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Epidemiological investigations in regard to porcine reproductive and respiratory syndrome (PRRS) in Quebec, Canada. Part 1: Biosecurity practices and their geographical distribution in two areas of different swine density

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ABSTRACT

Porcine reproductive and respiratory syndrome virus (PRRSV) is a considerable threat to the swine industry and implementing biosecurity measures is essential for the control of its transmission. The aims of this study were: (1) to describe biosecurity practices in production sites located in a moderate density (MD) and a high density (HD) pig area according to production type; (2) to group sites in different patterns according to their biosecurity practices; and (3) to determine the geographical distribution of sites according to biosecurity patterns. Biosecurity practices were selected based on PRRS epidemiology. A questionnaire was completed on 125 breeding sites (MD = 54; HD = 71) and 120 growing (HD) sites, between 2005 and 2008. Depending on area and production type, the frequency of biosecurity practices used ranged from 0 to 2% for barrier at site entrance, 0 to 19% for use of shower, 25 to 35% for washing truck between loads of pigs, 51 to 57% for absence of rendering or rendering without access to the site, and 26 to 51% for absence of gilt purchase or purchase with quarantine. Better practices pertaining to entrance protocol (i.e. "no-entry" sign, shower, ≥24 h downtime) were reported more frequently on breeding sites in the MD than the HD area ($P < 0.05$). In the HD area, growing sites had in general a lower level of biosecurity than breeding sites. Using a two-step clustering procedure performed separately for breeding and growing sites, two different patterns were obtained for each production type, which corresponded to a high and low level of biosecurity. For breeding sites, a higher biosecurity level was observed at sites located away from other pig sites, set at more than 300 m from the public road, having higher sow inventory, or being part of an integrated production ($P < 0.05$). Spatial clusters of sites for each biosecurity pattern were detected. This study identified some shortcomings regarding biosecurity that should be addressed before implementing any PRRSV regional control. Vicinity of sites with different biosecurity levels also suggests difficulties in planning priorities of intervention based on geographical distribution of sites.

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1. Introduction

Porcine reproductive and respiratory syndrome (PRRS) is a viral disease that has a major economic impact on the swine industry (Neumann et al., 2005). PRRS virus (PRRSV) causes late-term abortions and stillbirths, mummified or weak piglets in breeding phases and it also induces respiratory problems, impairs growth performance and increases mortality in weaner-finisher phases (Christianson and Joo, 1994). Several direct and indirect pathways are likely involved in transmission of PRRSV between herds, including the introduction of infected animals or semen, transport vehicles, aerosols, flying insects, waterfowl and fomites (Le Potier et al., 1997; Zimmerman et al., 1997; Dee et al., 2002, 2004b, 2009; Mortensen et al., 2002; Otake et al., 2002, 2004).

In Quebec, approximately 7 million pigs are slaughtered annually. Two thirds of swine production is concentrated in three administrative regions (Monteregie, Centre-du-Quebec, Chaudiere-Appalaches). The high density of production in these regions and proximity with neighbouring pig sites make the swine industry particularly vulnerable to transmission of PRRSV or other respiratory diseases (Stärk et al., 1992; Flori et al., 1995; Mortensen et al., 2002; Holtkamp et al., 2010). This can facilitate area spread of PRRSV through limited-distance mechanisms (e.g. aerosols, flying insects, etc.) or through an increased frequency of indirect contact via vehicles or people involved in the swine industry (Ribbens et al., 2009). In Quebec, these movements are further increased by a multi-site production system, a structure introduced 20 years ago to facilitate segregated early weaning strategies. Implemented to limit the transmission of pathogens from sow to piglets, the procedure unfortunately had the effect of increasing movement of pigs between premises, thus ultimately favouring dissemination of some pathogens (D'Allaire, 2000).

Biosecurity is defined as procedures, efforts and programs established to reduce the risk of new disease introduction (external biosecurity) or to slow down the transmission of endemic pathogens into populations (internal biosecurity) (Amass and Clark, 1999; Dargatz et al., 2002; Barrington et al., 2006; Gunn et al., 2008). Very few field studies have been conducted to evaluate associations between specific biosecurity practices on the farm and PRRSV health status (Mortensen et al., 2002; Evans et al., 2008, 2010; Holtkamp et al., 2010). However, the risk of PRRSV introduction on a production site is likely to be influenced by these measures, since mechanical transmission of PRRSV has been shown experimentally to occur through pig transportation or through fomites carried by people entering the unit (Dee et al., 2002, 2004a,b, 2007). Consequently, the success of PRRSV control is likely to depend on biosecurity implementation. Likewise, knowledge of the current biosecurity measures is essential in order to target priorities for the industry in terms of improving practices or to evaluate efforts needed before implementing a PRRSV regional control program.

