Department Clinical Research and Veterinary Public Health
Veterinary Public Health Institute
Vetsuisse Faculty University of Bern

Director Head of Institution: Prof. Dr. Gertraud Schüpbach-Regula

Scientific supervision was provided by
Dr. Laura Christina Falzon

Prioritization of zoonotic agents in Switzerland for their surveillance and control

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Nadine Sylvie Stebler

Veterinarian
from Zullwil, SO

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Contents

Summary (English)

There is a constant need to invest in research and surveillance programs to prevent future outbreaks as zoonoses have a significant impact on public health. However, given the limited resources available, it is important to prioritize diseases with respect to their need for control and surveillance. The objectives of this study were (i) to compare two different methods, a Delphi panel and Conjoint Analysis (CA), to elicit expert opinion, and (ii) to compare expert and student opinion using a CA questionnaire, on the prioritization of zoonoses in Switzerland.

Firstly, 28 disease criteria were assessed using a Delphi method. This elicitation process consisted of interviews with 7 experts from the Swiss Food Safety and Veterinary Office (FSVO), where the criteria were ranked along a paper arrow. Secondly, experts (including cantonal physicians and veterinarians, and the experts from the FSVO), as well as students, were asked to weight 8 of these 28 disease criteria through a CA questionnaire. Three different scores were used to rank 16 zoonoses.

For both groups, the most important criterion was “Severity of the disease in humans”. Other criteria were weighted differently depending on the method (Delphi panel vs. CA) and group (expert vs. student) involved.

Our study demonstrated that the weighting of criteria may vary depending on which method is used and the stakeholders involved. However, the ranking of diseases was similar, and this may help with allocation of future resources.

Zusammenfassung (Deutsch)

Zoonosen haben grosse Auswirkungen auf die Gesundheit von Mensch und Tier. Um Ausbrüche zu reduzieren, ist es nötig, in Forschungs- und Überwachungsprogrammen zu investieren. Wegen fehlender Ressourcen ist es wichtig, Krankheiten nach ihrer Wichtigkeit zu priorisieren.

Das Ziel dieser Studie war es, (1) zwei verschiedene Gewichtungsmethoden, ein Delphi Panel sowie eine Conjoint Analyse (CA), zu vergleichen, um die Meinung von Experten zu eruieren, und (2) durch eine CA die Krankheitswahrnehmung von Experten und Studenten gegenüberzustellen.

Als erstes wurden Kriterien zur Krankheitsbeurteilung mittels eines Delphi Panels gewichtet. Hierfür wurden Experten des Bundesamtes für Lebensmittelsicherheit und Veterinärwesen gebeten, die 28 Kriterien gemäss ihrer Wichtigkeit entlang eines Pfeils anzuordnen.

Als nächstes wurden Kantonsärzte und -tierärzte, die Experten aus dem Delphi Panel, sowie Studenten gebeten, 8 dieser 28 Kriterien mittels eines Fragebogens zu gewichten.

Drei verschiedene Gewichtungen wurden eingesetzt, um 16 Zoonosen zu beurteilen.

Beide Gruppen gewichteten das Kriterium „Schweregrad der Krankheit beim Menschen“ am Höchsten. Ansonsten wurden die Kriterien teilweise unterschiedlich beurteilt. Trotzdem waren die Krankheitsranglisten relativ ähnlich.

Unsere Studie zeigte, dass die Meinung der Experten beim Delphi Panel zwar in den Kriteriengewichtungen übereinstimmte, dass aber eine andere Methode die Prioritäten einzelner Krankheiten beträchtlich verändern kann.

Comparison of a modified Delphi panel and Conjoint Analysis questionnaire used for prioritization of zoonotic diseases based on expert opinion in Switzerland

Stebler, N.[1], Schuepbach-Regula, G.[1], Braam, P.[2], Falzon, L.C.[1]

[1]Veterinary Public Health Institute, University of Bern, Schwarzenburgstrasse 155, CH 3097, Liebefeld, Switzerland,

[2] Federal Food Safety and Veterinary Office, Schwarzenburgstrasse 155, CH 3097 Liebefeld, Switzerland.

Corresponding author:

Laura C. Falzon; email: laura.falzon@vetsuisse.unibe.ch; tel: +41 31 631 5733

Abstract

Zoonotic diseases have a significant impact on public health globally, accounting for more than 60% of all communicable diseases causing illness in humans. To prevent or reduce future outbreaks, there is thus a constant need to invest in research and surveillance programs for these zoonotic diseases. However, given the limited resources available, disease prioritization based on the need for their control and surveillance is important. As different prioritization methods have been described, the objective of this study was to compare the use of a semi-quantitative and quantitative research method for the prioritization of zoonotic diseases in Switzerland based on expert opinion.

Twenty-eight criteria relevant for disease control and surveillance were selected based on a literature review, and these were evaluated and weighted by 7 experts from the Swiss Federal Veterinary Office using a semi-quantitative modified Delphi panel. Subsequently, 32 experts, including cantonal physicians and veterinarians, were asked to weight 8 of these 28 disease criteria through a quantitative Conjoint Analysis (CA) questionnaire. Three scores were then used to rank 16 notifiable zoonoses: the median score assigned to each criterion by the experts involved in the Delphi panel; and the importance score of each criterion, and mean utility value of each criterion level, obtained from the CA questionnaire.

The experts involved in the Delphi panel weighted the majority of the criteria similarly, and the top three criteria were “Severity of disease in humans", "Incidence and prevalence of the disease in humans" and "Treatment in humans". Based on these weightings, the three highest ranked diseases were Avian Influenza, Bovine Spongiform Encephalitis (BSE), and Bovine Tuberculosis. The top three criteria, based on the CA questionnaire, were “Severity of disease in humans”, followed by “Economy” and “Treatment in humans”. Using the importance scores, the top three ranked diseases were BSE, Rabies and Nipah Virus Encephalitis, while the top three diseases using the mean utility values were BSE, Echinococcosis and Rabies.

This study illustrates that even though the group of experts may reach an agreement on the weighting of criteria in the modified Delphi panel, using another method to elicit expert opinion can change considerably the priorities of individual diseases. Future research should involve more stakeholders to improve overall representativeness of the weightings assigned to the criteria.

Keywords: semi-quantitative and quantitative research methods; disease control and prevention; zoonoses; health professionals; health priorities

1. Introduction

Zoonoses are defined as bacterial, viral or parasitic infections that are naturally transmitted between vertebrates, including humans (World Health Organization (WHO), 2013). Zoonotic diseases have a significant impact on public health globally, accounting for more than 60% of all communicable diseases causing illness in humans (Jones et al., 2008). Unsurprisingly, about one billion estimated cases of illness, and millions of deaths every year, are caused by endemic zoonoses (Karesh et al., 2012). Furthermore, they negatively impact animal production, and hinder international trade of animals and their products (WHO, 2013).

