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Trade patterns facilitating highly pathogenic avian influenza virus dissemination in the free-grazing layer duck system in Vietnam

A. Meyer[1] | T. X. Dinh[2] | T. A. Han[2] | D. V. Do[2] | T. V. Nhu[2] | L. T. Pham[3] | T. T. T. Nguyen[4] | S. Newman[4] | B. Häsler[1] | D. U. Pfeiffer[1,5] | T. Vergne[1,6]

[1]Veterinary Epidemiology, Economics and Public Health Group, Royal Veterinary College, London, UK

[2]National Institute for Animal Sciences, Hanoi, Vietnam

[3]Department of Animal Health, Ministry of Agriculture and Rural Development, Hanoi, Vietnam

[4]Emergency Centre for Transboundary Animal Diseases, Food and Agriculture Organization of the United Nations, Hanoi, Vietnam

[5]School of Veterinary Medicine, City University of Hong Kong, Hong Kong SAR, China

[6]MIVEGEC Group (UMR CNRS/IRD/UM2), Montpellier, France

Correspondence
A. Meyer, Veterinary Epidemiology, Economics and Public Health Group, Royal Veterinary College, London, UK.
Email: ameyer@rvc.ac.uk

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Summary

Highly pathogenic avian influenza (HPAI) viruses continue to threaten smallholder poultry producers in several South-east Asian countries, including Vietnam. In particular, the free-grazing duck system has been repeatedly highlighted as a major risk factor for HPAI outbreaks. Free-grazing ducks, which scavenge on rice paddies after the harvest, account for a large proportion of the duck population in Vietnam and the wider South-east Asian region. However, the structure and dynamics of the free-grazing duck production from farm to consumption has not been described for Vietnam. In this study, we used a value chain approach to provide a complete picture of the actors involved in the production and marketing of free-grazing duck eggs and spent layer ducks, as well as to investigate the governance structure of this food system. Group interviews and key informant interviews were conducted in two provinces located in the Mekong River Delta (MRD) and the Red River Delta (RRD). The results presented here highlight similarities and differences in farming and trade practices between the two provinces. The trade of spent layer ducks involved large volumes of live ducks being sent to China and Cambodia for consumption, generating a substantial risk of transboundary spread of pathogens, including HPAI viruses. We describe the major role of "duck yards", which act as hubs in the northbound trade of spent layer ducks. These yards should be considered as essential links in the value chain of spent layer ducks when considering HPAI surveillance and control. The veterinary authorities are only marginally involved in the value chain activities, and their influence could be strengthened by increasing surveillance activities for instance in duck yards. Last, we discuss the dynamics of the duck value chain and further implications for future HPAI management policies.

KEYWORDS

free-grazing ducks, highly pathogenic avian influenza, poultry trade, value chain analysis, Vietnam

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1 | INTRODUCTION

Poultry meat and pork are the main sources of animal protein in Vietnam (Le, 2003). The poultry production sector has been targeted by development policies since the late 1990s, in order to improve food security and tackle the widespread nutritional deficiencies in the country (Le, 2003). Among all poultry products, duck meat and duck eggs play an important role in Asia and their production has been increasing throughout the subcontinent (Tai & Tai, 2001). In Vietnam, although the duck production increased at a steady rate between 1990 and 2004, it has been stagnating since 2004 at around 60–80 million head per year (FAOSTAT, 2016). This has been attributed to the severe impact of the highly pathogenic avian influenza (HPAI) outbreaks from 2003 onwards, in particular in the free-grazing duck production systems (Rushton, Viscarra, Guerne Bleich, & McLeod, 2005). The duck egg production, however, has been increasing by 40% between 2010 and 2015 (General Statistics Office of Vietnam, 2016), indicating an increase in productivity. Three quarters of the duck egg production originate from two agro-ecological regions, namely the Mekong River Delta (MRD) in the south of the country and the Red River Delta (RRD) in the north (General Statistics Office of Vietnam, 2016).

Free-grazing ducks, which are herded on post-harvest rice paddies for scavenging purposes, represent around 73% of the duck population in Vietnam (Bui, 2010) and are widespread in other countries of the region, such as China and Indonesia. Free-grazing ducks can be transported over relatively long distances for grazing and can regularly be in direct or indirect contact with other flocks, themselves coming from different locations (Henning et al., 2013; Meyer et al., 2017). As infected ducks are able to shed HPAI virus without showing clinical signs (Hulse-Post et al., 2005), free-grazing ducks are suspected to play an important role in the maintenance and circulation of HPAI viruses (Gilbert et al., 2006; Songserm et al., 2006; Sturm-Ramirez et al., 2005). This is especially relevant given the fact that various strains of H5N1 and H5N6 viruses continue to circulate in poultry throughout Vietnam, with more than 400 outbreaks having been reported during the last 10 years (EMPRES-i, 2017).

While a few studies described the production of free-grazing ducks in Vietnam (Henning et al., 2013; Minh, Stevenson, Schauer, Morris, & Quy, 2010), none of them considered the other stakeholders involved in the value chain for duck products. Value chain analysis is a key tool to understand the dynamics and drivers of livestock production systems, especially in developing countries where the enforcement of rules and regulations is limited and supply chains are often long and complex (Rich & Perry, 2011). It provides a structured approach to identify disease risks within a food system and to assist the design of health management policies (FAO 2011). Value chain studies have proven essential to assess poultry production systems in the light of HPAI control, for example, in Cambodia, Indonesia and Thailand (McLeod, Kobayashi, Gilman, Siagian, & Young, 2009; Paul et al., 2013; Van Kerkhove et al., 2009). The study in Cambodia revealed substantial illegal cross-border poultry trade within the Greater Mekong Region (Van Kerkhove et al., 2009). The Indonesian study highlighted bird collectors and slaughter points as potential hot spots for HPAI transmission, while HPAI awareness was generally low among the actors of the poultry value chain (McLeod et al., 2009). Paul et al. (2013) showed that producers and collectors in Thailand used different coping strategies in case of HPAI outbreaks: some respected the legislation and reported outbreaks in order to receive compensation while other sold their stocks to avoid financial losses due to massive die-off of their flocks. These studies provided detailed descriptions of the trade patterns, disease hot spots, actor behaviours, informal rules, illegal movements and other factors essential to the understanding of the epidemiological aspects of HPAI spread and maintenance. Similar information on the free-grazing duck value chain in Vietnam will be useful to assist the design of successful HPAI management policies.