The aims of this study were: (1) to describe biosecurity practices according to production type in sites located in two geographical areas of different swine density; (2) to group sites into patterns according to their biosecurity practices; and (3) to determine the geographical distribution of sites according to biosecurity.

2. Materials and methods

2.1. Study design and source population

As part of a larger study on the transmission and control of PRRSV, we conducted a cross-sectional study to describe biosecurity practices in sites located in two regions of Quebec between May 2005 and August 2008. A high density (HD) area was selected, which corresponded to 10 adjacent municipalities with a density of 354 pigs/km^2 (Ministère de l'Agriculture des Pêcheries et de l'Alimentation du Québec; MAPAQ, 2010), located in the Monteregie administrative region, where all types of production were included. A moderate density (MD) area with 44 pigs/km^2 (Ministère de l'Agriculture des Pêcheries et de l'Alimentation du Québec; MAPAQ, 2010) was also selected, corresponding to the Estrie region of Quebec, in which only sites housing sows were included in our source population. This entire region was selected in order to obtain a comparable number of breeding sites in both areas. Weaners and finishers were not included in this latter area due to limited resources available for the study.

The unit of interest was the production site, defined as one or more barns located within 300 m of each other, belonging to the same owner (individual or corporate) and having the same animal source(s). In order to select sites, all producers listed in the Quebec Federation of Pork Producers (FPPQ) database and included in the source population were contacted. A written description of the project and a participation form to be signed and returned were initially sent to producers; participation was on a voluntary basis. In the absence of a response or with a refusal, producers were contacted by phone to seek their participation or to inquire into the reasons for the refusal.

2.2. Questionnaire

A questionnaire with mainly semi-closed questions was developed to assess potential risk factors previously mentioned in the literature for introduction of PRRSV on a production site. Four veterinarians specialized in swine production and three producers were consulted to assess relevance, clarity and completeness of questions. The questionnaire was filled out by the first author during a 45 min in-person interview with the owners of independent farms or with employees for farms under contract. When it was impossible to perform in-person interview (mainly because the producer was not available on the site), the questionnaire was completed during a phone interview. Information was gathered on type of production, ownership, pig inventory, pig flow, distance from the public road and the closest pig site (approximated by the producer) (Table 1). Geographical coordinates of the site (latitude/longitude) were obtained using a global positioning system (GPS). Data were also obtained on specific external biosecurity measures that can be implemented on the site by the producer which covered about

Table 1
Descriptive statistics for herd and neighbourhood characteristics of sites in a moderate (MD) and high (HD) density area according to production type in Quebec, Canada (125 breeding and 120 growing sites).

Herd and neighbourhood characteristics		MD		HD		
		Breeding n=54		Breeding n=71	Growing n=120	
Categorical variables		%		%	%	
Production type						
	Farrow-to-wean[a]	22		21	-	
	Farrow-to-grow	15		9	-	
	Farrow-to-finish	63		70	-	
	Weaners	-		-	19	
	Weaner-to-finish	-		-	12	
	Finishers	-		-	69	
Ownership						
	Independent	93		87	33	†
	Contract producer	7		13	67	
Pig flow						
	All-in all-out[b]	63		54	65	
	Continuous flow	37		46	35	
Distance from public road						
	>300 m	24	*	6	21	†
	≤300 m	76		94	79	
Continuous variables						
Number of productive sows	median	235	*	180	-	
Total number of animals[c]	median	1269		1190	1543	†
Distance from closest pig site (m)	median	2750	*	400	500	

[a]One boar stud was classified as a farrowing site.
[b]By farrowing rooms for breeding sites and by site or unit for growing sites.
[c]Including gilts, sows, weaners and finishers if present on site.
*Significant difference ($P \leq 0.05$) between breeding sites in the MD and HD area, as determined by the Pearson exact chi-square test or the Wilcoxon rank sum test as appropriate.
†Significant difference ($P \leq 0.05$) between breeding and growing sites in the HD area, as determined by the Pearson exact chi-square test or the Wilcoxon rank sum test as appropriate.