As resources for research, surveillance, prevention and control of diseases have become more limited in recent years, the need for disease prioritization has been emphasized (WHO, 2006). This is necessary to optimize the efficiency of available resources, and to ensure that these are adequately used for the control of diseases occurring with different frequencies and severities (WHO, 2006; Ng and Sargeant, 2013). The need for prioritization of zoonoses, and other communicable diseases, has been identified by veterinary offices worldwide, and several working groups have recently published their prioritization methods (Havelaar et al., 2010; Mourits et al., 2010; World Organization for Animal Health (OIE), 2010; Balabanova et al., 2011; Humblet et al., 2012; Ng and Sargeant, 2012a; Ng and Sargeant, 2012b). As this prioritization list needs to take into consideration the local situation, including socio-economic and animal health status, and structure of the livestock sector, results published by other countries such as Canada (Ng and Sargeant, 2013), or Germany (Balabanova et al., 2011), cannot be directly extrapolated to Switzerland. It is therefore important that a re-classification of the current list of notifiable zoonoses in Switzerland is performed based on the opinion of Swiss stakeholders.

The prioritization process should be evidence-based and systematic, using objective, transparent and reproducible pre-defined criteria to evaluate each relevant disease (Doherty, 2000). However, identifying relevant criteria and reaching a consensus between all stakeholders regarding their importance may be an arduous task (Aspinall, 2010; Cox et al., 2012), and while several methods have been described, there is still no accepted gold standard.

One described method is the Delphi panel, which seeks to identify a consensus between experts in the field (WHO, 2006). For this qualitative method, the experts are first asked to answer a research question, either individually or within a group discussion, and their responses are noted. Subsequently, each expert is informed of the other experts' responses, and is given the opportunity to revise their own answers based on this feedback. This process is repeated until a consensus is reached (WHO, 2006).

Another method that has recently also been described as a tool for disease prioritization is Conjoint Analysis (CA) (Ng and Sargeant 2012b; 2013). This method was developed in the sixties by the mathematical psychologists Luce and Tukey (Luce and Tukey, 1964), and is often used in the field of marketing and consumer research to obtain information on people's preferences for a certain product. Each product is described by a series of attributes, such as price, size or color, and stakeholders are then asked to choose between products possessing different levels of the same attributes. By choosing one product over another, people inadvertently provide information on which attributes they prioritize (Sawtooth Software Inc., 2013b), and this information can then be used for marketing purposes. The use of CA has also been described within the veterinary field, to obtain information on farmer's opinions and preferences for mastitis control strategies (Valeeva et al., 2007; Mollenhorst et al., 2012), or to elicit information from experts on the relative importance of risk factors concerning communicable animal diseases (Horst et al., 1996; van Schaik, 1998).

Since there is still no accepted gold standard method, various organizations may opt for different methods, leading to sometimes conflicting disease prioritization results depending on which method is used. Nevertheless, there have been no studies comparing the results obtained with the different methods. Therefore, the aims of this study were: (i) to identify criteria relevant for the prioritization of zoonotic diseases; (ii) to compare the weights assigned to these criteria based on expert opinion obtained using a semi-quantitative modified Delphi panel and a quantitative Choice-Based Conjoint Analysis (CBC) questionnaire; and (iii) to illustrate the consequences of different weighting methods by ranking a set of example zoonoses.

2. Materials and Methods

2.1 Selection of the criteria

Initially, a search was performed in PubMed using the search terms "priorit*" and "zoono*"/"disease*", and relevant articles were identified. Subsequently, these articles were reviewed and their references manually searched for additional articles assessing disease prioritization. In total, 38 relevant articles were retrieved (Table 1). From each article, the following information was extracted: (i) the country or organization involved; (ii) the method used; and (iii) the number, levels assigned, and type (qualitative, semi-quantitative or quantitative), of each criterion. This information was then used to compile several possible lists of criteria for disease prioritization, and preference was given to those criteria that were described in numerous papers and/or that were assigned a high weighting score. The goal was to select the minimum number of criteria that sufficiently covered the most important topics concerning the surveillance and control of zoonoses. Following consultation with experts from the Veterinary Public Health Institute at the University of Bern, and from the Swiss Food Safety and Veterinary Office (FSVO), a list with 28 criteria was chosen, and these criteria were classified under 5 main domains: "Burden of disease", "Epidemiology", "Prevention and control measures", "Economy" and "Society" (Table 2).

A five-tiered measurement scale was then developed for each criterion, and the levels for each criterion were defined based on literature (Council of the European Union (EU), 2008; OIE, 2010; O'Brien and Delavergne, 2012), and adapted to the current situation in Switzerland. As an example, the criterion "Severity of disease in humans" was classified as: (1) asymptomatic, very mild course of disease; (2) symptomatic, therapy is recommended, hospitalization is rare; (3) symptomatic, therapy is necessary, hospitalization is rare; (4) severe illness, hospitalization is necessary, fatal if complications, persisting handicaps may occur; and (5) fatal or severe long term damages. A full list of the levels assigned to each criterion may be found in the supplementary material (S1).

2.2. Evaluation and weighting of the criteria using a modified Delphi panel

For the modified Delphi panel, seven veterinarians working at the FSVO were asked to participate in a one-on-one interview. These experts worked in the sectors of animal health, monitoring of epizootics and zoonoses, food safety, knowledge translation and transfer, and communication.

Each of the seven experts was first asked to review the list of 5 main and 28 sub-criteria, to ensure its adequacy and completeness. Following that, the reviewers were asked to weight the relevance of each criterion for the prioritization of zoonoses using a semi-quantitative weighting method. This method is a refined weighting method first proposed by Simos (1990), and further described by Rogers and Bruen (1998), and uses two paper arrows (one with, and one without, a five-point scale) to visualize separately the relative importance of each main and sub-criterion. Specifically, each criterion was written on a separate card and these cards were given to the interviewee in a random order. The cards with the five main criteria were handed out first, and the experts were asked to arrange these criteria along the arrow according to their importance; cards placed closer to the arrowhead were considered more important than cards placed further from the arrowhead. Multiple criteria could be weighted similarly, and the reviewers also had the possibility to leave out criteria if they did not consider them relevant for the prioritization and/or to add any criteria they considered necessary on blank cards made available during the interview. In the first round, the arrow without a scale was used, and this served as a practice run-through so the experts could acquaint themselves with the method and criteria. After this, the blank arrow was replaced with an arrow that had a plotted scale from 1 (not important) to 5 (very important). The experts were once again asked to place the cards with the five main criteria along the plotted arrow, based on their assumed importance, and the score assigned to each criterion was recorded. The same process was repeated with the 28 sub-criteria; the blank arrow was used first to allow the experts to familiarize themselves with the sub-criteria. Subsequently, the blank arrow was replaced with the plotted arrow, and the scores assigned to all the sub-criteria were documented.

