms, particularly in conjunction with climactic variation across a region like California's Central Valley.

Temperature and Humidity

Climate data specific to the geographic location of each farm was analyzed in relation to SP prevalence. Climate and environmental data are important in understanding the obstacles faced by pasture-raised poultry farms, since the birds spend much of their lives outdoors exposed to varied weather and vegetation conditions. While temperature and humidity were not influential to *Salmonella* detection, they do provide interesting geographic measurements to be analyzed on future farms in variegated climates. Water activity (i.e., equilibrium relative humidity) levels above 0.85 appear to promote environmental survival and multiplication of *Salmonella* (Dufour-Zavala, 2008). Moist environments allow enteric pathogens to persist and proliferate (Bryan and Doyle, 1995), and high humidity was recorded at the farms along the California coastline (45% of participating farms). However, varied rates of humidity did not have a significant effect on SP prevalence. Interestingly, the only farm where SP was not detected was located in Fresno County, a semi-arid region with characteristically low humidity and high temperatures in summer and fall.

Soil Type

Soil type was found to be an insignificant indicator of SP prevalence on pastured poultry farms using a logistic regression model ($p < 0.05$). The most common soil types observed were mollisols and alfisols, with only one farm located on entisol soils. Entisols are soils that have little to no horizon development, and are found in sloped regions or in flood plains, such as the Sacramento-San Joaquin River Delta (found in Yolo County) (USDA NRCS, 1999). Mollisols are common to soft grasslands along the coastline (found in Santa Cruz County), and alfisols form in semiarid to humid areas under hardwood forest cover (found in Placer, Fresno, and Nevada counties) (USDA NRCS, 1999). Further research on soil characteristics and environmental parameters could lend insight to geographic differences among pastured poultry farms and *Salmonella* prevalence.

5.3 ENVIRONMENTAL VARIATION AND FARM MANAGEMENT

The risk factors identified above hold varied importance depending on place. Regional characteristics that were expected to have an effect on SP prevalence (e.g., standing water or humidity) proved to be insignificant, shedding light on the importance of place in food safety and poultry health studies. In the early 20th century, the outdoor environment posed a problem for egg production, and disease and predation hazards drove poultry indoors. Yet, the results of this study diverge from those assumptions, indicating that disease and food safety issues in outdoor poultry systems are more complex than predation and climate alone. Each farm is physically and socially embedded in a region with characteristics that distinguish it from other farms (Sonnino, 2007). The concept of "locality" is helpful in understanding a region's physical attributes, as well as the narrated and recreated space enacted by both farmers and consumers (Peluso and

Vandergeest, 2011; Raffles, 1999). Environmental indicators identified in this study were characterized by physical, social, and historical contexts. For example, waterfowl are often cited as disease vectors to outdoor poultry (Bryan and Doyle, 1995; Craven et al., 2000), a physical characteristic that directly affects poultry's interaction with wild birds. Some farms also used waterfowl to their advantage as predator protection for their flocks, despite the disease transmission risk. Farmers believed that incorporating geese, despite the increased pathogen load, was more important in the context of preventing flock loss from predation.

Standing water was another environmental indicator affected by geographic location and farmer decision-making. Many of the participating farms were physically situated on the Pacific Flyway near wetland habitat, such as those in Yolo and Fresno counties. Wetlands are a biophysical and natural component of these farms, integrated into the farming landscape as a result of location. These wetland-adjacent farms were also located in the Central Valley, where property must be irrigated in summer to maintain green vegetation. Irrigation created a wetland habitat that inadvertently encouraged visitation by migratory bird species. The combination of standing pools of irrigation water with high summer temperatures in the arid Central Valley is a complex dynamic. Farmers manage a tradeoff between cultivating crops and pasture with irrigation water versus maintaining flock health—a problem unique to localities in the Central Valley because of hot, dry summers. These connections illustrate the tension between natural and manipulated environments in agriculture. A relationship exists between biophysical space and husbandry decisions that directly affect disease risk and food safety in pasture-raised poultry.

While environmental indicators did not appear to affect SP prevalence, the significant risk indicators found in this study included flock size and wire floors. These two factors are not necessarily dependent on environment, as each is a husbandry decision made by farmers to improve egg production in their region. Flock size is often dependent upon the amount of land available to a farmer (Wells, 2011). Larger flock sizes increased the risk of *Salmonella* prevalence, acting as both an environmental and manmade limitation that affected flock health (Mollenhorst et al., 2005). Similarly, wire flooring was another management decision designed to enhance soil fertilization and improve ventilation in mobile coops. Poultry litter is considered to be one of the best organic fertilizers available (Moore et al., 1995), but litter alone may not provide the most balanced source of essential nutrients (nitrogen, phosphorous, and potassium) for crop and pasture growth. In addition to being a horizontal disease vector, poultry litter's high nitrogen levels can leach into groundwater or wash into watersheds if too much is applied (Wells, 2011). Farmers must reconcile these effects with their mobile coop design, and consider alternative construction options, such as feces capture via solid coop floors to reduce nitrogen pollution and disease transmission.