20 variables related to: layout of the site, entrance protocol, transportation of animals, dead pig disposal, pest and manure management and deliveries of feed, semen and gilts (Table 2). All questions pertained to practices at the time of questionnaire completion with the exception of questions regarding gilt purchases (previous six months). When a biosecurity practice was reported as only partially applied, it was considered that the measure was not applied. The questionnaire in French is available upon request from the first author.

2.3. *Statistical analyses*

2.3.1. *Descriptive statistics*

Data validation and descriptive statistics were performed in the SAS version 9.1 software (SAS Institute Inc., Cary, NC, USA). For the purpose of the analyses, sites were divided into two production types: breeding (farrowing, farrow-to-wean, farrow-to-finish, boar stud) and growing sites (weaner, weaner-to-finish, finishers for commercial pigs or gilt replacement). Differences in characteristics (herd management, neighbours, biosecurity practices) of breeding sites between the MD and HD area were assessed using Pearson exact chi-square test for categorical variables (Stokes et al., 2000) or Wilcoxon rank sum test for continuous variables ($\alpha = 0.05$). These characteristics were also compared between breeding and growing sites in the HD area.

2.3.2. *Two-step cluster analyses*

Sites were grouped according to their pattern of biosecurity practices using a two-step clustering procedure performed in the SPSS version 16.0 software (SPSS Inc., Chicago, IL, USA). This two-step cluster analysis is an agglomerative hierarchical clustering technique that can be used as an exploratory tool to reveal natural groupings within a dataset. For the analysis, sites represented objects to be clustered and biosecurity variables, the attributes upon which the clustering is based. In the first step of the algorithm, sites are pre-clustered into small sub-clusters. The software scans the data records one by one and decides if the site should be merged with previously formed clusters or introduced into a new cluster. The distance between two clusters is related to the decrease in the log-likelihood as they are combined into one cluster. In the second step, the sub-clusters previously identified are grouped hierarchically into clusters to assess multiple cluster solutions in one run. The two-step clustering procedure automatically selects the optimal number of clusters (Chiu et al., 2001). The number of clusters (patterns) is based on minimizing the ratio of change in Schwarz's Bayesian information criterion (BIC) provided for each cluster solution. Grouping

Table 2
Descriptive statistics for specific biosecurity practices (%) reported according to region and production type (245 sites).

Description of biosecurity practices	MD		HD		
	Breeding		Breeding	Growing	
	n=54		n=71	n=120	
	%		%	%	
Layout of the site					
Barrier at the entrance of the site, closed at all times	2		1	0	
Parking of vehicles at more than 30 m from the closest unit	7		4	0	†
Fence surrounding the site perimeter	2		0	1	
Entrance protocol for people					
No-entry sign on the entrance door	65	*	39	23	†
Locked doors at all times	31		25	48	†
Doorbell at the entrance	37		31	17	†
Hygiene level					
Shower	19		3	0	
Washing hands only	9	*	10	8	
No washing	72		87	92	
Clear separation between clean and contaminated areas (shower, line, bench)	30		17	18	
Downtime for visitors (≥24 hr)	59	*	18	7	†
No employee in contact with pigs from other sites, pigs in transport or slaughterhouses	81		72	54	†
Transportation of pigs					
Truck washed between loads of pigs	28		25	35	
Type of transport					
No commercial transport used	4		40	10	
Commercial without access to unit(s) by the driver	81	*	42	11	†
Commercial with access to unit(s) by the driver	15		18	79	
Pigs cannot re-enter the unit after loading	85		76	64	
Dead pig, pest and manure management					
Dead pig disposal					
No rendering (incinerator, burying or composting)	37		34	32	
Rendering without access to the site by rendering truck	14		23	20	
Rendering with access to the site by rendering truck	49		43	48	
Rodent control performed by exterminator	67		66	78	
Bird-proofed wire screens in unit(s)	67		72	65	
No dog or cat allowed within the unit(s)	91	*	77	94	†
No manure provided from other sites spread on the site	94		92	90	
Feed, semen and gilt deliveries					
No feed delivery personnel access to unit	72	*	87	87	
Purchase of semen					
No purchase	9		4	-	
Purchase without access to unit by the delivery personnel	69		76	-	
Purchase with access to unit by the delivery personnel	22		20	-	
Purchase of gilts					
No purchase	24		44	-	
Purchase with quarantine[a]	2	*	7	-	
Purchase without quarantine	74		49	-	