When all the seven experts had been interviewed, a personalized report was sent to each expert. This report included the score they had assigned to each criterion, as well as the median and range of each score based on the results from the seven experts. The experts were then given the possibility to revise their answer during a second interview (performed either in person or over the phone), and all changes were documented.

2.3. Weighting of the criteria using Choice-Based Conjoint Analysis

2.3.1. Questionnaire development

A questionnaire based on the CA methodology was developed to obtain weighting scores for each criterion from experts in both the veterinary and human medicine field. Since all criteria assessed must be independent, only 8 of the 5 main and 28 sub-criteria were included in the questionnaire (Table 3). The eight criteria were selected either because they were ranked as important by the seven experts interviewed in the modified Delphi panel (e.g. "Disease incidence" and "Severity of disease"), or because they encompassed several sub-criteria (e.g. "Economy" represented the sub-criteria "Direct and indirect economic costs", "Trade", and "Economic damage in the animal reservoir").

For each of the eight criteria, a three-tiered measurement scale was developed. As an example, the criterion "Treatment in humans" was classified as: (1) treatment lasts up to one week and side-effects are rare; (2) treatment lasts up to two weeks and side-effects are possible; and (3) treatment lasts a month or longer and serious side-effects and long-term damages are possible.

Due to the fairly large number of criteria to be assessed, a partial-profile Choice-Based Conjoint Analysis (CBC) survey was developed using Sawtooth Software CBC version 8.2.4. The partial-profile survey allows one to only assess part of the criteria in each choice task, while ensuring that all criteria are equally represented. The questionnaire contained 25 choice tasks, each comparing two fictitious diseases (Disease A and Disease B) described using four out of the eight criteria, and participants were asked to select the disease which they considered had the higher priority for surveillance and control (see Figure 1 for an example). The disease criteria and levels assessed varied in each choice task.

The questionnaire was pre-tested to assess the number and clarity of choice tasks, and any suggestions were incorporated into the final version. Two versions of the questionnaire were created using Sawtooth Software CBC version 8.2.4, and these were distributed as a paper-and-pencil survey for both logistical and practical reasons; all questionnaires were in German. The questionnaire is available from the corresponding author upon request.

2.3.2 Survey population

The questionnaire was administered in person to the six FSVO experts that participated in the second round of the modified Delphi panel, and to experts from the Federal Office of Public Health (FOPH). Moreover, the questionnaire was sent by mail to all German-speaking and bilingual (German- and French-speaking) Swiss cantonal official veterinarians and official physicians, who are responsible for the cantonal surveillance of animal and human health, respectively.

2.4 Selection and scoring of zoonoses

Sixteen zoonoses defined as either notifiable or emerging by the Swiss Animal Health Ordinance (Swiss Federal Chancellery, 2013), were selected for evaluation in this study. These diseases were selected either because of their current status in Switzerland and in neighbouring countries (such as bovine Tuberculosis which recently re-emerged in Switzerland (Meylan, 2013)), or due to their relative importance in other recently published ranking lists, such as Toxoplasmosis and Nipah virus encephalitis (Havelaar et al., 2010; Humblet et al., 2012; Ng and Sargeant, 2012a). Moreover, these 16 zoonoses represented either the 4 categories of notifiable diseases in Switzerland (i.e. highly infectious diseases; diseases that need to be eradicated; diseases that need to be controlled; and diseases that need to be monitored), or the category of emerging diseases. A list of the 16 diseases, and their respective classification based on the Swiss Animal Health Ordinance, may be found in the supplementary material (S2).

For each of the 16 zoonoses, a severity score from 1 to 5 was assigned independently by two of the authors (NS and LCF) to each of the 28 sub-criteria used in the modified Delphi panel, and the definitions described in Section 2.1 (and S1) were used as guidelines. This was then followed by a consensus process, where each assigned score was compared, and any disagreement was resolved through discussion. The data supporting the scoring decisions included a textbook (Palmer et al., 2013), recently published articles on the topic (e.g. O'Brien and Delavergne, 2012; Ng and Sargeant, 2012a), and official web-sites (FSVO, 2013; FOPH, 2013; OIE, 2013).

2.5. Statistical analysis

2.5.1 Weighting of criteria based on a modified Delphi panel

Descriptive statistics of the weight scores provided by the experts in the two expert surveys were computed using STATA 12.1® (StataCorp LP, Texas, USA). For each criterion, the median, minimum and maximum score were calculated, and the correlation between each expert's first and second scoring was described with the Spearman rank correlation coefficient. A Wilcoxon signed-rank test was then used to check for statistically significant differences between the score assigned to each criterion by the seven experts, and between the median weighting score of each criterion in the first and second round of the interview.

The median score of each criterion, based on the second interview, was used as a weight for the ranking of the zoonotic diseases.

2.5.2 Weighting of criteria based on Choice-Based Conjoint Analysis

Data obtained from each questionnaire were entered into an Excel spreadsheet (Microsoft Office Excel©, 2007), saved as a csv-file, and then imported into Sawtooth Software CBC/HB version 8.2.4. This software uses a Hierarchical Bayes (HB) model to estimate the part-worth utility values (ß) and importance scores of each respondent, based on which of the two diseases described in each choice task was selected for prioritization, and the corresponding attributes and levels used to describe that disease.

The HB model has an upper- and lower-level model; the former models the variation in preference between respondents (between variation) and serves as a prior information, while the latter models the variation between questions answered by the same respondent (within variation), and provides a likelihood. The model then determines posterior probability values based on the most optimal weight of the upper- and lower-level models, and these are equivalent to the mean utility values. These final individual-level parameter estimates represent the relative influence each criterion level had on respondent choices, with higher values indicating a stronger influence on choice.

Importance scores are then estimated for each criterion by dividing the difference between the highest and lowest criterion level mean utility value, by the sum of all mean utility value ranges across all criteria. Therefore, criteria that showed a large range between the different levels were assigned a larger importance score, indicating that these criteria had a stronger influence on which disease was prioritized.

The goodness-of-fit of the model was based on the expected percent certainty and root likelihood (RLH). The expected percent certainty is 0% for a chance model, and 100% for a perfect model, while the expected RLH is 0.5 for a chance model (1 divided by the number of questions, which in this study was 2), and 1.0 for a perfect model.

2.6. Ranking of the zoonotic diseases

Using the severity scores assigned to the zoonoses by the authors (Section 2.4), and the median scores from the modified Delphi panel (Section 2.5.1), and the mean utility values and importance scores from the CBC questionnaire (Section 2.5.2), three separate ranking lists were created (Figure 2).

2.6.1. Ranking of the zoonotic diseases based on a modified Delphi panel

For each zoonotic disease, the weighting score of each criterion (based on the median value assigned to that criteria in the second round) was multiplied by the severity score assigned to that criterion for that disease, and the product for each of the 28 criteria were added up to obtain a final disease score. Since certain criteria were not applicable for some of the diseases (e.g. "risk of disease entry" for diseases already present in Switzerland), a standardized score was created by dividing the final disease score by the maximal possible points. The diseases were then ranked based on this standardized final disease score.