This study aimed at identifying the features of the free-grazing layer duck value chain that are of relevance for HPAI surveillance and control in the MRD and RRD. The specific objectives of this study were to characterize the value chains of free-grazing duck eggs and spent layer ducks in the MRD and RRD and to understand the dynamics and governance mechanisms of these value chains.

2 | MATERIALS AND METHODS

2.1 | Conceptual approach

The working definition of value chain for this study was "the full range of activities, which are required to bring a product or service from conception, through the different phases of production to delivery to final consumers, and final disposal after use" (Kaplinsky & Morris, 2010). We used an institutional and functional analysis (Bockel & Tallec, 2005), which consists in studying the value chain of interest by defining the agents involved and their respective functions (institutional analysis) as well as the various interactions and flows between them (functional analysis). These elements were represented using a commodity flow chart for each of the two commodities studied: duck eggs and spent layer ducks. We explored the vertical and horizontal links (Faße, Grote, & Winter, 2009) between different types of agents along the chain and between agents with similar roles, respectively, in order to identify features relevant for HPAI surveillance and control. Last, we explored issues related to the governance of the value chain, identifying key stakeholders and regulation mechanisms that could be of importance for the development of effective and acceptable HPAI management policies (FAO 2011).

2.2 | Data collection and analysis

The study focussed on the layer duck value chain, including table eggs, hatching eggs and spent layer ducks. Duck farms were divided into two groups, raising short-distance free-grazing ducks and long-distance free-grazing ducks, respectively, according to definitions

previously used (Henning et al., 2013): short-distance free-grazing ducks graze within the home commune and are kept in confinement on the farm at night, while long-distance free-grazing ducks graze on rice paddies within or outside the home commune and do not return to the farm for extended periods of time. In Vietnam, a commune is a small administrative unit encompassing a central village and a varying number of hamlets. The value chains were investigated in the RRD and the MRD, which constitute the two main duck production regions in Vietnam. One province was selected in each region (Hai Phong in the RRD and An Giang in the MRD), based on a higher proportion of free-grazing ducks in the total duck production of the province than other nearby provinces. In order to capture local heterogeneities, six communes within each study province were selected for the study, based on the willingness of the local veterinary services to participate and the presence of long-distance free-grazing ducks at the time of the field activities. Additional stakeholders who were not residing in the study provinces, but who were involved in the value chains under study, were also recruited.

Group interviews were conducted in each study commune, gathering stakeholders involved in the free-grazing layer duck production, from producers to market managers and inspectors. The participants were selected by convenience sampling to include stakeholders from the entire value chain, according to recommendations from the communal animal health technicians. Contact was also established with the commune authorities in order to identify further relevant people. During the group interviews, the participants were asked to sketch a chart of the duck value chain, identify the agents and functions involved as well as to quantify the flows of eggs and spent layer ducks for the year 2015. Discussions were encouraged to allow the participants to reach a consensus for each figure. The participants were also asked questions about the governance of the value chains and the formal and informal regulation mechanisms in place. During the analysis phase, a summary flow chart for each commodity and province was constructed by averaging the individual charts produced by each of the commune groups. Group interviews were conducted in Vietnamese by two research assistants. Notes were taken in Vietnamese, but the discussions were not audio-recorded. The notes collected during the discussions were analysed to describe qualitative aspects of the value chains, such as the type of relationships between the agents and the dynamics affecting their interactions. The results of this analysis were then translated into English by a bilingual research assistant, and the accuracy of the translation was verified by one of the authors (DXT). The group interviews were conducted from October to December 2015.

Key informant interviews were also organized in order to characterize the precise role of each agent and triangulate information gathered during the group interviews. Participants of the group discussions were approached to request an individual interview. Those who accepted were interviewed at their usual workplace. Additional key agents of the value chain who were not present at the group meetings were identified by the meeting or interview participants and by veterinary officials. One questionnaire per type of agent was designed and refined after pilot interviews. Questions were used to define the main characteristics and functions of each agent (years of experience in the role, sources of inputs, destinations of outputs, etc.), as well as to identify and quantify the product flows in and out of each enterprise for the past year (questionnaire templates are available from the corresponding author on request). The individual interviews were conducted in Vietnamese by two Vietnamese research assistants. The study was initially limited to the value chain of free-grazing ducks, but it was found that only duck producers are specialized in free-grazing ducks, while other actors (e.g., collectors, wholesalers) work with both free-grazing and confined ducks. Consequently, the sample was expanded to include value chain actors that covered both types of systems. The majority of the interviews was conducted from October to December 2015, with the exception of the interviews with the duck yard owners and the inter-province wholesalers for spent layer ducks, which took place from October to December 2016. Stakeholders interviewed during the first and second rounds were asked to report figures related to product flows in 2015 and 2015–2016, respectively.

Thematic analysis (Braun & Clarke, 2006) was used in order to analyse the governance structure and dynamics of the value chains. The group interview notes and individual interview notes were reviewed carefully and the data of potential relevance to HPAI epidemiology and management were structured into codes, which were translated into English. The codes identified were sorted into themes that were used to structure the narrative of this analysis.