[a]Quarantine was defined as a minimum of 2 weeks of isolation for gilts before entering the sow herd and with an all-in all-out pig flow between groups of gilts.
*Significant difference ($P \leq 0.05$) between breeding sites in the MD and HD areas, as determined by the Pearson exact chi-square test.
†Significant difference ($P \leq 0.05$) between breeding and growing sites in the HD area, as determined by the Pearson exact chi-square test.

of sites was done separately for breeding and growing sites since some variables were highly correlated with production type. Before performing each clustering analysis, sites were randomly ordered to minimize potential order effect. Variables were excluded from the analysis if they had more than 10% missing values. Other missing values were imputed using the mode of the observed distribution by production type. The concordance between patterns allocated to sites with and without using imputation was assessed using kappa coefficient estimated for sites with no missing data. Differences in characteristics (herd management, neighbours, biosecurity practices) between biosecurity patterns were assessed using Pearson exact chi-square statistic or Wilcoxon rank sum test ($\alpha = 0.05$), performed separately for breeding and growing sites in order to describe variables associated or not to biosecurity patterns. For each production type, a level of biosecurity was attributed to patterns according to practices observed among sites.

2.3.3. Spatial analyses

The biosecurity level (low or high) attributed to each site was geographically interpolated for each production type using Thiessen Polygon method in ArcInfo version 9.3 software (Esri, Redlands, CA, USA) to preserve confidentiality of data. The area perimeter was hand-defined in order to produce a compact zone comprising all sites and excluding areas having no site. A small gap was allowed between sites and area boundaries. Geographical clusters of sites for each biosecurity pattern were assessed using the Spatial Scan Test performed in SaTScan version 8.0 software (Boston, MA, USA), based on a purely spatial Bernoulli distributional assumption model and scanning for circular clusters with a maximal population threshold of 50% of sites. These spatial analyses were performed to determine if specific zones of lower or higher biosecurity could be identified to help prioritize zones in which biosecurity should first be enhanced. Analyses were run separately for both areas and for each biosecurity level seeking high risk of cases; cases being defined as sites grouped into a specific biosecurity level and controls as all remaining sites. In the HD area, the procedure was performed combining biosecurity levels of breeding and growing sites to visualise the effort needed to manage both types of production on the territory. The statistical significance of clusters was determined through 9999 permutations and the most likely significant cluster ($P \le 0.05$) was mapped. To avoid ambiguity throughout the article, we will refer to groups resulting from the multivariate biosecurity classification as patterns or levels and to spatial clusters as clusters.

3. Results

A total of 306 producers listed in the FPPQ database were contacted for participation in the study. Among these producers, 30 were excluded due to the absence of swine production or of the targeted production type (MD only), 34 producers refused to participate due to a lack of interest or time, and 29 were unreachable. Participation was obtained for 77% of the producers and resulted in the inclusion of 191 sites (1 boar stud, 70 breeding and 120 growing sites) in the HD area and 54 breeding sites in the MD area. All questionnaires were filled out during in-person interviews except for 8% of the sites (phone interviews).

3.1. Description of biosecurity practices

Descriptive statistics for herd characteristics, neighbourhood characteristics, and specific biosecurity practices according to area and production type are presented in Tables 1 and 2. Following data exploration, some questions pertaining to quality of insect or rodent control, access to carcasses by wild or domestic animals, manure equipment used for spreading, and presence and use of a loading bay for shipping were excluded from subsequent analyses as they were prone to individual variability in their interpretation. Some biosecurity measures were reported with a low frequency as those regarding the layout of the site and the hygiene level for the entrance protocol (Table 2). Among the 49 sites respecting a clear separation between clean and contaminated zones for people entering the unit, 24% required a shower-in and 22% a hand washing. In the 93 sites with more than one building, changing boots and coveralls between units was required on 68% and 54% of the sites, respectively. Incinerating (33%), burying (42%) and composting (25%) were used as dead pig disposal in sites not using rendering. On sites using rendering, carcasses were picked-up at 30 m or less from the closest unit on 50% of the sites. No site was under air filtration.