2.6.2. Ranking of the zoonotic diseases based on the Choice-Based Conjoint Analysis

As the CA questionnaire evaluated 8 of the 5 main and 28 sub-criteria, only the severity scores of these 8 criteria were taken into consideration. Moreover, since certain criteria represented several of the original sub-criteria (e.g. "Economy" and "Control and prevention"), a standardized severity score was first created by adding the severity scores assigned to each of the sub-criteria represented by one criterion in the questionnaire, and then dividing this by the number of criteria assessed.

For the mean utility values, a final disease score was created by taking the mean utility value for the level that closest matched the severity score (or standardized severity score for those criteria represented by several sub-criteria) assigned to the eight criteria, for each disease. Since the severity scores were 5-tiered, while the mean utility values were 3-tiered, the intermediate severity scores (2 and 4) were matched with the next higher mean utility value. As an example, if "Disease incidence in humans" was scored as 2 for BSE, then the mean utility value for the middle level of that criterion was selected. The 8 mean utility values (one for each of the eight criteria) were added to create a final disease score, which was then used to rank the 16 zoonotic diseases. To test the uncertainty in the mean utility values, the 95% lower and upper confidence intervals were applied and used to compare the ranking of zoonoses.

For the importance scores, the standardized severity score for each of the eight criteria was multiplied with the respective importance score obtained from the CA questionnaire, and the product for each criterion was added to create a final disease score.

3. Results

3.1 Evaluation and weighting of the criteria using a modified Delphi panel

In the first round of the interview, four experts suggested that "Burden of disease" be differentiated between human and animals, as they considered "Burden of disease in humans" to be more important compared to "Burden of disease in animals". Moreover, the inclusion of "Biology of the agent", "Economy in animals", "Control in animals", "Epidemiology in animals", and "Epidemiology in the environment" were suggested as additional main criteria, each by only one expert. Another reviewer rated the sub-criterion "Knowledge" as very important, and suggested its inclusion as a main criterion.

With regards to the sub-criteria, three experts suggested that "Economic losses" be differentiated between humans and animals, while another expert proposed the addition of "Export" as a sub-criterion. None of the original main or sub-criteria was excluded.

Six of the seven experts participated in the second round of the interview, and all agreed to differentiate between "Burden of disease in humans" and "Burden of disease in animals" resulting in six main criteria; the latter was assigned a median score of 2. None of the other suggested modifications or inclusions was retained as they were not agreed upon by the majority of the experts.

When given the possibility to modify the weighting scores assigned to the criteria in the first round of the interview, only one reviewer made changes that resulted in a statistically significant difference between the scores from the first and second round of the interview ($p=0.0033$). Another three experts adjusted their weightings slightly towards the median score from the first round of the interview, while the other two experts did not change any of their weighting scores. Consequently, there was an overall high degree of correlation ($rho>0.78$) between each experts' first and second scores.

Table 2 presents the 6 main and 28 sub-criteria evaluated, and the median scores assigned, in the second round of the modified Delphi panel. Most criteria were weighted similarly by the different experts (e.g. "Severity of disease in humans", "Treatment in humans", "Prevention in humans"), and the three most important criteria were "Severity of disease in humans" (median score=5), "Incidence and prevalence of the disease in humans" (median score=5), and "Treatment in humans" (median score=4.5). The criteria concerning humans were considered as more important compared to the criteria concerning animals; as an example “Treatment in humans” had a median score of 4.25, compared to “Treatment in animals”, which had a median score of 2 (Table 2). The median of each sub-criterion based on the second interview, was used as the weighting score for the ranking of the diseases, while the median scores of the main criteria were not considered further.

3.2 Weighting of the criteria using a Choice-based Conjoint Analysis questionnaire

3.2.1. Survey population and response rate

The questionnaire was completed by six of the seven experts that participated in the modified Delphi panel, and four experts from the FOPH. Additionally, the questionnaire was completed and returned by mail by 6 out of 19 (31.6%) German-speaking or bilingual cantonal physicians, 14 out of 15 (93%) German-speaking or bilingual cantonal veterinary officers, 1 expert from the FOPH who could not be present on the day of the questionnaire administration, and 1 expert in Virology and Immunology who expressed a direct interest in completing the questionnaire. Of the 32 questionnaires, 4 (12.5%) had a few missing responses (median=3; range=1-6 missing responses). However, due to the small sample size, none of the questionnaires were excluded from the analysis.

Twenty-four mean utility values were estimated (3 levels for each of the 8 criteria), and these values ranged from -71.51 to 67.80 (Table 3). While the mean utility values of the criteria “Economy”, “Control and Prevention” and “Transmission” showed equal increments from one level to another, the mean utility values of ”Treatment in humans”, “Incidence in humans” and “Severity in animals” showed unequal increments, indicating that the level of that attribute played an important part in the prioritization decision.

The importance scores of the 8 criteria ranged from 8.43 to 16.52 (Table 3), and the three most important criteria were “Severity of the disease in humans” (16.52), “Economy” (16.41), and “Therapy in humans” (14.66). The least influential criterion was “Transmission” (8.43).

The overall fit of the model was above satisfactory, with a percent certainty fit of 83.6% and an RLH of 0.85.

3.3. Scoring of the zoonotic diseases

The 16 zoonoses were first scored independently by two of the authors, followed by a consensus process. The authors were in complete agreement for 90% of the scoring. For the remaining 10%, the authors differed by 1 level, in which case the disagreement was resolved through discussion and by looking up specific information in published literature.

3.4. Ranking of the zoonotic diseases

Three different ranking lists were prepared using the different weighting scores: the median score from the second round of the expert interview, and the importance scores and mean utility values from the CBC questionnaire (Table 4). The top three diseases based on the weighting scores from the modified Delphi panel were Avian Influenza, Bovine Spongiform Encephalitis (BSE), and Bovine Tuberculosis. In contrast, the highest ranked diseases based on the importance scores of the CBC questionnaire were BSE, followed by Rabies and Nipah Virus Encephalitis, while the top three diseases based on the mean utility values were BSE, Echinococcosis and Rabies.

The five least important diseases for prioritization based on the ranking list using the median score from the modified Delphi panel were Echinococcosis, New Castle Disease, West Nile Fever, Avian Chlamydiosis and Leptospirosis. When the importance scores from the CBC questionnaire were used, the bottom five diseases were Toxoplasmosis, West Nile Fever, New Castle Disease, Avian Chlamydiosis and Leptospirosis, while the ranking list based on the mean utility values differed slightly from that based on importance scores, with New Castle Disease ranking higher (9^{th} position), and Glanders and Toxoplasmosis ranking lower (14^{th} and 16^{th} position, respectively). When the upper and lower 95% confidence intervals were applied to test the uncertainty in the mean utility values, 9 of the 16 diseases did not change their position in the ranking list, while another 6 diseases moved 1 or 2 positions. Only one disease, Rabies, was ranked four positions lower, moving from the third to the seventh rank.