Interestingly, insignificant risk indicators in this study related directly to regional environmental variation (i.e., waterfowl, standing water, temperature and humidity, and soil type). Regional risk indicators were largely outside of farmers' control—one can make management decisions to mitigate these risks, but they are largely dependent upon a farm's geographic location. The significant risk indicators were a direct result of farmer decision-making and intervention (i.e., flock size and wire flooring), and altered the immediate environment for pasture-raised layers. This suggests that pasture-raised birds are not necessarily at higher risk of *Salmonella* exposure from environmental stressors, but in fact are at greater risk from structural and management decisions. An ironic switch, considering outdoor environmental risk is what pushed egg layers indoors almost a century ago. Greater regulation over manmade housing structures, rotation schedules, and flock size may be necessary to maintain adequate poultry health and food safety for consumers. Biophysical and ecological considerations remain important in rearing outdoor poultry, but no longer offer a complete explanation for poultry disease from flock to flock. The social and political drivers of human decision-making may be as important as environment in preventing food safety scares.

6. CONCLUSION

Research on *Salmonella* prevalence on pastured poultry farms must analyze *both* environmental parameters and management design decisions, rather than one or the other (Wallner-Pendleton et al., 2014). Comparisons between pasture-raised layers and their caged counterparts may prove to be less useful, as manmade structures on pastured poultry farms are unique to rotational systems and vary between farms. This study's small number of farms, combined with the narrow environmental sampling dates of July and August, restrict the ability to generalize findings more broadly on pastured poultry farms in California. Despite the small sample size, the study's findings provide important and valuable insight of potential risk factors on pastured poultry layer farms. It should be noted that while *Salmonella* Pullorum was found on ten of the 11 farms, *Salmonella* Enteritidis (a serotype harmful to humans) was noticeably absent, with one farm as an exception. Common *Salmonella* risk indicators, such as flock density and standing water, were identified. Yet, the two significant indicators that showed higher *Salmonella* Pullorum prevalence were large flock size and wire coop flooring. These findings on mobile coop structural characteristics are especially significant, since this is the first such study to date that has analyzed the effect of alternative housing systems on poultry disease risk. Specifically, the impact of design decisions (i.e., wire floors) on *Salmonella* Pullorum prevalence on pastured poultry farms indicates that epidemiological studies should include management indicators when analyzing disease risk.

As the pastured poultry industry grows and gains the attention of egg production companies, management and environmental differences between farms will be critical to preventing an epidemiological catastrophe like the 2015 Highly Pathogenic Avian Influenza (HPAI) outbreak. Over 49 million turkeys and chickens died or were euthanized because of

HPAI, and the price of table eggs rose by 85% in a single month (AP, 2015; Boak, 2015). It was the largest jump in egg prices since the government began recording them in 1937, and the disease outbreak primarily affected *indoor* poultry flocks (Boak, 2015). To avoid these outbreaks in outdoor poultry flocks, research must move beyond environmental risk analysis to include ecological and management differences. While consumers and producers alike cite the humane and sustainable nature of pastured poultry farming, its lack of regulation and monitoring raises questions. Reducing government surveillance programs in pastured poultry production allows for farmer creativity in structural design, but also ignores potentially problematic components of production. Mobile coops that are constructed to help fertilize pasture could actually increase the risk of disease transmission, as shown in this study. Management decisions are increasingly important as companies like Vital Farms and The Happy Egg Co. succeed and grow. New industries—particularly those in food production—cannot afford to go unchecked and unmonitored by regulatory bodies for long.

While this study is not an exhaustive review of pastured poultry farms in California, it does provide important exploratory information on husbandry practices, food safety, and poultry health in these systems. During informal discussions at field visits, many participating farms reported they were unaware of the husbandry and environmental indicators typically associated with *Salmonella* and other enteric pathogens, and even fewer were familiar with *Salmonella* surveillance methods and diagnostic laboratories (e.g., CAHFS) that could help diagnose avian diseases. Further research on climate variation and bird stress levels could illuminate connections between alternative poultry production systems and virulent diseases like *Salmonella*. Because pastured poultry rotation schemes are increasingly popular on farms across California and the U.S., there is an opportunity and need to develop farmer-oriented resources to improve the food safety and health of pastured poultry flocks. The lack of requisite monitoring on pastured poultry farms is not wholly negative. With adequate information, it grants producers the flexibility to implement preventative measures that can reduce the risk of *Salmonella* and other pathogens, improving the reputation of their product and safeguarding public health.

REFERENCES

AEB. (2015). History of Egg Production. Retrieved from http://www.aeb.org/farmers-and-marketers/history-of-egg-production

AP. (2015). Egg prices in the US nearly double after outbreak of avian flu. *The Guardian*. Retrieved from http://www.theguardian.com/us-news/2015/jul/16/egg-prices-in-the-us-nearly-double-after-outbreak-of-avian-flu

AWA. (2015). Laying Hen Standards. Retrieved January 11, 2016, from http://animalwelfareapproved.org/standards/layinghens-2015/

Bailey, J. S., & Cosby, D. E. (2005). Salmonella Prevalence in Free-Range and Certified Organic Chickens. *Journal of Food Protection*, *68*(11), 2451–2453.