In breeding sites, a higher frequency of biosecurity practices was observed in the MD compared to the HD area for measures pertaining to the entrance protocol for people, transportation of pigs, and dog or cat access to unit(s) (Table 2). However, greater proportions of sites not purchasing replacement gilts and prohibiting access to unit by feed delivery personnel were observed in the HD area. In the HD area, growing sites had in general a lower biosecurity level compared to breeding sites, mainly relating to parking areas for vehicles, some elements of the entrance protocol for people, and pig transportation. However, growing sites showed better practices for door locking and domestic animal access to unit(s).

3.2. Grouping sites into patterns according to their biosecurity practices

The two-step clustering procedure grouped the sites into two categories for breeding (A vs. B) and growing (C vs. D) sites. No variable had to be removed from the dataset for having more than 10% missing values. Seven missing data were imputed for breeding sites and 12 for growing sites. A good agreement was obtained for the grouping with and without imputation (kappa $\ge$ 0.79). Biosecurity patterns obtained for breeding and growing sites are described in Tables 3 and 4. Compared to pattern A, breeding sites included in pattern B always reported similar or higher frequency of advisable biosecurity measures, with the exception of gilt purchase practices. In growing sites, similar or better practices were reported for sites belonging to pattern D compared to pattern C, with the exception of dead pig disposal and employees having contact with pigs from external sources. Some herd and neighbourhood characteristics were associated with the biosecurity patterns of breeding or growing sites (Table 3). No significant association ($P = 0.12$) was found between biosecurity patterns of breeding sites and area. Table 4 shows which variables were significantly associated with the biosecurity patterns obtained.

Table 3
Descriptive statistics for herd and neighbourhood characteristics (expressed as % of total number of sites in each pattern) according to biosecurity patterns obtained through the classification of breeding (A and B; $n = 125$) and growing (C and D; $n = 120$) sites.

Herd and neighbourhood characteristics		Biosecurity patterns					
		Breeding			Growing		
		A	B		C	D	
		n=84	n=41		n=67	n=53	
Categorical variables		%	%		%	%	
Area							
	Moderate density (MD)	38	54		-	-	
	High density (HD)	62	46		100	100	
Production type							
	Farrow-to-wean[a]	8	49	*	-	-	
	Farrow-to-grow	11	12		-	-	
	Farrow-to-finish	81	39		-	-	
	Weaners	-	-		10	30	†
	Weaner-to-finish	-	-		13	9	
	Finishers	-	-		76	61	
Ownership							
	Independent producer	99	71	*	31	36	
	Contract producer	1	29		69	64	
Pig flow							
	All-in all-out[b]	55	63		64	65	
	Continuous flow	45	37		36	35	
Distance from public road							
	>300 m	6	29	*	21	21	
	≤300 m	94	71		79	79	
Continuous variables							
Number of productive sows	median	174	325	*	-	-	
Total number of animals[c]	median	1344	1000		1300	2000	†
Distance from closest pig site (m)	median	500	1220	*	457	610	

[a]One boar stud was classified as a farrowing site.
[b]By farrowing rooms for breeding sites and by site or unit for growing sites.
[c]Including gilts, sows, weaners and finishers if present on site.
*Significant difference ($P \leq 0.05$) between patterns A and B, as determined by the Pearson exact chi-square test.
†Significant difference ($P \leq 0.05$) between patterns C and D, as determined by the Pearson exact chi-square test.

3.3. Geographical distribution of sites according to biosecurity patterns

Fig. 1 shows the geographical distribution of production sites according to biosecurity patterns. Combining both higher, B and D, and both lower, A and C, biosecurity patterns, two spatial clusters were observed in the south-eastern part of the HD area. The first 2.7 km-radius cluster ($P = 0.01$) comprised 9 sites grouped into the higher biosecurity patterns whereas the second 9.8 km-radius cluster ($P = 0.04$) included 58 sites of which 48 belonged to the lower biosecurity patterns. A significant spatial cluster ($P = 0.05$) involving 11 sites with a low biosecurity pattern within a 15.8 km radius was identified in the south of the MD area.