4. Discussion

In this study, criteria related to zoonotic disease prioritization were first identified, and then evaluated and weighted by several experts in the field using a semi-quantitative and quantitative method. Regardless of the method used, “Severity of the disease in humans” was considered as the most important criterion, while the ranking of the other criteria varied according to which method was used. Consequently, the ranking of the diseases also varied depending on the weighting scores used.

Through the literature search, 38 relevant articles were identified and used to compile the most parsimonious, but sufficiently comprehensible, list of criteria (Tables 1 and 2). When the experts were asked to evaluate the criteria, no criterion was excluded, indicating that all these criteria were considered important for disease assessment. Moreover, the majority of the experts suggested a differentiation between “Burden of disease in humans” and “Burden of disease in animals”. This was not surprising as the former was weighted more than twice as important, compared to the latter, and this is similar to what other studies have found (Council of the European Union (EU), 2008; Cardoen et al., 2009; Cox et al., 2012).

The experts were asked to weight the criteria using a semi-quantitative weighting method, by placing cards with different criteria along a paper arrow. This method was first described for engineering projects (Rogers and Bruen, 1998), but has also been used in the veterinary field, including assessment of on-farm biosecurity measures (Kuster et al., 2013). It allows for an equal weighting of each experts’ opinion through independent one-on-one interviews, thus reducing the risk of over- or under-weighting an individual experts’ opinion based on their behavior in a group discussion. Moreover, the variance in the overall answers is minimized by allowing the experts to re-evaluate their own answers, having regard of the group consensus (Kuster et al., 2013). However, the need for one-on-one interviews may introduce logistical difficulties and could limit the number of participants involved.

In this study, there was an overall good agreement, both between experts and between the first and second round of the modified Delphi panel, and this is similar to findings reported by other studies (Weinberg et al., 1999; O’Brien and Delavergne, 2012; Ng and Sargeant, 2013). Only one of the experts made statistically significant changes between the weightings assigned in the first and second round.

The sub-criteria “Severity of disease in humans”, “Incidence and prevalence in humans” and “Treatment in humans” were considered as the most important, which is in agreement with other studies (Cardoen et al., 2009; Havelaar et al., 2010; Cediel et al., 2013; Ng and Sargeant, 2012a; 2012b; 2013).

The weightings obtained with the modified Delphi panel were compared with those obtained with a CBC questionnaire. The latter method provides a quantitative measurement with confidence intervals. Moreover, it can be administered to a larger study population, increasing the precision and representativeness of the estimates, and it can be used to elicit the respondents’ feelings towards the described criteria and attributes by quantifying subjective knowledge about the attributes (Horst et al., 1998). Another advantage of the CBC questionnaire, compared with the Delphi method, is that it can be done in one session, thus reducing the risk of loss to follow up which may sometimes occur in subsequent rounds of the Delphi panel.

The CA provided two measurements: an importance score for each of the 8 criteria, and 24 mean utility values for each criteria level. The former was equivalent to the weights assigned to the criteria in the modified Delphi panel, while the latter provided more information on the differentiation between criteria levels. Once again, the criterion “Severity in humans” was considered to be the most influential criterion in the decision to prioritize zoonoses. This was followed by the criteria “Economy”, and “Treatment in humans”, while the criterion “Transmission” was considered the least influential. In comparison, the criterion “Treatment in humans” also had a high median score (4.25/5) in the modified Delphi panel, while the economic sub-criteria were ranked in the middle (from 2/5 to 3.75/5). In contrast, the criteria describing the epizootic potential and speed of spread in the modified Delphi panel had a high rating (4/5), dissimilar from that obtained with the CA. These differences between criteria weightings may be explained by the relative importance of each criterion compared to the others, especially since fewer criteria were used in the CA compared to the modified Delphi panel.

The mean utility values often increased with the severity of the levels assigned; however, the difference between levels was not always equal (Table 3). As an example, for the criterion “Treatment in humans”, level 3 (treatment lasts more than 4 weeks) had a much higher influence on choice, compared with level 1 (treatment lasts less than a week) and level 2 (treatment lasts 2 weeks). Similarly, for the criterion “Incidence in humans”, level 2 (incidence in humans in the last 5 years in Switzerland is >500 persons) and level 3 (incidence in humans in the last 5 years in Switzerland is >1000 persons) had a much higher influence on choice, than level 1 (incidence in humans in the last 5 years in Switzerland is <50 persons). On the other hand, the mean utility values for the criterion “Trade” increased constantly from one level to the next, indicating that none of the levels had a much higher influence on choice, compared to the others.

Three different ranking lists were created based on the three different weighting scores (modified Delphi panel, importance scores and mean utility values) (Table 4). When the modified Delphi panel weighting scores were used, the top three ranked diseases were Avian Influenza, BSE and Bovine Tuberculosis. Avian Influenza ranked first because of its epidemiologic characteristics (high speed of spread, high variability of disease, many animal species affected, high persistence in environment), as well as its high impact on economy (trade, indirect economic losses, as well as high economic damage in the animal reservoir). Avian Influenza is ranked among the top five diseases in several other studies (Doherty, 2000, 2006; WHO, 2003; Havelaar et al., 2010; Balabanova et al., 2011; Humblet et al., 2012; Ng and Sargeant, 2012b; 2013; Cediel et al., 2013). In this study, BSE was ranked highly for the main criteria “Burden of disease in humans”, “Economy” and “Society”, as the disease is fatal and no treatment is available. Moreover, BSE has a high impact on the economy because of its high costs for control measures, resulting in high public awareness and social perception. Bovine Spongiform Encephalopathy variant Creutzfeld-Jakob Disease or Transmissible Spongiform Encephalopathies (TSE) are also among the top ten diseases in studies by Horby et al. (2001), Havelaar et al. (2010), and Ng and Sargeant (2012b). Bovine Tuberculosis was ranked third particularly because of its epidemiological characteristics, such as the high number of animal species affected, the bacterium’s persistence in the environment and its epizootic potential. This disease is also ranked highly in several other studies (Doherty, 2000; 2006; Cardoen, 2009; O’Brien and Delavergne, 2012), but was ranked very low in the studies by Ng and Sargeant (2012b, 2013).

