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Original Article

Differing perceptions – Swedish farmers' views of infectious disease control

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Abstract

Although farm biosecurity reduces the risk of disease spread among livestock, this knowledge is not always applied. Farmers' application of disease preventive measures is expected to depend on many things, e.g. whether they consider disease prevention possible and demographic factors. In this study, Swedish livestock farmers' perspectives on occurrence, control and communication related to infectious livestock diseases were investigated. A questionnaire study was performed in 2012–2013, and included responses from almost 2000 livestock farmers with cattle, pigs, sheep or goats. Associations between responses and factors related to herd type and demography were investigated using multivariable regression models. Results showed a strong general agreement among farmers that disease prevention is important. However, results also showed differing opinions among farmers. For example, female farmers indicated higher levels of perceived knowledge of disease spread and a stronger belief that they can prevent disease introduction. Results indicate that farmers who believe they have the necessary knowledge, have stronger sense of control and also demand that others take responsibility to prevent spread. Furthermore, dairy farmers were more likely to respond that repeated exposure to infections could be beneficial for animal health. The number of perceived disease outbreaks was also higher among these farmers. Regarding government issued compensation to farmers in case of outbreaks, a wide range of opinions were recorded. Responses confirm that the farm veterinarian is an important source of disease information and several different communication channels are needed to reach farmers. In conclusion, our results show that factors such as gender, education level and age influence how prevention and occurrence of disease outbreaks are perceived and best communicated. We suggest that efforts are made to increase knowledge about disease prevention among farmers and veterinary practitioners and that farm veterinarians should be encouraged to motivate farmers to strengthen farm biosecurity.

Keywords: disease prevention, biosecurity, perceived knowledge, compensation, demographic factors.

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Introduction

Spread of infectious diseases among livestock poses a continuous threat to animal welfare and health, and to the economy of individual farmers. Outbreaks of diseases that are listed and controlled on national or international level may also have consequences for the whole farming industry and have a strong impact on trade with products of animal origin. A universal conclusion is that prevention is better than cure, and this is also incorporated in one of the recent animal health strategies within the EU (Anonymous, 2007). This applies to both endemic and exotic diseases. Although the relative importance of different routes of transmission will depend on the disease in question, a common feature for most infections is that their spread may be influenced by the hygiene routines and biosecurity strategy applied on-farm. The obvious main actor in this part of disease prevention is the farmer. To what extent farmers apply biosecurity routines and are willing to invest time or money in increasing their biosecurity level is expected to depend on many things. One of the basic motivational factors could be whether the farmer considers disease prevention important, or at all possible. In addition, other attitudes and aspects, such as social and political factors, will be of importance (Gunn *et al.* 2008; Heffernan *et al.* 2009; Kristensen & Jakobsen 2011; Lam *et al.* 2011). It is also generally considered that economic factors such as compensation systems or penalties will influence farmers' behaviour in this matter (Lam *et al.* 2011; Ellis-Iversen *et al.* 2010). However, studies have shown that costs are not always the main determinant (Kristensen & Enevoldsen 2008; Hall & Wapenaar 2012).

In Sweden, there is a long-standing tradition to use collective efforts to control infectious diseases in the livestock populations. Examples of diseases that have been eradicated are brucellosis, bovine tuberculosis, infectious bovine rhinotracheitis, bovine viral diarrhoea, Aujeszky's disease and porcine reproductive and respiratory syndrome (Anonymous, 2012). However, even though the disease status on national level seems favourable, studies have shown that this is not necessarily combined with a high biosecurity level in individual farms. On the contrary, Nöremark *et al.* (2010) showed that effective biosecurity routines are missing in many livestock herds. This is in accordance with several findings from other European countries (e.g. Brennan & Christley 2012; Sahlström *et al.* 2014; Sarrazin *et al.* 2014). Results also indicated that some farmers find biosecurity routines unnecessary unless there is an ongoing outbreak. This reasoning ignores the silent phase of disease outbreaks and the ongoing spread of frequently occurring endemic diseases. A questionnaire sent to professionals that regularly visit farms also revealed that when it comes to avoidance of disease spread between farms, the on-farm conditions for visitors to keep good biosecurity are often limited (Nöremark & Sternberg Lewerin 2014). In addition, adequate quarantine measures are infrequently practiced (Nöremark *et al.* 2010) and, considering that movement of live animals is a main route of transmission for many diseases, this is a cause of concern. On the other hand, there is also ongoing work to establish and improve systems to increase on-farm biosecurity, to encourage 'safe' animal trade and to assess and certify the health status of individual herds. For example, this includes the recently launched farm biosecurity programme in Sweden (www.smittsäkra.se) and scoring tools such as Biocheck.ugent® (www.biocheck.ugent.be; Sarrazin *et al.* 2014). In order to successfully advice and motivate Swedish livestock farmers to increase biosecurity and to avoid potential risk behaviour, knowledge about the farmers' opinions and attitudes in these matters is needed.

The objective of this study was to investigate Swedish livestock farmers' opinions and perceptions related to occurrence and control of infectious disease among their livestock. This included views on potential consequences of disease and disease spread, access to information about herds' disease status, ongoing outbreaks and infectious diseases in general. An additional objective was to investigate whether these opinions and perceptions differed between different categories of farmers. The aim was to improve the basic knowledge about the farmers' perspectives in these matters, and thereby improving the basis for future disease prevention and control efforts.

Materials and Methods

The study was part of a larger research project with focus on on-farm biosecurity and prevention of disease spread among livestock in Sweden. The article deals with a selection of topics included in a national questionnaire survey which was preceded by a focus group investigation (not yet published).