Bailey, J. S., Stern, N. J., Fedorka-Cray, P., Craven, S. E., Cox, N. A., Cosby, D. E., … Musgrove, M. T. (2001). Sources and Movement of Salmonella through Integrated Poultry Operations: A Multistate Epidemiological Investigation. *Journal of Food Protection*, *64*(11), 1690–1697.

Barua, H., Biswas, P. K., Olsen, K. E. P., Shil, S. K., & Christensen, J. P. (2013). Molecular Characterization of Motile Serovars of Salmonella enterica from Breeder and Commercial Broiler Poultry Farms in Bangladesh. *PLoS ONE*, *8*(3), e57811.

Berry, W. (1977). *The Unsettling of America: Culture & Agriculture* (Revised edition). San Francisco: Counterpoint.

Blaikie, P., & Brookfield, H. (1987). *Land Degradation and Society*. London and New York: Methuen.

Boak, J. (2015). Egg prices blowing up because of avian flu. Retrieved April 11, 2016, from http://www.usatoday.com/story/money/2015/07/15/producer-price-index-june-egg-prices/30187641/

Boyd, W., & Watts, M. (1997). Agro-industrial just-in-time: the chicken industry and postwar American capitalism. In D. Goodman & M. Watts (Eds.), *Globalising Food: Agrarian Questions and Global Restructuring* (1 edition). New York: Routledge.

Brambell, F. (1965). *Report of the Technical Committee to Enquire into the Welfare of Animals Kept Under Intensive Husbandry Systems* (No. Command Paper 2836). London, UK: Her Majesty's Stationary Office.

Bryan, F. L., & Doyle, M. P. (1995). Health Risks and Consequences of Salmonella and Campylobacter jejuni in Raw Poultry. *Journal of Food Protection*, *58*(3), 326–344.

Buijs, S., Keeling, L., Rettenbacher, S., Poucke, E. V., & Tuyttens, F. a. M. (2009). Stocking density effects on broiler welfare: Identifying sensitive ranges for different indicators. *Poultry Science*, *88*(8), 1536–1543.

California Attorney General. Standards for Confining Farm Animals Initiative Statute (2015). Retrieved from http://vig.cdn.sos.ca.gov/2008/general/text-proposed-laws/text-of-proposed-laws.pdf#prop2

Cannella, M. P., & Smith, S. (2015). Scaling up egg production: management, markets, regulation and finances. *University of Vermont. UVM Extension Helps Individuals and Communities Put Research-Based Knowledge to Work. Issued in Furtherance of Cooperative Extension Work, Acts of May*, *8*, 3.

Carson, R., Lear, L., & Wilson, E. O. (2002). *Silent Spring* (Anniversary edition). Boston: Houghton Mifflin Company.

CCOF. (2013). How to Get Certified. Retrieved from http://www.ccof.org/certification/how

CDFA. (2013). California Shell Egg Food Safety Regulation Guidance. CDFA. Retrieved from https://www.cdfa.ca.gov/ahfss/mpes/pdfs/shelleggfoodsafetyregulationguidance.pdf

CDFA. (2015). *California Agricultural Statistics Review, 2014-2015* (Review). Sacramento, CA: CDFA.

Center for Food Safety and Applied Nutrition. (1998). Laboratory Methods - Bacteriological Analytical Manual (BAM). Retrieved January 28, 2016, from http://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm2006949.htm

Clark, M. S., & Gage, S. H. (1996). Effects of free-range chickens and geese on insect pests and weeds in an agroecosystem. *American Journal of Alternative Agriculture*, *11*(01), 39–47.

Colles, F. M., Dingle, K. E., Cody, A. J., & Maiden, M. C. J. (2008). Comparison of Campylobacter Populations in Wild Geese with Those in Starlings and Free-Range Poultry on the Same Farm. *Applied and Environmental Microbiology*, *74*(11), 3583–3590.

Cox, N. A., Bailey, J. S., Thomson, J. E., & Juven, B. J. (1983). Salmonella and Other Enterobacteriaceae Found in Commercial Poultry Feed. *Poultry Science*, *62*(11), 2169–2175.

Craven, S. E., Stern, N. J., Line, E., Bailey, J. S., Cox, N. A., & Fedorka-Cray, P. (2000). Determination of the incidence of Salmonella spp., Campylobacter jejuni, and Clostridium perfringens in wild birds near broiler chicken houses by sampling intestinal droppings. *Avian Diseases*, *44*(3), 715–720.

Cronon, W. (1995). The trouble with wilderness, or, getting back to the wrong nature. In W. Cronon (Ed.), *Uncommon Ground: Rethinking the Human Place in Nature* (pp. 69–90). New York: W. W. Norton & Co.

CUESA. (2011). Pastured Eggs: What it Really Takes. Retrieved from http://www.cuesa.org/article/pastured-eggs-what-it-really-takes

de la Peña, C. (2013). Good to Think with. *Food, Culture & Society*, *16*(4), 603–631.