When importance scores were used for the ranking process, the top three diseases were BSE, Rabies and Nipah Virus Encephalitis, while using the mean utility values BSE, Echinococcosis and Rabies were the top ranked diseases (Table 4). Rabies, the second or third ranked disease in this study, has also been ranked highly in other studies (Doherty, 2000, 2006; Institut de veille sanitaire, 2010; Balabanova et al., 2011; Ng and Sargeant, 2012b; 2013; Cediel et al., 2013). This disease is fatal once the afflicted person or animal starts to show signs, and there is still no treatment available, which is a likely explanation for its high ranking. Nipah Virus, which was ranked third using importance scores, is a highly pathogenic organism with a high case mortality in humans and animals, and has been classified as a Biosafety Level 4 organism due to its characteristics. A further explanation for the high ranking of Nipah Virus Encephalitis, which is similar to rankings in other studies, is the fact that many aspects of the disease are still unknown or unidentified (Humblet et al., 2012; O'Brien and Delavergne, 2012; Ng and Sargeant, 2012b; 2013). In our study, Echinococcosis received a high weighting (4th and 2nd position based on importance scores and mean utility values, respectively) because of the severity of the disease, the difficult treatment, and the medium to low effectivity of prevention and control measures. While in other studies, Echinococcosis is often ranked in the middle or towards the bottom of the list (Balabanova et al., 2011; O'Brien and Delavergne, 2012; Ng and Sargeant 2012b; 2013; Cediel et al., 2013), it was also classified as "significantly important" in the study by Cardoen et al. (2009). Moreover, *Echinococcus granulosus* and *Echinococcus multilocularis* were recently ranked as the second and third most important foodborne parasites, respectively, in a list compiled jointly by the Food and Agriculture Organization and the WHO, further highlighting the global burden of this disease (Food and Agriculture Organization of the United Nations, 2014).

In all three lists (Table 4), the least important zoonoses were similar (Toxoplasmosis, New Castle Disease, West Nile Fever, Avian Chlamydiosis and Leptospirosis), and this may be due to the low disease burden in humans and animals reported in the literature (Palmer et al., 2013). In other studies, the positions of these diseases vary. As an example, Toxoplasmosis is ranked highly by Cardoen et al. (2009), Institut de veille sanitaire (2010), Havelaar et al. (2010), Balabanova et al. (2011) and Cediel et al. (2013), in the middle by Ng and Sargeant (2012b, 2013), and low by Weinberg et al. (1999) and the WHO (2003).

Differences between the criteria weightings, and consequent ranking lists, were to be expected in this study for several reasons. Firstly, all the experts involved in the modified Delphi panel were animal health experts, while the study population for the questionnaire included both animal and human health professionals. Secondly, the modified Delphi panel and importance scores provided a weighting for each criterion, while the mean utility values were assigned to each criteria level, providing finer resolution information. Lastly, the modified Delphi method assessed 5 (6 in the second round of the interview) main and 28 sub-criteria, while only 8 criteria were assessed with the CBC questionnaire. Using a larger number of criteria allows for a more accurate assessment of the diseases, resulting in a more detailed ranking list. Furthermore, there is the possibility to compare not only the overall ranking list, but also the ranking of the disease main criteria. On the other hand, the use of fewer criteria for disease prioritization allows for a quick disease assessment, making the exercise more practical and accessible. Therefore, the use of importance scores obtained from a CA questionnaire could be a viable option for future disease prioritization processes.

One of this study's limitations was the relatively small sample size used. In the modified Delphi panel, seven (and six in the second interview) experts participated. However, research on qualitative and semi-quantitative studies shows that sample size is not as important as in quantitative studies, as it depends on when data saturation is reached (Mason, 2010). In this study, there was a high level of agreement within the group of experts. This might be explained due to the fact that the experts worked in a similar field of veterinary medicine and environment, resulting in data saturation. Moreover, the use of this semi-quantitative method made it possible to evaluate and further refine the criteria list, which would not have been possible using a quantitative method only. Similarly, the sample size for the CA was smaller than expected, with 32 completed questionnaires. To improve the response rate, e-mail reminders were sent to all participants and, when requested, the questionnaires were re-sent. Nonetheless, when the 95% confidence intervals were applied to the mean utility values, nine diseases did not change ranking position, six diseases changed by one or two ranks, and only one disease, Rabies, moved down by four ranks. This suggests that, despite the small sample size, the overall results were still quite stable, and this is in agreement with a paper published by the Sawtooth Software Company (Sawtooth Software Inc., 2013a), which suggests that HB models can still be effective for small sample sizes. Moreover, the percent certainty and RLH estimate both suggested a more than satisfactory fit of the model.

Overall, the cantonal veterinarians had a much higher response rate than the cantonal physicians (93% vs. 31%). This may be explained by the fact that the veterinarians are more aware of the importance of zoonoses, and were therefore more willing to participate in the study. We recognize that this discrepancy between animal and human health professionals may have influenced the overall weighting scores, as veterinarians were more likely to weight “Economy” as influential, compared to human health professionals. However, given the small sample size, we were unable to perform a stratified analysis for the animal and human health professionals.

Overall, this study provided information on which criteria are relevant for disease prioritization, and their respective weighting. Despite some differences in the results, there was an overall agreement with regards to “Severity of disease in humans” being the most important criterion. These ranking lists can be used by government officials and other stakeholders to prioritize diseases for their surveillance and control, and can be updated depending on the current epidemiological status of the diseases, or as more research information becomes available. Future research should be done to include more stakeholders in the decision-taking process, to make these ranking lists better representative of all Swiss stakeholders.

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Conflict of interest:

The authors declare no conflict of interest.

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Tables

Table 1: The 38 references that were reviewed, including the method used and the number, levels and type of criteria described, for information on criteria relevant for disease prioritization.

Author and Year	Country or Organization	Method	Criteria		
			Number	Levels	Type
Balabanova et al., 2011	Germany	Internal assessment of the pathogens; Delphi method	10	3	Semi-quantitative
Cardoen et al., 2009	Belgium	Workshop; Individual assessment	5	7	Semi-quantitative
Carter et al., 1991	Canada	N/A	12	5	N/A
Cediel et al., 2013	Colombia	Delphi method	12	3	Semi-quantitative
Council of the European Union (EU), 2008	EU	Modified Delphi method	34	5	Semi-quantitative
Cox et al., 2012	Canada	Questionnaire by e-mail; Delphi-like approach	40	2-6	Semi-quantitative
Cox et al., 2013	Canada	Questionnaire by e-mail; Delphi-like approach	40	2-6	Semi-quantitative
Del Rio Vilas et al., 2013	UK	Workshops; Meetings	Multi-criteria decision-analysis with 3 main models	3-5	N/A
Doherty, 2000	Canada	Assessment	10	3-6	Semi-quantitative
Doherty, 2006	Canada	Review of Carter et al. (1991) and Doherty (2000), with slight improvements	10	4-6	Qualitative and Semi-quantitative
Dufour et al., 2011	France	Working group	4	4-10	Qualitative
Gale et al., 2009	UK	Modified Delphi-method; Virus-specific questionnaires	N/A	N/A	N/A
Gauchard et al., 2005	France	Qualitative assessment at 10 group meetings	3	N/A	Qualitative
Havelaar et al., 2010	The Netherlands	Panel discussion; Questionnaire	9	4-5	Quantitative