Data collected via paper format questionnaires during the individual interviews were entered into an Excel database, checked, cleaned and translated into English. The quality of the translation was verified by one of the authors (DXT). Quantitative data were analysed in R (R Core Team 2014), while qualitative data were summarized and analysed manually. The Kruskal–Wallis test (and Dunn's test for post hoc comparisons), chi-squared test of independence and Fisher's test were used to assess the statistical significance between stakeholders from different locations (Hai Phong and An Giang), different systems (short- and long-distance) or different functions (e.g., collectors, retailers and wholesalers).

3 | RESULTS

A total of 12 group interviews were conducted in each study province in 2015, with a total of 188 stakeholders from different levels of the value chain (Table 1). The demographics of the 145 stakeholders who were interviewed individually are described in the following sections. As the interviewed stakeholders and the methods employed in the two types of exercises were different, some of the results obtained from each exercise slightly differed with each other. The origin of the data (group or individual interviews) is clearly indicated in the table and figure headings.

TABLE 1 Number of stakeholders per function (N = 188) recruited for the group interviews

Study site	Hai Phong (N = 94)	An Giang (N = 94)
Layer duck farmers	30	30
Intermediaries for duck eggs	16	16
Intermediaries for ducklings and hatcheries	16	16
Slaughterhouse owners and retailers	12	12
Live bird market management board members	10	10
Veterinary officers and market inspectors	10	10

Intermediaries: collectors, retailers, local wholesalers, inter-province wholesalers and duck yard owners.

3.1 | Agents and their respective functions

3.1.1 | Layer duck farmers

General characteristics of layer duck farmers (N = 95) recruited in the study and interviewed individually are shown in Table 2. A majority of farmers in Hai Phong used an exotic breed (65%) while all farmers in An Giang raised cross-bred ducks, which have been developed by private breeders in the MRD to improve the production performance while being able to thrive on outdoor scavenging systems. The annual egg yield was not significantly different between the provinces, with a median of 220 eggs per hen per year. Fifty-one of the 62 farmers interviewed in An Giang (82%) practised long-distance free grazing, while the other practised short-distance free grazing. The long-distance farmers practised full-time scavenging with their duck flocks (except for young flocks less than 2 months old). They provided the flocks with feed supplements when there was insufficient feed available on the paddies. On average, the short-distance farmers used the rice fields during 9.6 months per year (Table 2). In Hai Phong, 11 farmers (33%) practised short-distance free grazing all year round, using either waterways or post-harvest rice fields when available. The remainder practised short-distance free grazing only when post-harvest rice fields were available in their commune (between 2 and 5 months per year), and kept their flocks confined the rest of the time (detailed data not shown). Farmers in An Giang had statistically significantly larger flocks than in Hai Phong and tended to sell them earlier than farmers in Hai Phong did. Among An Giang participants, short-distance farmers had smaller flocks and sold them earlier than long-distance farmers did.

3.1.2 | Collectors, retailers and wholesalers

A number of agents were involved in the trade of ducks eggs and spent layer ducks in both provinces: collectors, retailers, local wholesalers, inter-province wholesalers and duck yard owners. These agents are hereafter collectively referred to as "intermediaries."

TABLE 2 Characteristics of layer duck farmers (N = 95) and their duck flock, by study site and production type, according to individual interviews conducted in 2015

Study site		Hai Phong (N = 33)		An Giang (N = 62)
Characteristics of the farmers				
Median experience in duck production (years)		13		16
Proportion of men		62%[a]		85%[b]
Education level (%)	None	0%		3%
	Primary school	15%		39%
	Middle school	53%		47%
	High school	32%		11%
Characteristics of the flocks				
Type of breed (%)	Exotic	65%		0%
	Cross-bred	35%		100%
Grazing system (%)	SD	100%[c]		18%[d]
	LD	0%		82%
Average time of free grazing per year (months)	SD	6.2[e]		9.6[f]
	LD	NA		12
			SD	LD
Median flock size (number of head)		525 [g]	1,000 [g]	3,000 [h]
Median laying duration (months)		24[i]	7[j]	16[k]

Figures on the same line not sharing any superscript letter were statistically significantly different ($p < .05$). LD, long-distance free grazing; SD, short-distance free grazing; NA, not applicable.

Collectors purchase live ducks mainly at farm gate and sell them to other agents in the value chain, but not directly to the consumers. The retailers purchase ducks from farmers or other intermediaries and sell them to the end consumers, either as live ducks or as fresh carcasses. All retailers in the survey used motorbikes to transport ducks. They traded smaller volumes than the other agents did, with an average of 1,300 heads per month, respectively (Table 3). Retailers were mainly women in both provinces. Both genders were represented among collectors and wholesalers in Hai Phong, but mainly men had these functions in An Giang. Retailers operated within a smaller geographic area than collectors did; the average distance travelled from their residence to buy ducks was 9 and 43 km, respectively, while the average distance travelled from their residence to sell ducks was 2 and 70 km, respectively (data not shown). Wholesalers generally bought larger quantities of live ducks at once, directly from farms or from local collectors, and sold them to other agents further along the value chain, but not directly to the consumers. Wholesalers in Hai Phong used motorbikes only, while boats, trucks and motorbikes were used in An Giang. Due to the

TABLE 3 Characteristics of intermediaries ($N = 50$) by study group, according to individual interviews conducted in 2015 (collectors, retailers, local wholesalers and some inter-province wholesalers) and 2016 (some inter-province wholesalers and duck yard owners)