Questionnaire construction

In all, the questionnaire was 18 pages long and contained five different parts. This study is based on the three parts that dealt with the farm and the respondent (17 questions), contagious animal diseases and biosecurity (8 questions) and communication and information (5 questions). Additional parts, which are not included in this article, were questions on buildings and cleaning, and questions focusing on behaviour related to providing protective clothing for visitors. The questions were closed, or semi-closed, and space was given for comments. Many questions were phrased as statements where the respondent was asked to indicate their reply on a scale with seven grades. The minimum and maximum of the scale was usually 'do not agree at all' and 'agree completely', respectively. An English translation of the questionnaire, which was originally in Swedish, is available as an electronic supplement to this article. The questionnaire was piloted on nine veterinarians working with disease control, of which some had previous experience from designing questionnaires. In a second phase, it was also piloted on six farmers and other livestock experts working in the field.

Table 1. Total number of holdings, selected farmers and respondents

Species	Holdings in SBA database	Selected farmers	Respondents
Cattle*	21 454	1800	1036
Pigs	1363	600	181
Small ruminants	10 285	800	486
Mixed	891	800	222
No animals or information missing			156
Total	33 993	4000	2081

Number of holdings in the original database, number of farmers in the selected sample and number of respondents, by animal species, in a questionnaire study of farmers' perceptions and opinions related to the occurrence and control of infectious diseases in livestock (Sweden, 2012–2013). *The number of respondents includes 185 dairy farmers that were not selected from the SBA database but were engaged via the Swedish Dairy Association.

Selection of farmers

A data set of all holdings, including information on animal owner, address and registered species, was retrieved from the national database of livestock holdings. Reporting of livestock ownership and holdings is mandatory in Sweden and the database is kept by the Swedish Board of Agriculture. Before selection, holdings without cattle, pigs, sheep or goats, and holdings with more than three of these species, were excluded from the data set. The reason for excluding farms with many species was that a large proportion of these was expected to be special types of farms, e.g. 4-H farms or zoo parks, whose owners were not the target of the questionnaire. Farmers were then selected by random sampling within each category of livestock species. The sample size for each stratum was 1800 cattle farmers, 800 sheep or goat farmers, 600 pig farmers and 800 farmers with animals in more than one of these categories of species. These sample sizes were roughly based on the total number of Swedish farms present within each category (Table 1), the likelihood to get enough responses from each group of farmers, and the financial restraint to include a maximum of 4000 farmers. The distribution and total number of livestock farms and animals in Sweden is reported annually by the Swedish Board of Agriculture and a short summary in English is available online (Anonymous 2012, 2013).

Questionnaire administration

The questionnaires were administered by mail twice, in December 2012 and January 2013. An accompanying letter, which explained the purpose of the study and that participation was voluntary and anonymous, was enclosed. A postage-paid response envelope was attached and farmers were also given the alternative to respond to the questionnaire on the Internet. No incentives were attached except a pen. In addition to the distribution of the questionnaire through postal service, a link to the online version of the questionnaire was sent by e-mail to all dairy cattle farmers that had registered their e-mail address with the Swedish Dairy Association (currently Växa Sweden) as part of their membership in this organisation. This was done to increase the response rate among dairy farmers and was based on the assumption that the members were not different from the average Swedish dairy farmer. In total, 76% (n = 3798) of all dairy farmers in the country were affiliated to the Swedish Dairy Association in 2012 (Anonymous, 2014). The e-mail list was not recently updated but included farmers from approximately 2000 herds.

Data entry and data cleaning

Responses to the paper questionnaire were entered in the electronic version of the questionnaire through single entry, and all data entries were done by one person. Replies from respondents that stated that they do no longer keep livestock were excluded from the final data set. In case of extreme data values, the original questionnaire was checked and erroneous data entries were corrected.

For description and analysis purpose, responses regarding information about the farm were categorised. For cattle, all farms with at least some dairy cows were considered 'dairy'. If suckler cows were reported and the farm had no dairy production, the type of production was instead set to 'suckler'. If no adult cattle were present on a farm, the production type was set to 'specialised beef'. For pigs, breeding herds and gilt-producing herds were merged into one category. If a farm was reported to be breeding but had less than 50 sows, the farm was instead classified as 'multiplying'. Farms that were reported to be the central unit or a satellite unit of a sow pool system were all categorised as 'sow pool system herd', regardless if other production types were also reported. The farm was classified as 'integrated' if both multiplying and fattening production types were reported. Both sheep and goat farms were categorised as 'small ruminants'. If more than one species of livestock were reported present on the farm, the farm category was set to 'mixed'. Presence of animals of other species than cattle, pigs, sheep and goats was ignored in this categorisation. For modelling purposes, the variable 'farm type' was set up to combine species and type of production using the following six categories: 'cattle, dairy', 'cattle, other', 'pigs, piglets' (i.e. including all types with piglets), 'pigs, fattening', 'small ruminants' and 'mixed'. In one of the models, the pig categories of 'farm type' were merged. Depending on associations to the outcome and model fit, type of production was ignored in some models and only a species variable was used.

For categorisation of farm size, different approaches and combination of variables were considered. In the end, the number of persons working fulltime on the farm was considered the best proxy for farm size. Based on the design of this question, missing information was interpreted as zero persons working fulltime. Replies to a question on the expected or planned future development of the farm or its' production were merged into two categories: 'stop or decrease' and 'maintain or increase'. The response alternatives 'the production on the farm has been shut down', 'I am in the process of ceasing production' and 'the number of animals present on the farm will have decreased' were categorised as 'stop or decrease', while 'the production will remain as it is today', 'the number of animals has increased', or 'a successor has taken over' were categorised as 'maintain or increase'. Although 'the production type has been changed' could have been used to indicate expectations of both increased and decreased production, this alternative was placed in the category 'maintain or increase'. Respondents indicated geographical location based on 21 counties, i.e. Nomenclature of Territorial Units for Statistics (NUTS) level 3, but were grouped into eight larger regions (NUTS level 2). In some models, the three most northern regions were merged into one region, and the Stockholm region was merged with the East Middle Sweden region (in total five regions, Table 3).