Dimitri, C., Effland, A., & Conklin, N. (2005). The 20th Century Transformation of U.S. Agriculture and Farm Policy. USDA Economic Research Service.

Doyle, M. P., & Erickson, M. C. (2006). Reducing the Carriage of Foodborne Pathogens in Livestock and Poultry. *Poultry Science*, *85*(6), 960–973.

Dufour-Zavala, L. (2008). *A laboratory manual for the isolation, identification, and characterization of avian pathogens*. Athens, GA: American Association of Avian Pathologists.

Edwards, D. R., & Daniel, T. C. (1992). Environmental impacts of on-farm poultry waste disposal — A review. *Bioresource Technology*, *41*(1), 9–33.

Elson, H. A., Gleadthorpe, A., & Vale, M. (2011). Housing and Husbandry of Laying Hens: past, present and future. *Lohmann Information*, *46*(2), 16–24.

Estevez, I. (2007). Density Allowances for Broilers: Where to Set the Limits? *Poultry Science*, *86*(6), 1265–1272.

FDA. (2013). Eggs - Draft Guidance for Industry: Questions and Answers Regarding the Final Rule, Prevention of *Salmonella* Enteritidis in Shell Eggs During Production, Storage, and Transportation (Layers with Outdoor Access). Retrieved January 11, 2016, from http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/Eggs/ucm360028.htm#Other

Friedman, H., & McMichael, P. (1989). AGRICULTURE AND THE STATE SYSTEM: The rise and decline of national agricultures, 1870 to the present. *Sociologia Ruralis*, *29*(2), 93–117.

Garber, L., Smeltzer, M., Fedorka-Cray, P., Ladely, S., & Ferris, K. (2003). Salmonella enterica Serotype enteritidis in Table Egg Layer House Environments and in Mice in U.S. Layer Houses and Associated Risk Factors. *Avian Diseases*, *47*(1), 134–142.

Gast, R. K. (1997). Detecting infections of chickens with recent Salmonella pullorum isolates using standard serological methods. *Poultry Science*, *76*(1), 17–23.

Gast, R. K. (2007). Serotype-Specific and Serotype-Independent Strategies for Preharvest Control of Food-Borne Salmonella in Poultry. *Avian Diseases*, *51*(4), 817–828.

Gast, R. K., & Holt, P. S. (1998). Persistence of Salmonella enteritidis from one day of age until maturity in experimentally infected layer chickens. *Poultry Science*, *77*(12), 1759–1762.

Good Eggs. (2015). Eggs & Dairy. Retrieved from https://www.goodeggs.com/sfbay/dairy

Gracia, A., Barreiro-Hurlé, J., & Galán, B. L. (2014). Are Local and Organic Claims Complements or Substitutes? A Consumer Preferences Study for Eggs. *Journal of Agricultural Economics*, *65*(1), 49–67.

Guthman, J. (2004). The Trouble with "Organic Lite" in California: A Rejoinder to the "Conventionalisation" Debate. *Sociologia Ruralis*, *44*(3), 301–316.

Hansen, B., Alrøe, H. F., Kristensen, E. S., & Wier, M. (2002). *Assessment of food safety in organic farming* (Working paper). Danish Research Centre for Organic Farming.

Harper, G. C., & Makatouni, A. (2002). Consumer perception of organic food production and farm animal welfare. *British Food Journal*, *104*(3/4/5), 287–299.

Harrison, R. (2013). *Animal Machines*. CABI.

Harvey, D. (2012). USDA Economic Research Service - Background. Retrieved April 4, 2016, from http://www.ers.usda.gov/topics/animal-products/poultry-eggs/background.aspx

Hastings, M. M. (1909). *The Dollar Hen*. Arcadia Press.

Henry, R. (2002). *Organic Poultry - Eggs* (Maritime Certified Organic Growers). Canada: Agriculture and Agri-Food Canada.

Henzler, D. J., Ebel, E., Sanders, J., Kradel, D., & Mason, J. (1994). Salmonella enteritidis in eggs from commercial chicken layer flocks implicated in human outbreaks. *Avian Diseases*, 37–43.

Hermansen, J. E., Strudsholm, K., & Horsted, K. (2004). Integration of organic animal production into land use with special reference to swine and poultry. *Livestock Production Science*, *90*(1), 11–26.

HFAC. (2014). "Free Range" and "Pasture Raised" officially defined by HFAC for Certified Humane® label. Retrieved January 11, 2016, from http://certifiedhumane.org/free-range-and-pasture-raised-officially-defined-by-hfac-for-certified-humane-label/

Hilimire, K. (2012). The grass is greener: Farmers' experiences with pastured poultry. *Renewable Agriculture and Food Systems*, *27*(03), 173–179.

Hilimire, K., Gliessman, S. R., & Muramoto, J. (2013). Soil fertility and crop growth under poultry/crop integration. *Renewable Agriculture and Food Systems*, *28*(02), 173–182.