Variable	Location	Collectors	Retailers	Local wholesalers	Inter-province wholesalers	Duck yard owners
Number of agents						
	Hai Phong	4	4	4		
	An Giang	3	6	3		
	All	7	10	7	17	9
Median experience in duck trade (years)						
	Hai Phong	13	12	20		
	An Giang	18	13	18		
	All	15[a]	12[a,b]	20[a]	9[b]	8[b]
Proportion of men						
	Hai Phong	50%	0%	25%		
	An Giang	100%	30%	100%		
	All	71%[c,d]	20%[c]	57%[c,d]	94%[d]	100%[d]
Average number of ducks traded (heads per month)						
	Hai Phong	42,300	1,100	5,800		
	An Giang	55,700	1,500	20,000		
	All	48,000[f,g]	1,300[e]	11,900[e,g]	79,500[f]	67,300[f]
From which, free-grazing ducks						
	Hai Phong	6,300*	210	3,100		
	An Giang	55,700*	220	19,000		
	All	27,400[h,i]	200[i]	10,000[i]	55,700[h]	52,400[h]

Figures on the same line not sharing any superscript letter were statistically significantly different ($p < .05$). Within an agent group, figures were not statistically different between provinces, except for the pair marked with an asterisk.

local topography and to their higher loading capacity, boats constituted the most common mode of duck and duck egg transportation in An Giang. Three types of wholesalers were identified: local wholesalers, inter-province wholesalers and duck yard owners (see following section). Local wholesalers worked within their province of origin while inter-province wholesalers conducted their activities over at least two provinces. Inter-province wholesalers handled larger volumes of spent layer ducks (up to 150,000 heads per month) than retailers or local wholesalers did (Table 3).

3.1.3 | Owners of duck yards

The so-called duck yards are facilities in the northern provinces of Vietnam that serve as exchange hubs for wholesalers trading spent layer ducks, which might have travelled hundreds of kilometres to reach the duck yard. The ducks present in the yards are owned by the yard owners, who are in charge of feeding the ducks with concentrates until they reach the minimum weight required by the buyers. Yard owners reported that up to 30% of the ducks delivered on their yards were underweight and had to be fed. The ducks were kept on the yards for an average of 2.7 days before being collected (data not shown). The yard owners recruited in the study traded on average 67,300 spent layer ducks per month (Table 3), and none of them was involved in the trade of other animal species or duck products. In five of the nine yards, ducks were kept in a fenced paddock without protection from wild birds, while the duck resting areas of the other four were covered by a roof. The presence of wild birds was not observed during the visits, but rodents were present in the duck feed storage areas. Ducks had access to a pond in seven yards. The mean capacity of the duck yards visited during this study was 14,000 heads. No biosecurity measures were reported by the owners. Neither the personnel nor the visitors wore protective equipment. The duck transport trucks had direct access to the duck-keeping areas. The newly arrived duck flocks were directly mixed with the flocks already present. No cleaning and disinfection procedures of the facilities between flocks were reported.

3.2 | Product flows within the value chains

3.2.1 | Inputs used by layer duck farmers

Most farmers sourced their ducklings from local hatcheries (Table 4), which play an important role as they are expected to maintain the quality of the breed over time as well as provide healthy animals. A minority of farmers collected the ducklings directly at the hatchery (14%), while the remainder had their new flocks delivered on farm by the seller (data not shown). Although ducks fed on leftover rice

TABLE 4 Origin and provision of inputs used by layer duck farmers (*N*=95) according to individual interviews conducted in 2015

Study group	Hai Phong	An Giang (LD)	An Giang (SD)
Main sources of day-old ducklings			
State-owned breeding farm (%)	6	0	0
Local hatchery (%)	62[a]	90[b]	55[a]
Other household (%)	3	2	18
Other (e.g., collector) (%)	29	8	27
Sources of duck feed			
Farm product retailer (%)	15[c,d]	10[c]	45[d]
Itinerant seller (%)	85	90	55
Sources of veterinary medicines			
Veterinary shop (%)	71	69	64
Itinerant seller (%)	29	31	36

Figures on the same line not sharing any superscript letter were statistically significantly different ($p < .05$).
LD, long-distance; SD, short-distance.

grains on post-harvest rice fields, all farmers supplemented their flocks with concentrates, which were mainly purchased from itinerant sellers (84%). Other inputs included veterinary products, which were sourced from specialized shops (69%) or itinerant sellers of veterinary drugs. Farm inputs (ducklings, feed, medicines) were usually delivered to the farm or at the grazing site by motorbike (80%, 77% and 100%, respectively), but trucks and boats were also used (data not shown).

3.2.2 | Destinations of duck eggs from the farms

In Hai Phong, only 12% of farmers sold eggs to a hatchery while most farmers sold table eggs to intermediaries (Table 5). A total of 90% of the egg production in this province was handled by intermediaries (collectors, local wholesalers and inter-province wholesalers), while hatcheries only received 10% of the production (Figure 1, right panel). Hatcheries sold the day-old ducklings to farmers, while the unfertile eggs were sold to retailers for consumption. The egg value chain was more complex in An Giang, where a larger number of intermediaries and commodities were involved (Figure 1, left panel). Hatcheries handled the majority of the eggs produced by An Giang farmers, and redistributed them as ducklings, embryonated table eggs or plain table eggs. The volume of eggs directly sold to other agents such as retailers or consumers was usually limited (between 2% and 5% of the total farm production). In An Giang, most of the eggs were consumed within the province where they were produced, while only 40% of the eggs produced in Hai Phong were consumed locally (Figure 1). Respondents reported seasonal variations in the selling patterns in both provinces. During the high-price seasons (before the mid-autumn and New Year festivals), the competition between buyers was reported to be high and intermediaries purchased the eggs directly at the farm gate, while during the rest of the years, farmers would deliver most of the eggs to a local market for direct sale.