Statistical analysis and software

The questionnaire was designed and administered online using the web survey software EasyResearch (QuestBack International HQ, Oslo, Norway). Data were managed and analysed using Stata (StataCorp 2013, Stata Statistical Software: Release 13, College Station, TX; StataCorp LP) and descriptive statistics were obtained for all questions in the questionnaire. Five of the questions (specified in the Results section) were chosen to be further investigated using regression analysis. Associations between question replies and demographic variables (such as species, farm size, age of the respondent, etc.) were investigated by chi-squared tests (Pearson's chi-square test or Fisher's exact test), Wilcoxon rank-sum tests and univariable-ordered logistic regression. Variables of potential interest ($P < 0.25$) were included as explanatory variables in multivariable models, where variables were manually removed and reintroduced in a stepwise process until all remaining variables showed a significant association ($P < 0.05$) to the outcome. Interactions between variables were not included. The fit of alternative models was compared by calculation of the Akaike's information criterion and the Bayesian information criterion. Models were not accepted as final if collinearity between variables or violation of the proportional odds assumption was indicated. In Stata, perfect collinearity between variables in a model is automatically tested and adjusted for as part of the regression command. However, collinearity diagnostic measures such as the variance inflation factor were also investigated. The proportional odds assumption of the models was tested using Brant's test. For some models, outcome categories were merged into a smaller number of categories in order to meet this assumption.

Results

Response

In total, the number of replies to the questionnaire was 2081. There were 1923 replies to the questionnaire administered by postal service, and 1863 (97%) of these were sent in by post, while 60 (3%) were filled in online. The number of replies filled in online in response to the questionnaire link sent by e-mail to the dairy farmers of the Swedish Dairy Association was 185. The total number of replies by species category is shown in Table 1.

Demographic description of respondents

The questionnaire replies from respondents that reported at least one animal of the relevant species on the farm (n = 1925) was included in a data set for further analysis. The reported number of animals on the farms is summarised by species and animal category in Table 2. In total, the numbers of farms for each farm type were: cattle farms, n = 1036; pig farms, n = 181; sheep or goat farms, n = 486; and mixed farms, n = 222. The number of farms within each region is summarised in Table 3. The geographical distribution of replies corresponded roughly to the distribution of farms in the country, with more and relatively larger farms in the south part. A farmer with cattle was the most frequent type of

Table 2. Respondents' herd sizes by production type of the animals

Production type	Number of herds	Number of animal units			Animal unit
		Average	Min	Max	
Cattle					
Dairy	452	79.7	1	600	Dairy cows
Beef, suckler	576	22.7	1	220	Cows
Beef, calves for slaughter	134	48.6	1	750	Slaughtered cattle per year
Other	89	31.7	1	800	Cattle
Total	1251				
Pigs					
Breeding	10	196.1	75	380	Sows
Multiplying	48	200.1	1	1000	Sows
Pool	22				
Nucleus		1480.0	700	2500	Sows
Satellite		5910.5	800	17 000	Piglets per year
Integrated	60	215.9	1	800	Sows
Slaughter	76	3306.3	1	19 000	Slaughtered pigs per year
Total	216				
Small ruminants					
Sheep	623	29.2	1	1108	Ewes
Goats	63	17.0	1	500	Goats
Total	686				

Number of herds with average number of animal units by species and production type in a questionnaire study of farmers' perceptions and opinions related to the occurrence and control of infectious diseases in livestock (Sweden, 2012–2013).

Table 3. Regional distribution of respondents

Region categories (merged categories)	(NUTS2)	Number of respondents (*n*)	(%)
North	Upper Norrland	66	3.4
	Middle Norrland	132	6.9
	North Middle Sweden	181	9.4
East Middle	East Middle Sweden	342	17.8
	Stockholm	42	2.2
West	West Sweden	484	25.1
South East	Småland and the islands	371	19.3
South	South Sweden	292	15.2
Information missing		15	0.8
Total		1925	100.0

Number of farmers, in different regions of Sweden, responding to a questionnaire study of farmers' perceptions and opinions related to the occurrence and control of infectious diseases in livestock (Sweden, 2012–2013).

respondent from all regions (approximately 45–60%) and two thirds of respondents with pig herds were located in South Sweden or West Sweden. The number of persons working fulltime on the farm was less than one in 52% of the farms. The 95th percentile and maximum number of persons working fulltime were 3 and 14, respectively. According to the majority of respondents, their farm production would remain the same (47%) or increase (19%) in the next 5 years. Almost one-third (27%) believed that their production would decrease or stop within 5 years.

The majority of respondents were owners of the farm (93%). Overall, the proportions of men and women were 70% and 25%, respectively. However, the proportions differed by farm type and for sheep and goat farms almost half of the respondents (46%) were women. In addition, the education level of respondents varied by gender. For example, 40% of female respondents and 21% of male respondents had a higher education (university or equivalent). In total, 45% had an education focused on agriculture. Most respondents (29%) were 51–60 years old and 74% were 41–70 years old. The majority of respondents (78%) had worked with their current species of animals for more than 10 years. According to 37% of respondents, the purpose of their livestock production, or employment at a livestock farm, was to make a living, while 24% responded that their livestock farming was pure hobby. The purpose of livestock farming differed between species, where the majority of cattle farmers (52%) and pig farmers (76%) had their production to make a living, while only 6% of sheep and goat farmers kept their animals for this purpose. Instead, 56% of sheep and goat farmers indicated that their animal production was pure hobby.