Holt, P. S., Davies, R. H., Dewulf, J., Gast, R. K., Huwe, J. K., Jones, D. R., … Willian, K. R. (2011). The impact of different housing systems on egg safety and quality. *Poultry Science*, *90*(1), 251–262.

Hoover, H. (1928). A Chicken for Every Pot. *New York Times*.

Howard, P. H., & Allen, P. (2006). Beyond organic: consumer interest in new labelling schemes in the Central Coast of California. *International Journal of Consumer Studies*, *30*(5), 439–451.

Jones, P., Peter Shears, David Hillier, Daphne Comfort, & Jonathan Lowell. (2003). Return to traditional values? A case study of Slow Food. *British Food Journal*, *105*(4/5), 297–304.

Karsten, H. D., Patterson, P. h., Stout, R., & Crews, G. (2010). Vitamins A, E and fatty acid composition of the eggs of caged hens and pastured hens. *Renewable Agriculture and Food Systems*, *25*(Special Issue 01), 45–54.

Kenner, R. (2010). *Food, Inc.* Film.

Kijlstra, A., Meerburg, B. G., & Bos, A. P. (2009). Food Safety in Free-Range and Organic Livestock Systems: Risk Management and Responsibility. *Journal of Food Protection*, *72*(12), 2629–2637.

Kinde, H., Castellan, D. M., Kerr, D., Campbell, J., Breitmeyer, R., & Ardans, A. (2005). Longitudinal Monitoring of Two Commercial Layer Flocks and Their Environments for Salmonella enterica Serovar Enteritidis and Other Salmonellae. *Avian Diseases*, *49*(2), 189–194.

Kinde, H., Read, D. H., Chin, R. P., Bickford, A. A., Walker, R. L., Ardans, A., … Gardner, I. A. (1995). Salmonella enteritidis, Phage Type 4 Infection in a Commercial Layer Flock in Southern California: Bacteriologic and Epidemiologic Findings. *Avian Diseases*, *40*(3), 665–671.

Koerkamp, P. W. G. G., & Elzing, A. (1996). Degradation of nitrogenous components in an volatilization of ammonia from litter in aviary housing systems for laying hens. *Transactions of the ASAE*, *39*(1), 211–218.

Lulka, D. (2011). California's Proposition 2: Science, Ethics, and the Boundaries of Authority in Agriculture. *Culture and Agriculture*, *33*(1), 29–44.

Lund, V. (2006). Natural living—a precondition for animal welfare in organic farming. *Livestock Science*, *100*(2), 71–83.

Martinez, S. W. (2002). *Vertical Coordination of Marketing Systems: Lessons From the Poultry, Egg and Pork Industries* (Agricultural Economic Report No. AER-807). USDA.

Mattocks, J. (2002). *Pasture-Raised Poultry Nutrition* (Nutrition Publication). Little Rock, Arkansas: Heifer International.

McIntosh, W. A. (2000). The Symbolization of Eggs in American Culture: A Sociologic Analysis. *Journal of the American College of Nutrition*, *19*(sup5), 532S–539S.

Melendez, S. n., Hanning, I., Han, J., Nayak, R., Clement, A. r., Wooming, A., … Ricke, S. c. (2010). Salmonella enterica isolates from pasture-raised poultry exhibit antimicrobial resistance and class I integrons. *Journal of Applied Microbiology*, *109*(6), 1957–1966.

Mench, J. A., Sumner, D. A., & Rosen-Molina, J. T. (2011). Sustainability of egg production in the United States—The policy and market context. *Poultry Science*, *90*(1), 229–240.

Midmore, P., Naspetti, S., Sherwood, A.-M., Vairo, D., Wier, M., & Zanoli, R. (2005). Consumer attitudes to quality and safety of organic and low input foods; a review. *Report of EU-Funded Project "Improving Quality and Safety and Reduction of Cost in the European Organic and 'Low Input'Food Supply Chains." Univ. Wales, Aberystwyth, UK*. Retrieved from http://www.qlif.org/research/sub1/QLIF_Review_Reanalysis_%200509.pdf

Mollenhorst, H., Woudenbergh, C. J. van, Bokkers, E. G. M., & Boer, I. J. M. de. (2005). Risk factors for Salmonella enteritidis infections in laying hens. *Poultry Science*, *84*(8), 1308–1313.

Moore, P. A., Daniel, T. C., Gilmour, J. T., Shreve, B. R., Edwards, D. R., & Wood, B. H. (1998). Decreasing Metal Runoff from Poultry Litter with Aluminum Sulfate. *Journal of Environment Quality*, *27*(1), 92.

Moore, P. A., Daniel, T. C., Sharpley, A. N., & Wood, C. W. (1995). Poultry manure management: Environmentally sound options. *Journal of Soil and Water Conservation*, *50*(3), 321–327.

Nakamura, M., Nagamine, N., Takahashi, T., Suzuki, S., Kijima, M., Tamura, Y., & Sato, S. (1994). Horizontal transmission of Salmonella enteritidis and effect of stress on shedding in laying hens. *Avian Diseases*, *38*(2), 282–288.