3.2.3 | Destinations of spent layer ducks from the farms

A majority of the spent layer ducks were bought from farmers by wholesalers (from within or outside the province) in both study provinces. Collectors handled 25% of the production in An Giang, while they were not involved in Hai Phong. In 2015, the proportion of spent ducks sold to markets or to consumers locally did not exceed 20% and 1.4% of the farm production in Hai Phong and An Giang, respectively (Figure 2). No farmers reported selling spent ducks directly to slaughterhouses or at slaughter points. In An Giang, two collectors sold laying duck flocks to other free-grazing duck farmers for further egg production, depending on the local availability of harvested rice fields and the demand in duck eggs. Retailers sold the ducks to consumers either on markets, in restaurants or at slaughter points for those owning their own slaughtering facilities. The local wholesalers sold the ducks on wholesale markets within the province of origin or in other provinces, to large slaughterhouses, retailers or inter-province wholesalers.

In 2015, the majority of the spent layer ducks produced in Hai Phong and An Giang was sold to Chinese intermediaries (Figure 2). On average, 72% of the birds from An Giang were collected by inter-province wholesalers and transported by truck to the duck yards in the northern provinces of Vietnam, from where they were exported as live birds into China by truck. The intermediaries reported that exports to Cambodia were negligible. Most of the remaining birds from An Giang were slaughtered locally and exported to China as frozen carcasses. Around 80% of the spent ducks from Hai Phong were also sold to Chinese intermediaries, via the duck yards or directly by inter-province wholesalers. The yards collected spent layer duck flocks from the three main duck-producing regions in the country: on average, 22%, 22% and 56% of the ducks originated from the northern, central and southern provinces, respectively (data not shown). The owners of the yards were mainly supplied by other intermediaries (local wholesalers and inter-province wholesalers provided 83% of the total volume), but they also purchased ducks directly from the farms (17% of the ducks). Stakeholders in the group interviews estimated that between 700,000 and 2 million spent layer ducks were exported each month to China between January 2015 and February 2016. In March 2016, the price offered for spent layer ducks by traders at the border with China dropped significantly. Consequently, the price of ducks at the yard level went down by 22% (from 67,000 to 52,000 VND per head). The cause of this event was reportedly an increased intensity of the border controls, where custom officials refused some duck shipments in the first months of 2016. Because of these events, there was a sharp reduction of duck exports to China from March 2016 onwards. After this date, around 77% of the spent layer ducks produced in An Giang were sold for local consumption in the Mekong region or exported to Cambodia (data not shown), compared to an average of 1.4% during the previous period (Figure 2).

TABLE 5 Destination of outputs produced by layer duck farmers (N = 95) according to individual interviews conducted in 2015

Study group	Hai Phong	An Giang (LD)	An Giang (SD)
Farmers selling duck eggs to each agent (%)			
Hatcheries	12[a]	100[b]	100[b]
Intermediaries in the province	68[c]	0[d]	0[d]
Intermediaries outside the province	24[e]	0[f]	0[f]
Retailers	44[g]	8[h]	9[g,h]
Consumers	29	53	18
Average proportion of duck egg production sold to each agent among farmers selling to that agent (%)			
Hatcheries	90[i]	99[j]	99[j]
Intermediaries in the province	78	NA	NA
Intermediaries outside the province	63	NA	NA
Retailers	33[k]	2[l]	5[l]
Consumers	24[m]	2[n]	4[m,n]
Farmers selling spent layer ducks to each agent			
Intermediaries in the province	97	94	91
Intermediaries outside the province	32	31	18
Slaughter points and retailers	35[o]	2[p]	0[p]
Other	6	2	0
Average proportion of spent duck production sold to each agent among farmers selling to that agent (%)			
Intermediaries in the province	87	87	95
Intermediaries outside the province	32	58	75
Slaughter points and retailers	15[q]	2[r]	NA
Other	3.5	2	NA

Figures on the same line not sharing any superscript letter were statistically significantly different ($p < .05$). LD, long-distance; SD, short-distance; NA, not applicable.
Intermediaries: collectors, retailers, local wholesalers, inter-province wholesalers and duck yard owners.
The lines "Farmers selling duck eggs to each agent" and "Farmers selling spent layer duck to each agent" refer to proportions of agents, while the other two lines refer to proportions of production sold to specific agents among farmers for whom this proportion is not null.

3.3 | Governance

Two main themes linked to the governance of the spent layer duck value chain were identified during the group and individual interviews: the major role of collectors and wholesalers, respectively. As insufficient data were collected on the governance of the egg value chain, they are not presented here.

In both provinces, collectors have access to essential information about both the current availability of and demand for spent layer ducks and duck eggs in terms of volume, location and timing. Collectors may have trade contacts with wholesalers and retailers in the provincial urban centres where the demand is higher than it is in rural areas. They have an important role as brokers, influence the product prices and form a key link between the farmers and other actors such as wholesalers in terms of sharing of information on demand and supply.

Wholesalers are able to purchase large quantities of ducks within a short period, thus being able to buy ducks for a smaller price than local intermediaries are. They had the longest experience in duck trade (Table 3), suggesting that they form a group of established and experienced traders, who have built and control strong trade networks. They have direct access to information on the current demand in duck products via their contact networks, which gives them a substantial advantage over the other stakeholders. In Hai Phong, hatchery managers were also identified as an important source of information for wholesalers regarding the availability of spent layer ducks. Consequently, wholesalers monopolize a large proportion of the spent layer duck trade, mainly via trade connections with China and Cambodia, from which they are able to acquire the information on demand. Stakeholders reported that wholesalers were the most important group in terms of influence over the trade patterns of spent layer ducks and of control over the product prices. A subgroup of wholesalers also had a specific role as border intermediaries with their Chinese counterparts, but could not be approached during the study (Figure 2). Trust was repeatedly mentioned as an essential element in the working relationships between the actors involved in spent layer duck export. It was highlighted that repeated failure of an agent to provide ducks would result in loss of confidence from the partners along the chain and rupture of business links.