Replies to questions on disease control

A vast majority (89%) of the respondents agreed completely with the statement 'To keep the herd free from infectious diseases is very important to me'. The proportions of respondents that agreed completely with the statements 'If infectious disease would spread from my herd to other herds, there would be negative consequences for me' and 'An outbreak of infectious disease in my herd would have negative effects on my economy' were also large, 72% and 76%, respectively. Results from statistical analysis of each of the remaining five questions on disease control, related to demographic factors, are given for each question below and in Tables 4–8.

If the animals are regularly exposed to infections they will become more resistant and have less disease

Compared to farmers with dairy cattle, all other types of farmers agreed less to this statement ($P < 0.001$). There were also differences between female and male farmers, where male farmers indicated a stronger agreement to this statement (OR = 1.3, $P = 0.022$). Respondents' production purpose, i.e. indicated degree of making a living from livestock production, was associated with the outcome, but to a slightly smaller degree (OR = 1.1, $P = 0.023$). Future plans of production, age and education level were all close to significant, but not included in the final multivariable model (Fig. 1a, Table 4).

Has the farm experienced an outbreak of infectious disease that seriously affected the animals or production?

Based on multivariable regression, farm type seemed to influence whether the farm had experienced out-

Table 4. Opinion on infection exposure and effects on animal health

Explanatory variable tested Category	OR	95% confidence interval		P-value[‡]
Farm type				<0.001
Cattle, dairy	Reference category			
Cattle, other	0.41	0.30	0.55	
Pigs, piglets	0.27	0.17	0.42	
Pigs, fattening	0.20	0.11	0.38	
Small ruminants	0.29	0.20	0.42	
Mixed	0.56	0.39	0.80	
Region				*n.s.*
Number of full-time workers				*n.s.*
Future plan of production				*n.s.*
Production purpose*	1.06	1.00	1.11	0.034
Age[†]				*n.s.*
Gender				0.022
Female	Reference category			
Male	1.32	1.04	1.68	
Education level				*n.s.*

Results from a multivariable-ordered regression model used to investigate associations between demographic factors and farmers' agreement with the statement 'If the animals are regularly exposed to infections they will become more resistant and have less disease'. Replies were given on a 7-grade scale ranging from 'totally disagree' to 'agree completely', and was part of the response to a questionnaire study of farmers' perceptions and opinions related to the occurrence and control of infectious diseases in livestock (n = 1651, Sweden, 2012–2013). *Non-significant variables (*n.s.*) were not included in the final model.[†]Degree of making a living from livestock production, 7-grade scale from 'hobby' to 'make a living from production'.[‡]Increase by 10-year categories.

Table 5. Perceived occurrence of outbreaks

Explanatory variable Category	OR	95% Confidence interval		P-value[‡]
Farm type				<0.001
Cattle, dairy	Reference category			
Cattle, other	0.34	0.25	0.47	
Pigs, all types	0.57	0.40	0.82	
Small ruminants	0.28	0.18	0.42	
Mixed	0.51	0.35	0.75	
Region				<0.001
South	Reference category			
South East	0.74	0.52	1.07	
West	1.00	0.72	1.39	
East Middle	0.86	0.60	1.22	
North	0.53	0.37	0.76	
Number of full-time workers				*n.s.*
Future plan of production				*n.s.*
Production purpose*	1.31	1.23	1.39	<0.001
Age[†]				*n.s.*
Gender				*n.s.*
Education level				0.006
Compulsory school (9 years)	Reference category			
Upper secondary school	1.58	1.18	2.11	
University or equivalent	1.60	1.14	2.24	

Results from a multivariable-ordered regression model used to investigate associations between demographic factors and farmers' response to the question 'Has the farm experienced an outbreak of infectious disease that seriously affected the animals or production?' Replies were given on a 7-grade scale ranging from 'never' to 'many times', and was part of the response to a questionnaire study of farmers' perceptions and opinions related to the occurrence and control of infectious diseases in livestock (n = 1755, Sweden, 2012–2013). *Non-significant variables (*n.s.*) were not included in the final model.[†]Degree of making a living from livestock production, 7-grade scale from 'hobby' to 'make a living from production'.[‡]Increase by 10-year categories.

breaks of infectious disease according to the respondent. The indicated trend was that, compared to farms with dairy cattle, all other types of farms, and especially farms with small ruminants, had experienced considerably less outbreaks. In addition to this, the purpose of production was associated to the outcome. Respondents that to a higher extent made a living out of the production were more likely to reply that the farm had experienced an outbreak (OR = 1.3, $P < 0.001$). Moreover, there was a difference between regions ($P < 0.001$) where, in particular, respondents in the north of Sweden indicated less outbreaks compared to other regions (north parts vs. South Sweden; OR = 0.5, $P = 0.001$). Respondents with education levels higher than 9 years of compulsory school were approximately 50% more likely to indicate a higher degree of experienced outbreaks compared to the reference category ($P = 0.006$) (Fig. 1b, Table 5).

Do you know how different infectious diseases spread and what you can do to prevent introduction of infections into the herd?

Region was significantly associated with the perceived level of knowledge as regards spread and prevention of infectious diseases ($P = 0.015$) and, in particular, the region 'Småland and the islands' indicated a lower level of knowledge compared to most other regions. Good knowledge was reported more often by respon-

Table 6. Perceived knowledge of disease control

Explanatory variable Category	OR	95% Confidence interval		P-value[‡]
Farm type				*n.s.*
Region				0.015
South	Reference category			
South East	0.62	0.44	0.88	
West	0.77	0.55	1.08	
East Middle	1.04	0.73	1.50	
North	0.88	0.62	1.26	
Number of full-time workers				*n.s.*
Future plan of production				*n.s.*
Production purpose*	1.20	1.15	1.26	<0.001
Age[†]	1.19	1.09	1.30	<0.001
Gender				<0.001
Female	Reference category			
Male	0.56	0.44	0.73	
Education level				0.024
Compulsory school (9 years)	Reference category			
Upper secondary school	1.13	0.85	1.50	
University or equivalent	1.51	1.10	2.08	

Results from a multivariable-ordered regression model used to investigate associations between demographic factors and farmers' response to the question 'Do you know how different infectious diseases spread and what you can do to prevent introduction of infections into the herd?' Replies were given on a 7-grade scale ranging from 'do not know at all' to 'know very well', and was part of the response to a questionnaire study of farmers' perceptions and opinions related to the occurrence and control of infectious diseases in livestock (n = 1679, Sweden, 2012–2013). *Non-significant variables (*n.s.*) were not included in the final model.[†]-Degree of making a living from livestock production, 7-grade scale from 'hobby' to 'make a living from production'.[‡]Increase by 10-year categories.