NCAT. (2015). National Center for Appropriate Technology. Retrieved April 15, 2016, from https://www.ncat.org/

O'Bryan, C. a., Crandall, P. g., Davis, M. l., Kostadini, G., Gibson, K. e., Alali, W. q., … Marcy, J. a. (2014). Mobile poultry processing units: a safe and cost-effective poultry processing option for the small-scale farmer in the United States. *World's Poultry Science Journal*, *70*(04), 787–802.

Patterson, P. H., Venkitanarayanan, K., & Kariyawasam, S. (2014). Introduction: Reducing SalmonellaEnteritidis contamination of shell eggs. *The Journal of Applied Poultry Research*, japr940.

Peluso, N. L., & Vandergeest, P. (2011). Political ecologies of war and forests: Counterinsurgencies and the making of national natures. *Annals of the Association of American Geographers*, *101*(3), 587–608.

Perkins, D. (2013). A Brief History of Chicken Flocks in the US and Some Useful Tips on Raising Them. University of New Hampshire Cooperative Extension.

Pollan, M. (2007). *The Omnivore's Dilemma: A Natural History of Four Meals*. New York: Penguin.

Ponte, P. I. P., Prates, J. a. M., Crespo, J. P., Crespo, D. G., Mourão, J. L., Alves, S. P., … Fontes, C. M. G. A. (2008). Restricting the Intake of a Cereal-Based Feed in Free-Range-Pastured Poultry: Effects on Performance and Meat Quality. *Poultry Science*, *87*(10), 2032–2042.

Ponte, P. I. P., Rosado, C. M. C., Crespo, J. P., Crespo, D. G., Mourão, J. L., Chaveiro-Soares, M. A., … Fontes, C. M. G. A. (2008). Pasture Intake Improves the Performance and Meat Sensory Attributes of Free-Range Broilers. *Poultry Science*, *87*(1), 71–79.

Raffles, H. (1998). *Igarapé Gauriba: nature, locality, and the logic of Amazonian anthropogenesis*. Ph.D. Dissertation, Yale University, New Haven, CT.

Rakonjac, S., Bogosavljević-Bošković, S., Pavlovski, Z., Škrbić, Z., Dosković, V., Petrović, M. d., & Petričević, V. (2014). Laying hen rearing systems: a review of chemical composition and hygienic conditions of eggs. *World's Poultry Science Journal*, *70*(01), 151–164.

Roenigk, W. P. (1991). *Broiler Industry Vertical Integration*. Unpublished, National Broiler Council.

Rojas, T. C. G., Maluta, R. P., Parizzi, L. P., Koenigkan, L. V., Yang, J., Yu, J., … Silveira, W. D. da. (2013). Genome Sequences of Avian Pathogenic Escherichia coli Strains Isolated from Brazilian Commercial Poultry. *Genome Announcements*, *1*(2), e00110–13.

Salatin, J. (1996). *Pastured Poultry Profit$*. Swoope, VA: Polyface.

Schaar, U., Kaleta, E. F., & Baumbach, B. (1997). Comparative studies on the prevalence of Salmonella enteritidis and Salmonella typhimurium in laying chickens maintained in batteries or on floor using bacteriological isolation techniques and two commercially available ELISA kits for serological monitoring. *Tierarzlichen Praxis*, *25*, 451–459.

Shady Oak Organic Eggs. (2014). Shady Oak Organic Eggs: Turlock, California. Retrieved from http://www.localharvest.org/shady-oak-organic-eggs-M41419

Siemon, C. E., Bahnson, P. B., & Gebreyes, W. A. (2007). Comparative Investigation of Prevalence and Antimicrobial Resistance of Salmonella Between Pasture and Conventionally Reared Poultry. *Avian Diseases*, *51*(1), 112–117.

Sims, L. (2008). Risks associated with poultry production systems. In *Avian Influenza and Beyond* (pp. 1–24). Bangkok, Thailand.

Sonnino, R. (2007). The power of place: embeddedness and local food systems in Italy and the UK. *Anthropology of Food*, (S2). Retrieved from http://aof.revues.org/454

Sossidou, E. n., Dal Bosco, A., Castelini, C., & Grashorn, M. a. (2015). Effects of pasture management on poultry welfare and meat quality in organic poultry production systems. *World's Poultry Science Journal*, *71*(02), 375–384.

Stadelman, W. J. (1999). The incredibly functional egg. *Poultry Science*, *78*(6), 807–811.

Stevenson, S. (2009). Raising poultry on pasture (Research Brief #57) | Center for Integrated Agricultural Systems. Retrieved from http://www.cias.wisc.edu/raising-poultry-on-pasture/

Stevenson, S., & Schuster, D. (2003). Large-scale pastured poultry farming in the U.S. (Research Brief #63) | Center for Integrated Agricultural Systems. Retrieved from http://www.cias.wisc.edu/large-scale-pastured-poultry-farming-in-the-us/

Stumo, M. C. (2005). The Problem of Monopsony in Food and Agriculture. In *New Perspectives on Food Security* (pp. 87–92). Glynwood Center, VA: Glynwood Center, Airlie Foundation, and Leopold Center.