4. Discussion

Although most sites had several biosecurity practices in place, enhancement would be advisable to further decrease the risk of disease introduction. The general layout of the farm was not appropriate on most sites and allowed proximity of vehicles or unauthorized people to the barn, which can act as mechanical vectors for PRRSV between pig farms (Bates et al., 2001; Dee et al., 2002; Pitkin et al., 2009; Ribbens et al., 2009). The situation was worsened by the fact that several farms had rather low standards regarding entrance protocol that represents the last physical barrier to people for disease prevention. The usefulness of good entrance practices has been well documented for PRRS as well as for other diseases (Elbers et al., 2001; Amass et al., 2004; Dee et al., 2004a; Holtkamp et al., 2010; Pitkin et al., 2010). A shower-in protocol or a Danish entrance, or at least washing hands combined with a change of boots and coveralls respecting clean and contaminated entrance zones are recommended procedures. However, the constant effort that would be needed by everyone entering the unit to fulfill these requirements might explain the rather low frequency of these practices (Wurtz et al., 1994). Having a clean truck for pig transportation was also less frequent than desired, possibly because of an insufficient number of washing stations in these two areas. This could certainly contribute to pathogen contamination of the site by truck wheels or by aerosols (Dee et al., 2002; Otake et al., 2010).

Table 4
Descriptive statistics for specific biosecurity practices (expressed as % of total number of sites in each pattern) according to biosecurity patterns obtained through the classification of breeding (A and B; $n = 125$) and growing (C and D; $n = 120$) sites.

Description of biosecurity practices	Biosecurity patterns					
	Breeding			Growing		
	A	B		C	D	
	n=84	n=41		n=67	n=53	
	%	%		%	%	
Layout of the site						
Barrier at the entrance of the site, closed at all times	0	5		0	0	
Parking of vehicles at more than 30 m from the closest unit	1	15	*	0	0	
Fence surrounding the site perimeter	0	2		1	0	
Entrance protocol for people						
No-entry sign on the entrance door	38	76	*	21	26	
Locked doors at all times	6	73	*	16	89	†
Doorbell at the entrance	13	76	*	12	23	
Hygiene level						
Shower	0	29		0	0	
Washing hands only	4	22	*	0	17	†
No washing	96	49		100	83	
Clear separation between clean and contaminated areas (shower, line, bench)	4	61	*		38	†
Downtime for visitors (≥24 hrs)	23	63	*	1	13	†
No employee in contact with pigs from other sites, pigs in transport or slaughterhouses	74	80		70	34	†
Transportation of animals						
Truck washed between loads of pigs	17	46	*	31	38	
Type of transport						
No commercial transport used	32	7		13	6	
Commercial without access to unit(s) by the driver	49	80	*	7	15	
Commercial with access to unit(s) by the driver	19	12		79	79	
Pigs cannot re-enter the unit after loading	73	95	*	60	72	
Dead pig, pest and manure management						
Dead pig disposal						
No rendering (incinerator, burying or composting)	35	32		45	13	
Rendering without access to the site by rendering truck	14	27		9	32	†
Rendering with access to the site by rendering truck	51	41		46	55	
Rodent control performed by exterminator	63	73		64	94	†
Bird-proofed wire screens in unit(s)	68	73		52	81	†
No dog or cat allowed in the unit(s)	76	98	*	90	100	†
No manure provided from other sites spread on the site	93	93		91	89	
Feed, semen and gilt deliveries						
No feed delivery personnel access to unit	76	90		79	96	†
Purchase of semen						
No purchase	6	7		-	-	
Purchase without access to unit by delivery personnel	70	78		-	-	
Purchase with access to unit by delivery personnel	24	15		-	-	
Purchase of gilts						
No purchase	43	19		-	-	
Purchase with quarantine[a]	2	10	*	-	-	
Purchase without quarantine	55	71		-	-	

[a] Quarantine was defined as a minimum of 2 weeks of isolation for gilts before entering the sow herd and with an all-in all-out pig flow between groups of gilts.
* Significant difference ($P \leq 0.05$) between patterns A and B, as determined by the Pearson exact chi-square test.
† Significant difference ($P \leq 0.05$) between patterns C and D, as determined by the Pearson exact chi-square test.