Table 7. Perceived ability to control infectious diseases

Explanatory variable Category	OR	95% Confidence interval		*P*-value[‡]
Species on the farm				0.015
Cattle	Reference category			
Pigs	1.69	1.22	2.34	
Small ruminants	1.14	0.91	1.43	
Mixed	1.05	0.78	1.40	
Region				<0.001
South	Reference category			
South East	1.21	0.89	1.64	
West	1.47	1.11	1.96	
East Middle	1.52	1.12	2.05	
North	2.07	1.52	2.83	
Number of full-time workers				*n.s.*
Future plan of production				0.047
Maintain or increase	Reference category			
Stop or decrease	0.82	0.67	1.00	
Production purpose*				*n.s.*
Age[†]				*n.s.*
Gender				<0.001
Female	Reference category			
Male	0.60	0.48	0.75	
Education level				*n.s.*

Results from a multivariable-ordered regression model used to investigate associations between demographic factors and farmers' response to the question 'Do you think that you can influence whether the herd is affected by infectious diseases or not?'. Replies were given on a 7-grade scale ranging from 'No, not at all' to 'Yes, to a high degree', and was part of the response to a questionnaire study of farmers' perceptions and opinions related to the occurrence and control of infectious diseases in livestock (n = 1672, Sweden, 2012–2013). *Non-significant variables (*n.s.*) were not included in the final model.[†]Degree of making a living from livestock production, 7-grade scale from 'hobby' to 'make a living from production'.[‡]Increase by 10-year categories.

dents who to a higher degree made a living out of livestock production (OR = 1.2, $P < 0.001$) and older respondents (OR = 1.2, $P = 0.001$). Compared to women, men perceived their level of knowledge lower (OR = 0.6, $P < 0.001$). In addition to this, respondents with a university education indicated a higher level of knowledge compared to respondents with just 9 years of compulsory school (OR = 1.5, $P = 0.011$) (Fig. 2a, Table 6).

Do you think that you can influence whether the herd is affected by infectious diseases or not?

Among the different farm types, respondents from pig farms were significantly more confident compared to all other farm types (OR = 1.5–1.7, P = 0.002–0.031) that they can influence whether infectious diseases affect their herd or not. There were also statistical differences between regions ($P < 0.001$) where the trend was that respondents were more confident in this matter further north. In addition, the indicated confidence in this matter was higher among female farmers compared to male farmers (OR = 1.7, $P < 0.001$) and among respondents that planned to maintain or increase their production in the future compared to respondents that planned to stop or decrease production (OR = 1.2, $P = 0.047$) (Fig. 2b, Table 7).

Table 8. Opinion on compensations in case of disease outbreaks

Explanatory variable Category	OR	95% Confidence interval		*P*-value
Species on the farm				<0.001
Cattle	Reference category			
Pigs	0.50	0.36	0.70	
Small ruminants	0.68	0.54	0.87	
Mixed	0.92	0.68	1.24	
Region				*n.s.*
Number of full-time workers				*n.s.*
Future plan of production				
Maintain or increase	Reference category			0.005
Stop or decrease	1.37	1.10	1.70	
Production purpose*				*n.s.*
Age†				*n.s.*
Gender				0.015
Female	Reference category			
Male	1.33	1.06	1.68	
Education level				0.006
Compulsory school (9 years)	Reference category			
Upper secondary school	0.73	0.56	0.95	
University or equivalent	0.61	0.45	0.82	

Results from a multivariable-ordered regression model used to investigate associations between demographic factors and farmers' response to the question 'In case of an outbreak, do you think that all affected farmers should get equal compensation levels, whether or not they have routines present to prevent introduction of the disease in question (e.g. through participation in a biosecurity programme)?' Replies were given on a 7-grade scale ranging from 'No, no compensation unless routines' to 'Yes, equal to all', and was part of the response to a questionnaire study of farmers' perceptions and opinions related to the occurrence and control of infectious diseases in livestock (n = 1357, Sweden, 2012–2013). *Degree of making a living from livestock production, 7-grade scale from 'hobby' to 'make a living from production'.†Increase by 10-year categories.