4 | DISCUSSION

The results presented here provide an extensive and detailed description of the value chain of free-grazing layer ducks. Because

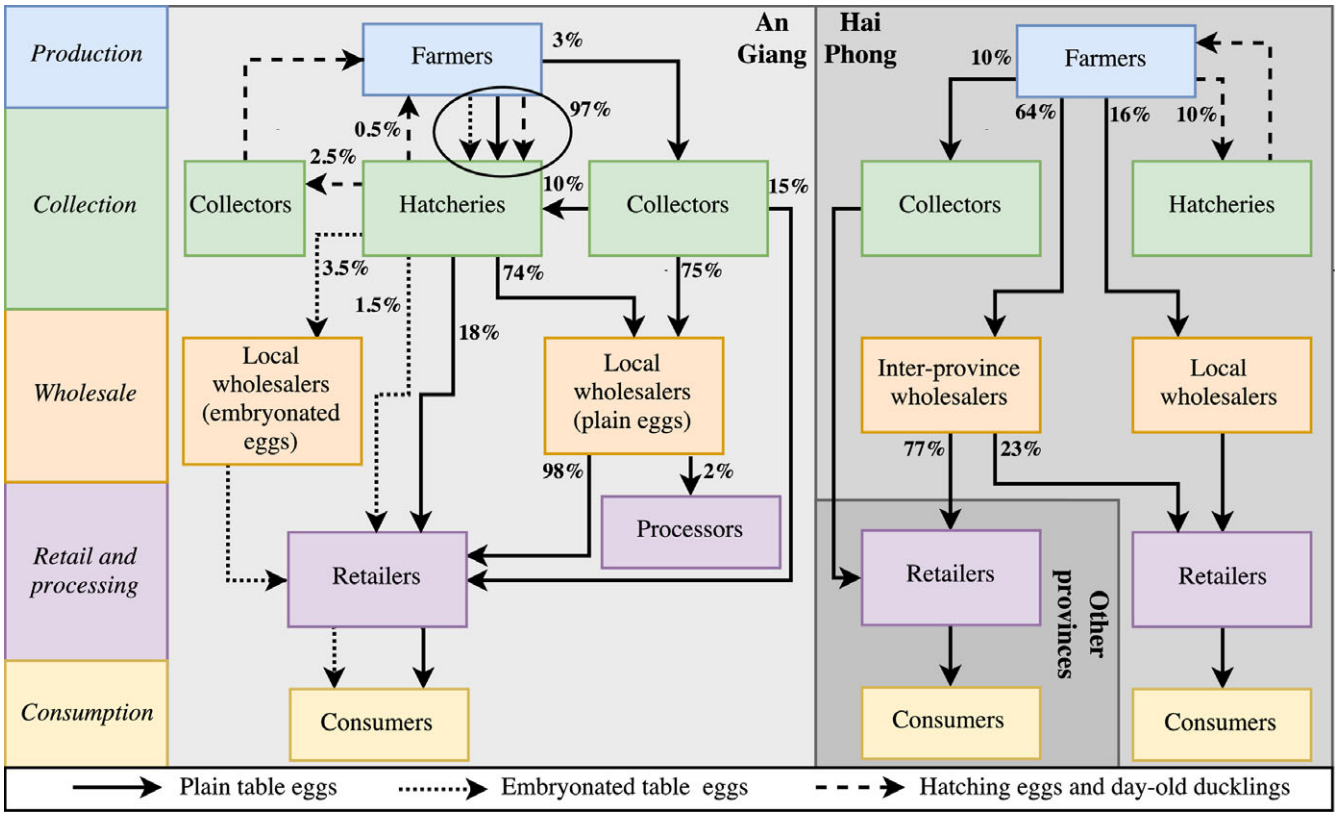

FIGURE 1 Flow chart of the duck egg value chain in the study provinces: Hai Phong (right panel) and An Giang (left panel) according to group interviews conducted in 2015. The percentages indicate the volume of products (as a proportion of the total volume handled by the agent at the origin of the arrow) moving through each branch. The flows of spent layer ducks are omitted from this figure and described in Figure 2 [Colour figure can be viewed at wileyonlinelibrary.com]

all post-farm gate actors work with both free-grazing and confined ducks, it was not possible in this study to obtain figures specific to free-grazing ducks when characterizing the trade volumes beyond the production level. However, we believe that the figures presented here accurately reflect the trading patterns of duck eggs and spent layer ducks from free-grazing systems during the study period. As the participants were recruited in a subset of communes only, it is possible that we did not capture all the relevant actors from the free-grazing duck value chains. However, we interviewed all the actors whose names were provided by the animal health official services and we recruited further actors who were mentioned during the interviews. As such, we believe that the description of the value chains provided here is sufficiently complete so that meaningful inferences can be drawn.

The trade of live poultry has long been recognized as a major route for HPAI virus dissemination in Asia (Fournié, de Glanville, & Pfeiffer, 2012). As they bring together various susceptible bird species coming from various locations, live bird markets are known to contribute to the spread of HPAI viruses and have regularly been found contaminated in endemic contexts (Amonsin et al., 2008; Chen et al., 2014; Indriani et al., 2010; Negovetich et al., 2011; Nguyen et al., 2005). Similarly, we believe that the duck yard system may be involved in the epidemiology of avian influenza viruses, and HPAI viruses specifically, for various reasons. First, we found that a large number of HPAI-susceptible ducks are collected from the entire country and gathered in the yards, where flocks from different origins often mingle for several days. Second, long-distance transport is a stressful event and has been previously reported as a risk factor for avian influenza infection (Beaudoin et al., 2014) due to a negative impact on the immunity of the birds. Spent duck hens are transported over 2,000 km from the farms in South Vietnam to the yards, and although the reported average mortality during transport was low, around 0.5%, it may reach 70% under difficult weather or traffic conditions (data not shown). Third, poor biosecurity measures in duck yards (such as absence of personal protective equipment, absence of cleaning and disinfection procedures, mixing of flocks from different origins, lack of visitor control and deficient protection from wild birds) were observed during the study. Last, intermediaries (collectors, retailers, local wholesalers, inter-province wholesalers and yard owners) circulate between source farms and duck yards to collect and deliver ducks and they never reported disinfecting the transport vehicles or the cages used to contain the ducks (data not shown). These factors together provide extremely favourable conditions for the spatial dissemination of HPAI viruses, with duck yards potentially acting as hubs and promoting amplification, spread and reassortment of the viruses. As spent layer ducks do not re-integrate the poultry production sector after leaving the duck yards, the risk of direct disease transmission to susceptible poultry other than spent