Horby et al., 2001	UK	Mail questionnaires; Delphi method	5	5	Semi-quantitative
Horst et al., 1996	The Netherlands	Interviews; Conjoint analysis questionnaire	6	2	Dichotomous
Horst et al., 1998	The Netherlands	Workshop with computerized elicitation sessions; ELIcitation	7	2	Dichotomous
Hubert and Haury, 1996	France	Questionnaires; Individual assessment and discussion; Delphi method	7	N/A	Qualitative
Humblet et al., 2012	Belgium	Questionnaire	57	8	Qualitative and Semi-quantitative
Institut de veille sanitaire, 2010	France	Questionnaire; Working group	40	3-5	Qualitative
Kemmeren et al., 2006	The Netherlands	"Outcome trees"	6	N/A	Quantitative
Krause et al., 2008	Germany	Delphi method	12	3	N/A
McKenzie et al., 2007	New Zealand	Rapid Risk Analysis	4	4-6	Semi-quantitative
Morgan et al., 2009	UK	Decision tree; Discussion	3	3-5	Qualitative
Mourits et al., 2010	The Netherlands	Questionnaire; Identification of alternatives; Interviews; Discussion	17	N/A	Quantitative and Qualitative
Ng and Sargeant, 2012a	Canada	Individual identification of criteria; discussion in six focus groups	59	N/A	N/A
Ng and Sargeant, 2012b	North America	Online Adaptive Conjoint Analysis	21	3-4	Semi-quantitative
Ng and Sargeant, 2013	North America	Online Adaptive Conjoint Analysis	21	3-4	Semi-quantitative
O'Brien and Delavergne, 2012	European Technology Platform for Global Animal Health	Workshop; Questionnaire	29-30	5	Semi-quantitative
Palmer et al., 2007	UK	Qualitative decision trees	N/A	2	Qualitative
Ross and Sumner, 2002	Australia	N/A	11		Qualitative and Quantitative

Spencer et al., 2007	North America	Multi-Factorial Risk Prioritization	4	3-5	Quantitative, Semi-quantitative and Qualitative
Surveillance, Zoonoses and Emerging Issues Division, 2006	UK	Workshops	40	2-5	Semi-quantitative
Valenciano, 2002	France	Questionnaire; Discussions; Working group	25	3-4	Quantitative and Qualitative
Weinberg et al., 1999	EU	Modified Delphi method	9	5	Qualitative
World Health Organization, 2003	7 EU Member states	Workshop; Questionnaire; Delphi method	8	5	N/A
World Health Organization (WHO), 2006	WHO	Workshop; Delphi method	5-8	5	Semi-quantitative
World Organization for Animal Health, 2010	OIE	Workshop; Questionnaires; Decision trees	43	2-6	Quantitative and Semi-quantitative

N/A=this information was either not provided in the reference, or not accessible through the University of Bern library.

Table 2: The 28 sub-criteria, classified under 5 main domains ("Burden of disease", "Epidemiology", "Prevention and control measures", "Economy" and "Society"), that were evaluated and weighted (from 1 to 5) by 7 experts involved in a modified Delphi panel on zoonotic disease prioritization in Switzerland.

Criteria	**Weighting score (Median Score from second expert interview)**
Burden of disease	
Burden of disease in humans	**4.25**
Severity of disease in humans, including long-term disability	5
Availability and effectivity of diagnostic tools in humans	3.5
Treatment in humans	4.25
Burden of disease in animals	**2**
Severity of disease in animals	2
Availability and effectivity of diagnostic tools in animals	3
Treatment in animals	2
Impact of disease and control measures on animal welfare and biodiversity	1
Epidemiology	**4**
Number of animal species susceptible to the disease	3
Persistence of the agent in the environment	3
Epizootic potential/potential of spread to susceptible species	4
Probability of introduction, transmission routes	3
Incidence and prevalence in humans in Switzerland and in neighbouring countries	5
Disease trend	4
Incidence and prevalence in animals, including wildlife and vectors	3.75
Speed of disease spread	4
Impact of climate change on animal hosts and vectors, potential of risk change, variability of disease, change of vectors	2
Knowledge	4

Prevention and control measures	**4**
Prevention in humans	4
Prevention in animals	3
Effectiveness of control measures and surveillance in animals	3.5
Biosafety	2.5
Economy	**3.5**
Direct economic losses (cost for each human case)	3
Indirect economic costs	2
Impact on international trade of live animals and animal food products	3.75
Economic damage in animal reservoir (costs for each year)	3.25
Society	**4**
Public awareness	4
Social perception of the disease	3.5
Potential impact on media	3.5

Table 3: The eight criteria used in a Choice-Based Conjoint Analysis questionnaire on zoonotic disease prioritization, and their Relative Rank (based on the Importance Score), the Importance Score (and Standard Deviation), and the Mean Utility Values of each criterion level.

Disease criteria	Relative Rank (based on the Importance Score)	Importance Score (Standard Deviation)	Mean Utility Values (for each level)		
			Level 1	Level 2	Level 3
Severity in humans	1	16.52 (6.39)	-71.51	14.86	56.66
Economy	2	16.41 (5.25)	-67.59	5.65	61.93
Treatment in humans	3	14.66 (4.96)	-41.15	-26.66	67.80
Incidence in humans	4	13.00 (3.87)	-56.54	22.45	34.10
Control and Prevention	5	11.78 (5.26)	32.75	9.01	-41.76
Severity in animals	6	10.53 (4.39)	-44.70	17.42	27.28
Incidence in animals	7	8.67 (5.34)	-32.44	13.22	19.22
Transmission	8	8.43 (4.05)	-17.61	-10.78	28.39

Table 4: The 16 notifiable zoonoses which were ranked using weightings obtained from the modified Delphi panel, and the Importance Scores and Mean Utility Values from a Choice-Based Conjoint Analysis questionnaire based on expert opinion in Switzerland, and the rank difference (relative to Delphi ranking).

Diseases ranked using Median Score (modified Delphi panel)	Rank	Diseases ranked using Importance Scores	Rank difference	Diseases ranked using Mean Utility Values	Rank difference
Avian Influenza	1	Bovine Spongiform Encephalopathy	1	Bovine Spongiform Encephalopathy	1
Bovine Spongiform Encephalopathy	2	Rabies	3	Echinococcosis	10
Bovine Tuberculosis	3	Nipah Virus Encephalitis	3	Rabies	2
Campylobacteriosis	4	Echinococcosis	8	Avian Influenza	-3
Rabies	5	Avian Influenza	-4	Listeriosis	2
Nipah Virus Encephalitis	6	Glanders	4	Salmonellosis	2
Listeriosis	7	Listeriosis	0	Q-Fever	2
Salmonellosis	8	Campylobacteriosis	-4	Bovine Tuberculosis	-5
Q-Fever	9	Bovine Tuberculosis	-6	New Castle Disease	4
Glanders	10	Salmonellosis	-2	Campylobacteriosis	-6
Toxoplasmosis	11	Q-Fever	-2	Nipah Virus Encephalitis	-5
Echinococcosis	12	Toxoplasmosis	-1	Leptospirosis	4
New Castle Disease	13	West Nile Fever	1	West Nile Fever	1
West Nile Fever	14	New Castle Disease	-1	Glanders	-4
Avian Chlamydiosis	15	Avian Chlamydiosis	0	Avian Chlamydiosis	0
Leptospirosis	16	Leptospirosis	0	Toxoplasmosis	-5

Figures

In your opinion, which of these two diseases should be prioritized for control and prevention in Switzerland?