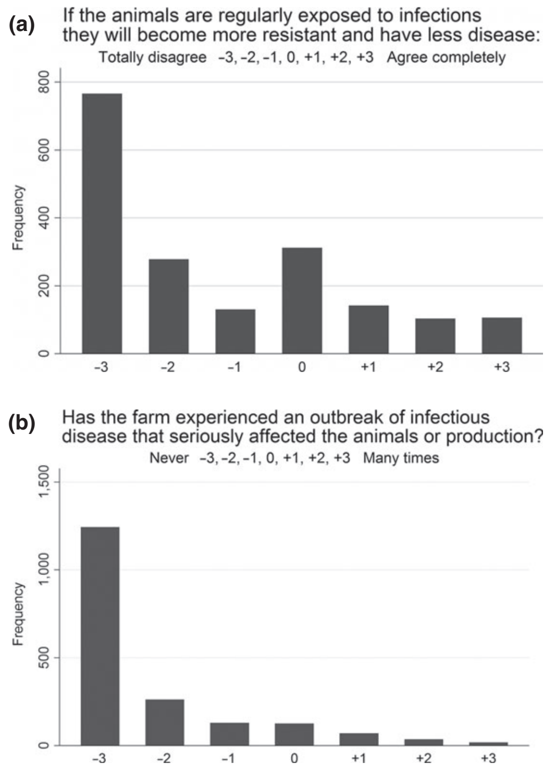

Fig. 1 a-b. Perceived consequences and occurrence of infectious diseases. Distribution of farmers' replies to questions about the consequences and occurrence of infectious diseases in livestock. The survey was based on a questionnaire and included farmers with cattle, pigs or small ruminants from all parts of Sweden (2012–2013). The questions had seven response alternatives, ranging from −3 to +3, where the most extreme alternatives corresponded to different variants of 'completely negative' and 'completely positive', respectively. The exact definitions and questions are given within each graph.

In case of an outbreak, do you think that all affected farmers should get equal compensation levels, whether or not they have routines present to prevent introduction of the disease in question (e.g. through participation in a biosecurity programme)?

A relatively large proportion of respondents (18%) replied that they were uncertain and could not give their opinion in this matter. For this question, declining to give an opinion was significantly associated to gender (men vs. women; OR = 1.6, P = 0.001) and education level (high education vs. basic education; OR = 2.5, P < 0.001). Among the respondents that did give an opinion in this matter, farmers with pigs or small ruminants were less positive to equal compensation compared to cattle farmers (pig farm, OR = 0.5, P < 0.001; sheep or goat farm OR = 0.7, P = 0.002). Male respondents were more positive to equal compensation compared to female respondents (OR = 1.3, P = 0.015) and respondents with a higher education were less positive compared to respondents with just a basic education (OR = 0.6, P = 0.001). Respondents that planned to maintain or increase their production were less positive to equal compensation compared to respondents that planned to decrease or stop their production within 5 years (OR = 0.7, P = 0.005) (Fig. 3, Table 8).

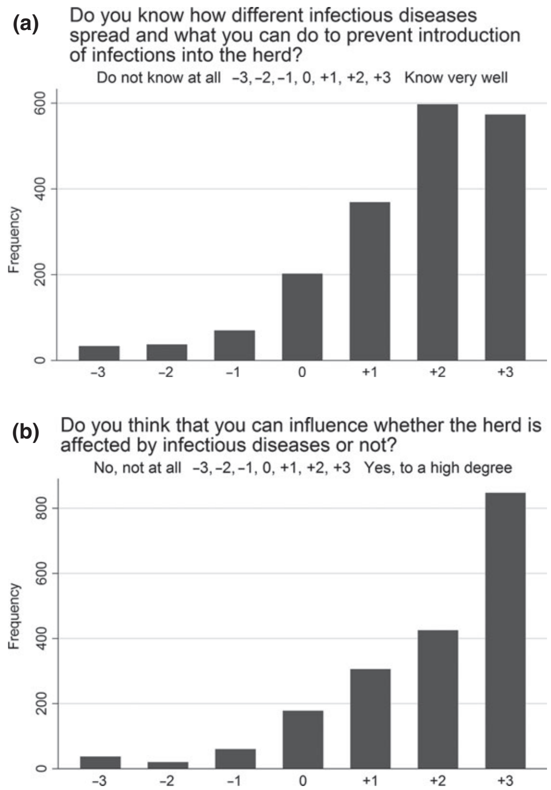

Fig. 2 a-b. Perceived knowledge and control of infectious diseases. Distribution of farmers' replies to questions about knowledge and control of infectious diseases in livestock. The survey was based on a questionnaire and included farmers with cattle, pigs or small ruminants from all parts of Sweden (2012–2013). The questions had seven response alternatives, ranging from −3 to +3, where the most extreme alternatives corresponded to different variants of 'completely negative' and 'completely positive', respectively. The exact definitions and questions are given within each graph.

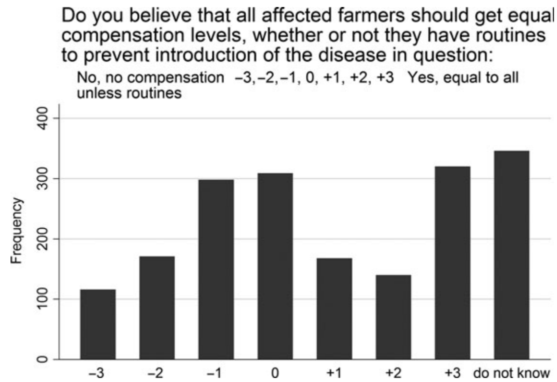

Fig. 3 Opinions on compensations in case of disease outbreaks. Distribution of farmers' replies to a question about disease outbreak compensations related to biosecurity requirements. The survey was based on a questionnaire and included farmers with cattle, pigs or small ruminants from all parts of Sweden (2012–2013). The question had seven response alternatives, ranging from −3 to +3, where the most extreme alternatives corresponded to 'No, no compensation unless routines' and 'Yes, equal to all', respectively.

Replies to questions on communication and information

When farmers were asked how they prefer to get access to information that could help them understand the causes of a disease problem in their herd, most (79%) replied that they prefer discussions with their farm veterinarian. Many also favoured information retrieval from web pages of animal health organisations and associations (40%), or of Swedish authorities and universities (26%). One-third (30%) replied that they would ask their friends, relatives or colleagues, and 22% indicated that they would use industry branch journals and magazines. A national phone line for medical information, which exists for diseases in humans, was considered a potential resource by 19% of respondents. Information source alternatives indicated by approximately 10% or less were short summaries and pamphlets, books and compendia, lectures and courses, video clips online, smart phone applications, web pages of other producers, web pages of insurance companies, conferences and fairs, foreign web pages and other sources.