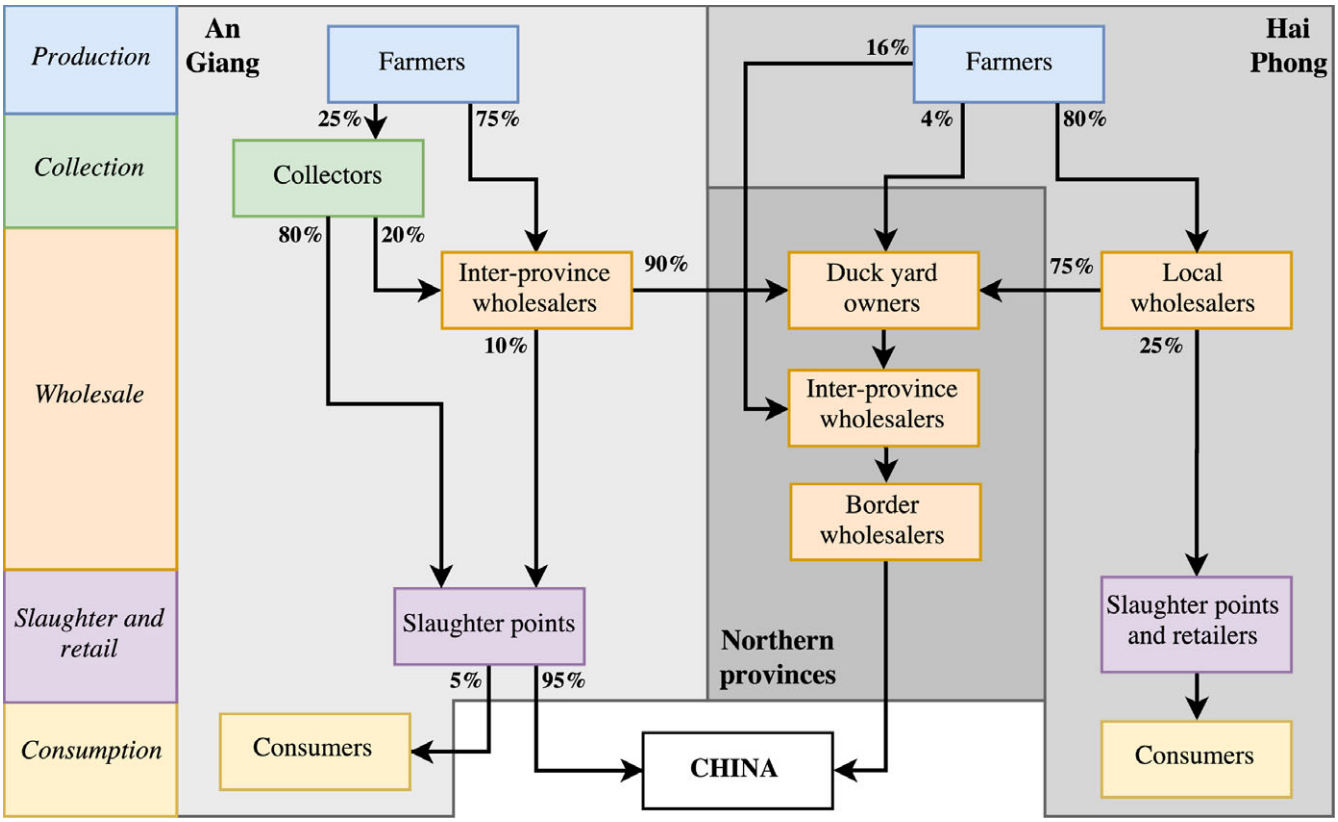

FIGURE 2 Flow chart of the spent layer duck value chain in An Giang and Hai Phong provinces, according to group interviews and completed with information from individual interviews with duck yard owners and inter-province wholesalers on 2015 trade patterns. The percentages indicate the volume of products (as a proportion of the total volume handled by the agent at the origin of the arrow) moving through each branch [Colour figure can be viewed at wileyonlinelibrary.com]

layer ducks is limited. However, a large number of stakeholders are involved in the value chain and may be exposed to HPAI viruses shed by these flocks. Further, the limited biosecurity measures in place in the duck yards suggest that local dissemination of the virus in the surroundings of the duck yards or via duck yard workers is possible. It is striking that there is no published empirical study looking at the presence of HPAI viruses in these duck yards. The characteristics of the duck yards highlighted in the current study demonstrate that they should be considered as an essential link in the value chain of spent layer ducks, especially when considering HPAI surveillance and control.