This risk would even be higher for producers using rendering for dead pigs and authorizing free access to the main entrance of the site by the truck, which accounted for a high proportion of our sample. Furthermore in some instances, the distance between the unit and the carcass pick-up bin was less than 30 m. The use of rendering for carcass disposal and the number of rendering lorries entering the farm have been identified as risk factors for other diseases (Rose

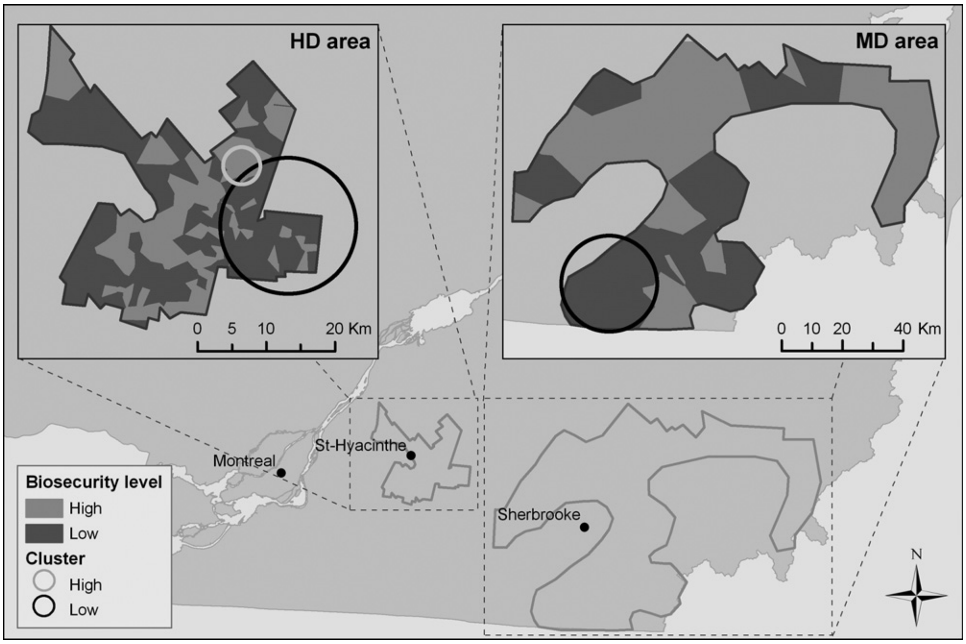

Fig. 1. Geographical distribution of production sites in the high density (HD) and moderate density (MD) areas according to biosecurity levels, high or low. The background map represents the Province of Quebec with the two selected areas along with the major cities.

and Madec, 2002; McQuiston et al., 2005). In contrast, a high level of compliance was observed for pest control. Easier daily implementation, concerns about damage caused by rodents or birds to infrastructure, or a greater awareness of the risk of disease transmission through animal pest vectors may explain this observation.

Breeding sites located in the HD area had in general lower standards of biosecurity. These producers might have already given up following simple biosecurity measures in response to the very high prevalence of PRRSV positive sites (Lambert, 2011). Differences could also partly be attributed to higher sow inventory on sites located in the MD region. Indeed better biosecurity requirements and greater awareness of disease prevention are reported among managers of larger herds compared to smaller ones (Boklund et al., 2003; Ribbens et al., 2008; Noremark et al., 2009). Regional differences in training, technical support and type and age of infrastructure could also exist. The high frequency of sites not purchasing gilts in the HD area may be the result of a higher proportion of herds infected with PRRSV, since one method of controlling PRRSV is to close the herd to reduce viral circulation and stabilize infections within the breeding herd (Schaefer and Morrison, 2007). But the economic losses due to PRRSV in these infected herds might also have precluded the purchase of replacement gilts (Neumann et al., 2005). The lower standard of biosecurity practices observed in this HD area may constitute greater challenge for PRRS control (Vieira et al., 2009). Proximity of pig sites and density of neighbouring pig herds are reported as important risk factors for PRRS, which can contribute to virus dissemination by increasing the likelihood of virus dissemination by aerosols, insect or indirect contacts by vehicles or people involved in the swine industry (Rose and Madec, 2002; Otake et al., 2004, 2010; Ribbens et al., 2009).