Considering the scenario that an outbreak of an emerging animal disease was detected in Sweden, a large majority (n = 1558, 81%) replied that an efficient way for authorities to reach them as farmers would be by letters administered through ordinary mail. Other communication channels considered efficient by many farmers were text messages sent by mobile phones (60%), e-mail (52%), radio (50%) or local information meetings (40%). However, for each of these categories a large part of the remaining percentage of respondents was not indifferent, but considered these channels inefficient. Approximately one third or less of the respondents favoured updated information on the web pages of the Swedish Board of Agriculture or the National Veterinary Institute. Social media (such as Twitter or Facebook) or smart phone applications were not popular alternatives, 45% and 37%, respectively, considered these channels inefficient.

Many farmers were positive, and 31% replied that they totally agreed to share the disease status of their herd publicly online. However, there were also many farmers that were unsure or even completely negative (20%) to this. Many farmers considered information about the disease status of other farms useful, however, only ~50% were positive or very positive to this. The majority of farmers in the study indicated that they avoid purchasing animals from herds with an unknown health status, and 62% replied that they would never do this. Result stratification by age category showed a tendency that older farmers are more strict; among the eldest farmers, 78% replied that they would never purchase animals without knowing the disease status of the selling herd. However, among farmers younger than 30 years, this proportion was 45%.

Discussion

This was the first study focused on farmers' views of infectious disease control in Sweden. Some of the results confirm conclusions from studies in other countries, which is interesting considering differences in livestock population structures, diseases present, legislation, traditions, etc. The study also included aspects rarely investigated in scientific studies, such as farmers' general views of the occurrence and consequences of animal infections, and of financial compensation in case of outbreaks. Testing of associations between replies to different questions and demographic factors also identified significant differences in opinions and perceptions among categories of farmers.

One variable that was significantly associated to many of the questions in the survey was gender, which here should be seen as a behavioural and social factor (as opposed to biological sex). In general, female farmers had a stronger tendency to opt for responses indicating a high biosecurity awareness. Although not frequently investigated in studies of veterinary disease control, previous studies have found female participants to be more responsive to health and hygiene information and more likely to perform precautionary behaviour (e.g. Sax *et al.* 2007; Wright *et al.* 2008). In this study, female farmers stated a higher level of perceived knowledge when it comes to disease prevention, compared to male farmers. As a group, they also indicated a higher degree of confidence that they can prevent infectious diseases in their herd. This seems reasonable, as perceived knowledge is likely to increase the sense of personal control. Interestingly, the finding matches results from research on differences in health beliefs and behaviour, where it has been found that men believe less strongly that they have control over their own future health (Courtenay *et al.* 2002). In addition, female farmers were significantly more negative to a strategy where authorities offer equal compensation to all famers in a disease outbreak, irrespectively of their biosecurity routines. This finding probably reflects a connection between the opinion that disease can be prevented and expectations on oneself or fellow farmers to maintain and improve farm biosecurity. Our conclusion is that increasing the perceived disease control knowledge among farmers, regardless of their gender, is likely to strengthen their motivation to actively prevent diseases, and to also contribute to peer pressure on other farmers to do the same.

Peer pressure, or lack of it, can be an important factor in influencing people's behaviour. As for all types of cooperative systems, social or community trust (Wollebæk *et al.* 2012), including expectations on others, is one component in building a successful system for disease prevention. Studies have shown that social trust is particularly high in the Nordic countries (Delhey & Newton 2005). This may have influenced the responses to many of the questions in this questionnaire. Several disease eradication programmes have been performed in the Nordic countries and it is obvious that social factors such as willingness to obey common rules, collaborate and trust in others have contributed to the results. This has been discussed in the context of bovine viral diarrhoea by Heffernan *et al.* (2009). Lack of trust has been identified and suggested as one potential factor behind absence of motivation to apply and improve preventive disease control measures (Gunn *et al.* 2008; Heffernan *et al.* 2008; Elbers *et al.* 2010;

Enticott *et al.* 2012). On the other hand, it should be noted that blind trust, e.g. in trading partners, or in authorities' ability to keep the country free from disease, may not work in favour of disease prevention. In fact, in accordance with conclusions by Wachinger *et al.* (2013), it may lead to the same insufficient on-farm biosecurity as is caused by lack of trust.

The farmers' education level was significantly associated with their opinions and perceptions of biosecurity and similar results have been found in other studies. In a study by Racicot *et al.* (2012), respondents with a higher education had a higher biosecurity compliance, and in a recent study by Laanen *et al.* (2014), farmers with more knowledge about biosecurity were more convinced about its positive effects. Although actual knowledge was not measured in the present study, it can be assumed that the estimated effects of education and of perceived knowledge, as discussed above, to some extent represent an effect of actual knowledge. Results from a study involving farm workers potentially exposed to toxic pesticides also showed that access to information about the hazard increased their perceived control (Arcury *et al.* 2002). A high perceived control was also associated to an increased probability of performing safety behaviour, while level of perceived risk was not. On a similar note, Brennan & Christley (2013) suggest that, in order to take action, producers need to perceive that something is within their capabilities.

As expected, production type and species of animals on the farm also influenced the farmers' opinions and their perception of the risk and occurrence of disease outbreaks. In general, farmers with pigs, and especially those with piglet production, chose response alternatives connected to higher biosecurity awareness. In addition, farmers with dairy cattle often opted for higher biosecurity alternatives, relative to other cattle farmers. This is in accordance with the general perception among veterinarians and with results from previous studies (Nöremark *et al.* 2010; Nöremark & Sternberg Lewerin 2014; Sahlström *et al.* 2014). However, our study reveals that dairy farmers differ considerably from other types of farmers in their high proportion of farmers that consider regular exposure to infections beneficial to animal health. This is particularly interesting considering that many farmers within this category also indicated that their herd had experienced outbreaks that seriously affected the animals or the production. The findings highlight that further work to communicate the negative effects of infections is needed. The findings also highlight that further work is needed to communicate that some infections may have serious economic consequences and that there is a benefit in trying to prevent them.