Vietnamese people prefer consuming meat from meat ducks rather than spent layer ducks, while the latter are in high demand in China, according to the participants of the study. This generates a higher price for spent layer duck meat in China, creating an incentive for export of products towards this country. As a result, it was reported that over 98% of the spent layer ducks produced in An Giang were sold abroad during the first part of the study, in 2015 (Figure 2). Given that the trade of live ducks between Vietnam and China is officially forbidden due to the high risk of transboundary spread of pathogens, including HPAI viruses, all transfers are conducted illegally. Although the export of spent layer ducks to Cambodia was mentioned only anecdotally in 2015, intermediaries reported that substantial volumes of spent layer ducks were sold to Cambodia during the course of 2016. Such illegal trade of live ducks from Vietnam to Cambodia had been previously reported in the literature (Van Kerkhove et al., 2009). The export of live spent layer ducks from Vietnam is likely to facilitate the transboundary circulation of various pathogens and of HPAI viruses in particular, between China, Vietnam and Cambodia. Recent HPAI H5N1 and H5N6 outbreaks (early 2017) reported in the south-east of Cambodia and in Vietnam demonstrate that the virus is still circulating in the region (EMPRES-i, 2017). In contrast to the challenge posed by the export of live ducks in terms of HPAI circulation, it was shown that the risk of transmission of HPAI via meat from vaccinated poultry is extremely low (Swayne & Beck, 2005). According to our study, only 26% of the spent layer ducks produced in An Giang were exported as frozen carcasses in 2015 (Figure 2). As most free-grazing duck flocks in An Giang are vaccinated against HPAI (Meyer et al., 2017), the export of frozen duck meat from this region is likely to be far less risky than the export of live ducks. The development of regulations and incentives promoting this marketing channel could help improve the management of HPAI in Vietnam and in the region. The demand for frozen meat is still relatively limited in South-East Asia given the traditional preference of consumers for freshly slaughtered poultry. However, the increasing share taken by supermarkets in food retailing (Reardon, Peter Timmer, Barrett, & Berdegué, 2003) suggests that the demand for chilled and frozen poultry will increase in the near future.

The characteristics of the duck value chains presented here, in particular the important role of the inter-province wholesalers and yard owners, also have implications in terms of HPAI surveillance. The veterinary authorities have a role in the trade of spent layer ducks as they issue movement certificates when ducks are transported across province borders (for instance from the MRD to the duck yards). The wholesalers from the MRD recruited in our study reported that all the northbound trucks were inspected and sealed before departure. However, the ducks collected in the RRD were mainly transported by motorbike without veterinary inspection (data not shown). The duck yards in the RRD are under the jurisdiction of the provincial veterinary services, whose offices are located distant from the yards. In addition, most transactions from and to the duck yards occur at night-time, in order to minimize the stress for the animals. Consequently, the likelihood of effective inspection by the veterinary services in the duck yards was reported as low. Most importantly, the active surveillance for HPAI viruses in Vietnam is mostly implemented in live bird markets (Nguyen et al., 2014). Free-grazing ducks represent around 73% of the total duck production in the MRD (Bui, 2010), and our study showed that over 98% of them did not transit through live bird markets in 2015. Therefore, a considerable proportion of the HPAI at-risk population bypasses the traditional surveillance activities implemented in LBMs. In the light of the results of this value chain analysis, we strongly recommend to monitor the HPAI status of duck yards as a complement to LBM surveillance.

Management practices of free-grazing duck farmers differed between the two provinces. First, all farmers in An Giang practised free grazing with their flocks all year round, but 67% of farmers from Hai Phong kept their flocks confined on the farms for a substantial part of the year. This is consistent with previous studies reporting that free-grazing duck practices differ between agro-ecological regions in Vietnam (Desvaux, Ton, Phan Dang, & Hoa, 2008; Edan, 2006). Second, the production cycle of layer duck flocks was longer in Hai Phong than it was in An Giang (median of 24 and 15 months, respectively) (Table 2). The length of the production cycle has implications in terms of vaccination protocols. Although vaccination is widely used in duck flocks, suboptimal protection has been previously demonstrated against some of the virus strains circulating in Vietnam (Cha et al., 2013). Moreover, limited reports of the actual duration of vaccine-induced HPAI immunity in ducks are available. Tian et al. (2005) showed that protective immunity lasted at least 1 year after two vaccine injections. Therefore, free-grazing layer flocks should be vaccinated at least twice in their first year of life, and a booster should be administered during their second year. Last, eggs produced by the layer flocks were traded differently in the two provinces. In An Giang, most of the eggs were handled by hatcheries, which distributed them further as plain table eggs, embryonated table eggs or ducklings depending on the demand. For instance, the demand for table eggs is particularly high before the mid-autumn and New Year (January or February) festivals, generating an increase in egg prices around these periods. On the other hand, the duck egg trade in Hai Phong was shared between different stakeholders, namely hatcheries, collectors, wholesalers and retailers. Still, hatchery managers were reported to play an important role in terms of information sharing in this province and were considered as important control points within the value chain by the participants.

The value chains presented here were subjected to fluctuation in demand and product availability, linked not only to seasons, but also to climatic, disease and cultural events. Therefore, trade agreements between stakeholders are essential for the survival of their businesses during difficult periods. According to the participants in this study, the export of the spent layer ducks produced in Vietnam is dependent on the demand abroad and on the ease of border crossing. The decrease in prices linked to incidents with the custom officers early 2016 leads to a significant re-routing of the products towards local consumption and export to Cambodia. Farmers bear most of the economic consequences of these changes in the trade patterns. They may hold on to their laying flocks for longer than they usually do if the prices offered by the intermediaries are not high enough. However, this is only profitable for a limited amount of time, as the egg productivity of older ducks slowly decreases. In addition, as farmers in An Giang do not use duck confinement, they have to transport their flock to another location when paddies are no longer available in their home commune, generating further costs. The farmers' interviews presented here were conducted in 2015, and it would be valuable to explore the consequences of the changes intervened in 2016 in the duck trade on the farmers themselves. Wholesalers were reported to have a much larger power as they are able to explore more profitable market opportunities by exploiting their contact networks. Consequently, duck farmers have very limited influence over the trade patterns and prices of their products. Overall, the large number of trading agents involved and the rapidity of the transactions are an additional challenge for surveillance activities. The value chains presented here are very dynamic and future HPAI surveillance activities should be flexible enough to accommodate for the important features highlighted by this work. The results of this study will be useful to inform future policy regarding HPAI management in Vietnam.

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