Sumner, D. A., Gow, H., Hayes, D., Matthews, W., Norwood, B., Rosen-Molina, J. T., & Thurman, W. (2011). Economic and market issues on the sustainability of egg production in the United States: analysis of alternative production systems. *Poultry Science*, *90*(1), 241–250.

The Happy Egg Co. (2016). Eight Acres of Freedom - The Happy Egg co. Retrieved April 13, 2016, from http://thehappyeggco.com/farms/

Thornton, P. K., & Herrero, M. (2001). Integrated crop-livestock simulation models for scenario analysis and impact assessment. *Agricultural Systems*, *70*, 581–602.

Trimble, L. M., Alali, W. Q., Gibson, K. E., Ricke, S. C., Crandall, P., Jaroni, D., & Berrang, M. (2013). Salmonella and Campylobacter prevalence and concentration on pasture-raised broilers processed on-farm, in a Mobile Processing Unit, and at small USDA-inspected facilities. *Food Control*, *34*(1), 177–182.

United Egg Producers. (2016). Animal Welfare. Retrieved from http://www.unitedegg.org/AnimalWelfare/default.cfm

USDA ERS. (2015). Americans consumed 19 pounds of eggs per person in 2012. Retrieved April 13, 2016, from http://www.ers.usda.gov/data-products/chart-gallery/detail.aspx?chartId=51602

USDA NRCS. (1999). *Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys* (Soil Survey No. 2nd Edition). Washington, D.C.: USDA Natural Resources Conservation Service.

Van Bommel, K., & Spicer, A. (2011). Hail the Snail: Hegemonic Struggles in the Slow Food Movement. *Organization Studies*, *32*(12), 1717–1744.

Van Loo, E. J., Alali, W., & Ricke, S. C. (2012). Food Safety and Organic Meats. *Annual Review of Food Science and Technology*, *3*(1), 203–225.

Vital Farms. (2016). About Us. Retrieved from http://vitalfarms.com/about-vital-farms/our-farmers/

Wallner-Pendleton, E. A., Patterson, P. H., Kariyawasam, S., Trampel, D. W., & Denagamage, T. (2014). On-farm risk factors for Salmonella Enteritidis contamination. *The Journal of Applied Poultry Research*, japr943.

Waltman, W. D., & Horne, A. M. (1993). Isolation of Salmonella from Chickens Reacting in the Pullorum-Typhoid Agglutination Test. *Avian Diseases*, *37*(3), 805–810.

Wells, M. L. (2011). Response of Pecan Orchard Soil Chemical and Biological Quality Indicators to Poultry Litter Application and Clover Cover Crops. *HortScience*, *46*(2), 306–310.

Wiegand, A. N., Menzel, S., King, R., & Tindale, N. (2011). Modelling the aeolian transport of ammonia emitted from poultry farms and its deposition to a coastal waterbody. *Atmospheric Environment*, *45*(32), 5732–5741.

Xu, H., Su, H., Su, B., Han, X., Biswas, D. K., & Li, Y. (2014). Restoring the degraded grassland and improving sustainability of grassland ecosystem through chicken farming: A case study in northern China. *Agriculture, Ecosystems & Environment*, *186*, 115–123.

Yeung, R. M. W., & Morris, J. (2001). Consumer perception of food risk in chicken meat. *Nutrition & Food Science*, *31*(6), 270–279.

Yiridoe, E. K., Bonti-Ankomah, S., & Martin, R. C. (2005). Comparison of consumer perceptions and preference toward organic versus conventionally produced foods: A review and update of the literature. *Renewable Agriculture and Food Systems*, *20*(04), 193–205.

Zhang-Barber, L., Turner, A. K., & Barrow, P. A. (1999). Vaccination for control of Salmonella in poultry. *Vaccine*, *17*(20–21), 2538–2545.

APPENDIX

Pastured Poultry Salmonella Enteritidis Online Survey Example

GENERAL

1. What county is your farm in?
2. What is the name of your farm?
3. How many acres do you farm?

PASTURE ROTATION

4. How many total acres do you use for chickens?
5. Do you rotate your chickens on your pasture?
    a. If yes, how often do you rotate? (daily, weekly, monthly)
    b. What is the average size of an individual rotation plot?
6. Does your rotation system include other livestock or crops?
    a. If yes, what livestock species or crops?
        i. Livestock: cattle, pigs, sheep, goats, turkeys, quail, other
        ii. Crops: vegetables, fruits, nuts, flowers, herbs
7. Do you irrigate your pasture: (all year, a couple months of the year, when it looks dry, never)
    a. If you irrigate, about how much water do you use per acre?
    b. Is there a water reservoir on your property? (e.g., pond, surface water, creek, spring)
8. Do you fertilize your pasture?
    a. If yes, do you use: (manure, chemical-based, compost)?
9. Do you have other livestock or crops separate from your chicken pasture?
    a. If yes, what else do you farm?
    b. How many total acres do you use for other livestock?
    c. How many total acres do you use for crops?