In the HD area, a lower level of biosecurity was observed on growing compared to breeding sites. This is possibly related to a higher frequency of all-in all-out flow by site or unit for growing sites. With this type of pig flow, consequences of a PRRSV outbreak would be more limited in time, which may account for a certain laxity in biosecurity requirements (Harris and Alexander, 1999). However, the importance of a good entrance protocol should be emphasized for growing sites in our study since their employees had a high risk of contact with external sources of pigs either from other sites, slaughterhouses or pig transportation.

Breeding sites in pattern B showed generally equivalent or higher biosecurity standards compared to pattern A (Table 4), similar to findings obtained for growing sites regarding the comparison of pattern D versus C. Again a higher biosecurity pattern was observed in sites with larger inventories possibly due to a greater awareness of risk and consequences of disease introduction (Boklund et al., 2003; Noremark et al., 2009). Farrowing and weaner production types were more frequently observed in the higher biosecurity pattern. As a consequence of the advent of early weaning and multi-site production in Quebec, these sites could have more modern infrastructure allowing easier implementation of biosecurity (D'Allaire, 2000) and might have adopted better biosecurity practices to avoid potential economic impact of disease introduction on piglet sales in later stages of production. In both areas, the higher biosecurity pattern was more frequent in breeding sites located farther from the closest pig site or at more than 300 m from public roads. This could be explained by more recent infrastructures where managers consider biosecurity as a whole, which would include farm location as well as specific biosecurity practices.

Characterizing the geographical distribution of sites according to biosecurity patterns may help to target interventions. Clusters of sites with lower biosecurity levels as detected in the two areas revealed zones for which significant improvement in basic biosecurity practices is needed. On the contrary, clusters of sites belonging to the higher biosecurity level could be interpreted as zones in which producers are more inclined to reduce the risk of disease introduction and possibly be more willing to work toward regional control or elimination of disease. However, the high and low biosecurity clusters in the HD area were in the vicinity of each other, making priorities for changes more difficult to determine.

A high percentage of the listed producers of the two areas participated in the survey, which favour a good internal validity of the results. Moreover, some of the ones who could not be reached might have been out of business, resulting in an underestimated participation. The FPPQ list used for selection only records producers having more than $5000 CA of annual income from agriculture; thus very small or hobby farms were probably excluded from our study. These small producers may have lower biosecurity levels and could represent a real threat to larger producers (Costard et al., 2009). Moreover, this investigation mostly included commercial swine operations; higher biosecurity standards are to be expected in multiplier herds.

A single interviewer completed all the questionnaires with people working directly on the site to decrease the potential for information bias. Most questions referred to the current period of time, decreasing recall bias. However, results relied on answers given by the interviewees who might have reported what was expected from them rather than what they were actually doing. To limit the extent of this possibility, confidentiality of answers was assured and the aim of the broader project, which was to assess the importance of biosecurity in relation to PRRS epidemiology, was emphasized. The compliance of workers and visitors with biosecurity protocols was not monitored over time. This could have overestimated the biosecurity level, but would not affect our conclusion regarding the need to enhance preventive measures. In contrast, a partial application of a biosecurity measure was automatically classified as the absence of the measure. Consequently, this would have overvalued the need for biosecurity enhancement. The procedure to classify production sites according to biosecurity involved a statistical criteria (BIC) to avoid subjectivity in choosing the number of clusters, a problem often reported with hierarchical clustering (Everitt et al., 2001). Results obtained are dependent on variables used to perform classification. Therefore, as this investigation of biosecurity practices was driven by PRRS epidemiology, readers should be cautious about extrapolating conclusions from our spatial clusters to regional management of other diseases. Furthermore, the relative impact of specific biosecurity practices on the risk of introduction of PRRSV on a site needs to be assessed in order to prioritize recommendations for biosecurity and to ensure efficacy of regional control or elimination programs against PRRSV.

5. Conclusion

This study described biosecurity measures in two major swine production areas in Quebec. Differences were observed between production types and geographical areas and these should be considered before implementing any control or elimination program against PRRSV. Although a biosecurity plan should be farm specific, a more global approach is necessary as the vicinity of sites with different biosecurity levels adds difficulties in prioritizing interventions. Producers and other swine industry partners should be encouraged to act jointly on disease management since collaboration is essential to the success of any regional control approach. Currently, the relative importance of specific biosecurity practices in reducing the risk of PRRSV transmission and the principal drivers of compliance with rules are poorly understood and warrant further studies.

Conflict of interest

None.

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