One question where the responses differed considerably was whether farmers involved in an outbreak of a serious disease should get equal compensation from the authorities, irrespectively of their biosecurity level. One out of four farmers responded that they were uncertain and although a large proportion seems to support equal compensation, a large proportion also indicated a much more negative attitude to such a strategy. This is important information for coming revisions or planning of compensation systems. The finding that farmers that plan to maintain or increase their production leaned more towards the opinion that farmers without biosecurity measures should not have any compensation, may be seen as an indication for the future.

Our results suggest that in order to reach as many farmers as possible during an outbreak, more than one communication alternative is needed. Similar results have been found in other studies (Ellis-Iversen *et al.* 2010; Alarcon *et al.* 2014). In a study from 2008, 11% of Swedish pig farmers responded that they were unaware of a previous outbreak of an exotic disease, even though they had been sent an information letter by the Swedish Boards of Agriculture 6 months earlier (Nöremark *et al.* 2009). Preferred modes of communication are expected to change over time. However, in 2012–2013, Swedish farmers were still negative to using social media for disease outbreak communication. As expected, not only younger farmers were more positive, but also among this group, half of the respondents indicated that social media is a poor communication channel for this purpose. Nevertheless, this may change quickly, especially for some categories of farmers. After the recent detection of avian influenza H5N8 in northern parts of Europe, we observed that information from authorities was linked to and spread through large Facebook groups of Swedish hobby farmers just a few days after it was published online.

Although almost all of the farmers in this study responded that they think it is important to protect their animals from diseases, recent studies have shown that strict biosecurity routines are missing in many herds (Nöremark *et al.* 2010; Nöremark & Sternberg Lewerin 2014). There are different explanations why a gap exists between this type of general statement and a farmer's everyday behaviour, and in recent years, these aspects have gained increasing attention within the field of veterinary epidemiologic research (Gunn *et al.* 2008; Ellis-Iversen *et al.* 2010; Brennan & Christley 2013; Laanen *et al.* 2014). To some degree, farmers will base their decisions on their knowledge about different diseases and how they are spread. Awareness of the positive effects that good biosecurity routines will have on the prevention of disease and the reduction of financial losses is likely to influence farmer's motivation to apply and prioritise such routines. Although many farmers in this study reported that they know how infectious diseases are spread, this did not apply to all. Insufficient knowledge about infectious diseases and biosecurity has been found in other studies (Young *et al.* 2010; Laanen *et al.* 2014). Focus group discussions with Swedish farmers also indicate that knowledge gaps are present and that awareness of the cost of infectious diseases is not to be taken for granted (not yet published). Considering that most farmers responded that they prefer to learn more about animal diseases through discussions with their farm veterinarian, it seems reasonable that this type of information should be mediated through the farm veterinarian. Encouragement of good biosecurity from this category of advisors is also likely to be more efficient, as several studies have shown that farmers trust and listen to their farm veterinarian in these matters (Ellis-Iversen *et al.* 2010; Young *et al.* 2010; Brennan & Christley 2013; Garforth *et al.* 2013; Alarcon *et al.* 2014; Laanen *et al.* 2014). In accordance with conclusions made by other authors (Gunn *et al.* 2008; Hall & Wapenaar 2012; Laanen *et al.* 2014; Sayers *et al.* 2014), we suggest that efforts are focused on updating and improving veterinary practitioners' knowledge about disease prevention and its benefits. Strong arguments considering the cost-benefit and time-saving effects of disease prevention will probably be useful in convincing practitioners to be more pro-active in communicating and motivating farmers to strengthen their disease prevention strategies.

Conclusion

Many Swedish farmers agree that prevention of livestock diseases is beneficial and important. However, type of farm and demographic factors, such as gender and education, influence opinions and perceptions in this matter. Results from this study support previous suggestions that the farmers' knowledge about livestock infections may have an impact on their perceived control and motivation to maintain or improve on-farm biosecurity. Equal compensation in case of serious outbreaks is not supported by all farmers and, in the future, it can be expected that an even higher proportion of farmers are negative to this. Results indicate that efforts should be made to increase the farmers' sense of knowledge and control when it comes to infectious livestock diseases.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

Author Contribution

JF and MN designed and performed the study. The online version of the questionnaire and the response database was set up by MN. Statistical analysis was performed by JF and both authors were involved in the assessment of models and model output. Both authors drafted and critically revised the manuscript.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Output from univariable- and multivariable-ordered regression models used to investigate associations between demographic factors and farmers' replies to a statement considering connections between infection exposure and diseases among livestock (n = 1651, Sweden, 2012–2013).

Table S2. Output from univariable- and multivariable-ordered regression models used to investigate associations between demographic factors and farmers' replies to a question considering occurrence of disease outbreaks in the their herd (n = 1755, Sweden, 2012–2013).

Table S3. Output from univariable- and multivariable-ordered (logistic) regression models used to investigate associations between demographic factors and farmers' replies to a question considering perceived knowledge about prevention of infectious diseases in livestock (n = 1679, Sweden, 2012–2013).

Table S4. Output from univariable- and multivariable-ordered regression models used to investigate associations between demographic factors and farmers' replies to a question considering their potential influence on occurrence of disease outbreaks in the their herd (n = 1672, Sweden, 2012–2013).

Table S5. Output from univariable- and multivariable-ordered regression models used to investigate associations between demographic factors and farmers' replies to a question considering the level of government issued compensation of costs due to livestock disease outbreaks and farmers' application of biosecurity measures (n = 1357, Sweden, 2012–2013).