HUSBANDRY

10. What is your total number of laying hens, pullets and broilers?
11. What breeds of hens do you use?
12. Do you separate your flocks by age?
13. Do you have a mixed multi-aged flock?
    a. How old are your oldest birds?
14. How do you cull your flock (CO2, cervically dislocate, knife, other)?
    a. What do you do with culled poultry (throw out, carcass compost, harvest meat)?
15. What type of rodent control do you use (tin cats, bait stations, snap traps, sticky traps)?
16. What other preventative measures do you use for:
    a. Illness/disease?
    b. Predation (i.e., fences, roosters, or dogs)?
17. How often do you see the following wildlife? (rodents, water fowl, feral pigs, coyotes, hawks)
18. What types of predators do you see on your farm? (Please rank according to how frequently you see a predator.)
    a. How much of your flock do you lose to predators per year?
19. Of the following what are the most common sources of mortality (predators, disease/illness, unknown, poultry (pecking))?
20. In the last 12 months, did your flock get sick?
    a. If yes, did you seek help from: veterinarian, laboratory diagnosis?
21. Have you ever submitted sick or dead birds to a veterinarian or the the CAHFS lab?
    a. If yes, what was the reason?

EGGMOBILES/STATIONARY BARNS

22. Do your birds live in a: (eggmobile, stationary coop)?
    a. If you use a mobile coop, how often do you move it?
23. Does your coop have shared (colony) or individual nest boxes?
    a. Individual: how many hens use one nest box?
    b. Shared (Colony): how many square feet per nest box?
24. Are eggs collected from inside or outside of the coop?
25. What materials do you use for nest bedding? (straw, wood shavings, etc.)
    a. How often do you change the nest bedding?
26. Does your eggmobile have slotted/screened floors (i.e., chicken wire flooring)?

FOOD SAFETY

27. How often do you harvest eggs (once a day, 2x a day, EOD etc)
28. Within 36 hours of being laid our eggs are (check all that apply):
    a. (in the next box, in the fridge post-washing, in the fridge, at the store)
29. Where do you process your eggs? (home kitchen, garage, outdoor facility)
30. How do you process your eggs?(i.e. do you wash your eggs)
    a. If you wash your eggs, what temperature do you wash your eggs at?
    b. If you wash the eggs, how do you wash them (sprayers, faucet)
    c. If you wash your eggs what type of disinfectant do you use if any (none, soap, potassium hydroxide, quaternary ammonia, sodium carbondate, other,)
    d. Do you rinse the eggs after washing?
    e. Do you include an sanitizer in your rinse? If so which one (chlorine, quaternary ammonia)
    f. Do you dry the eggs after washing and/or rinsing
31. How do you store your eggs?
32. Do you candle the eggs to look for defects?
33. Do you "oil" the egg with food grade mineral oil?
34. What is the average amount of time the eggs are not refrigerated?
35. Have you ever done any surveillance for Salmonella on your farm?
36. Do you vaccinate your birds against Salmonella?

DATA COLLECTION

37. Approximately, how much money do you charge for one dozen eggs?
    a. How did you decide on this price?
38. Where do you sell your eggs (i.e., wholesale, farmer's market, CSA, direct to consumer, restaurants)?
    a. What labels do you use to market your eggs?
        i. Conventional, Organic, Pasture-Raised, Free-Range, Other
39. Do you know the feed conversion ratio for your flock (how much feed does your flock consume)?
40. Do you collect data about your flock (i.e., dead hens, sick hens)?
    a. If so, how do you collect and manage your data?
41. Do you collect data about egg production (i.e., number of eggs, number of eggs with cracks, blood spots, number of eggs with dirt)?
    a. If so, how do you collect and manage your data?
42. Do you participate in an organic or welfare certification program?
    a. Certified Humane, American Humane, Animal Welfare Approved, CCOF, USDA Organic, etc.

Pastured Poultry Field Survey Example

Producer Name:	**Coop_1**	**Coop_2**
Flock Age		
Floor Type - solid, wire?		
External Materials		
Internal Materials		
Clustering under coop?		
Bird Breed and brown or white?		
Floor Space (Length)		
Floor Space (Width)		
Feeders - circular, trough?		
Feeders # circular		
Feeders # trough		
Drinkers - bells or nipples?		
Drinkers (total number bells, nipples)		
Food, Water Inside?		
Nest Boxes - individual or colony?		
Nest Boxes - #		
Nest Boxes - length x width x height		
Height of lowest nest box from floor		
Perching - #		
Perching - dimensions		
Perching - height of lowest perch		
Predators		
Fencing		
Ground Cover		
Vaccinated?		
# SE Positive		
Total # Hens		
NOTE: Coops Are Numbered 1-5	*Drag Swabs (for each coop):*	*BE Swabs (for each coop):*
	A = floor	*A = nest box*
	B = nest box	*B = roost/perch*
	C = under coop	*C = floor*
		D = water
		E = feed