Disease A	**Disease B**
In Switzerland, less than 50 animals had this disease in the past five years, while 500 persons in Switzerland had this disease in the past five years. More than 30 of every 100 human cases are fatal. The control and prevention measures in place for this disease (e.g. vaccination, quarantine) are 95% effective.	In Switzerland, more than 1000 animals had this disease in the last five years, while less than 50 persons in Switzerland had this disease in the past five years. Less than 1 out of every 100 human cases are fatal. The control and prevention measures in place for this disease (e.g. vaccination, quarantine) are 50% effective.

Figure 1: An example of a choice task used in the Choice-Based Conjoint Analysis questionnaire to obtain expert opinion on zoonotic disease prioritization in Switzerland. In each choice task, two fictitious diseases were presented (Disease A and Disease B), each of which was described using different levels of four out of eight criteria; the disease criteria and levels varied in each choice task.

Note: The questionnaire used in this study was in German, and this choice task has been translated into English specifically for publication.

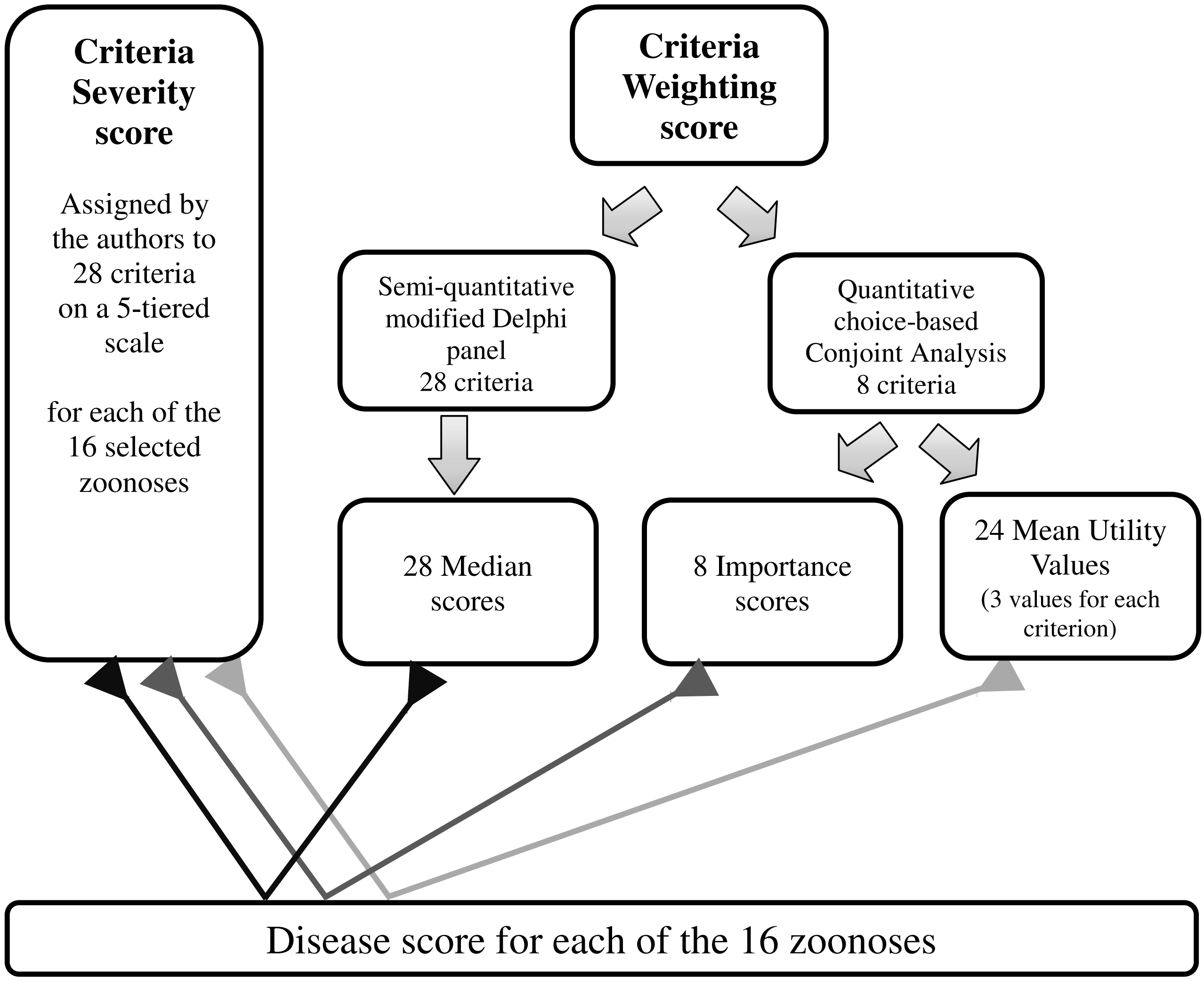

Figure 2: A schematic diagram to illustrate the weighting and prioritization process used for prioritization of zoonotic diseases based on expert opinion in Switzerland. The disease score for each of the zoonosis was obtained by multiplying the severity scores assigned by the authors, with the weighting score obtained from either a semi-quantitative Delphi panel (median scores), or a choice-based Conjoint-Analysis questionnaire (importance scores or mean utility values).

Supplementary information

S1: A list of the 28 criteria that were selected for evaluation and weighting in a modified Delphi panel on zoonotic disease prioritization, and the 5-tiered classifications

	1	**2**	**3**	**4**	**5**
Burden of disease in humans					
Severity of disease in humans, including long-term disability and after effects	Asymptomatic, very mild course of disease, health care utilization is rare, medical treatment is rarely necessary, lack of work <1day, no persisting handicaps case fatality rate <0.01%	Symptomatic, therapy is recommended, hospitalization is rare, lack of work <2 days, persisting handicaps are rare	Symptomatic, therapy is necessary, hospitalization is rare, lack of work <5 days, persisting handicaps are rare	Severe illness, hospitalization is necessary, fatal if complications, persisting handicaps occur	Fatal or severe long term damages
Availability and effectivity of diagnostic tools in humans	None: no tests available, Difficult or unreliable confirmation technique, often only suspected diagnosis, isolation of the pathogen is not possible	Low: diagnosis only in specified laboratories or difficult or unreliable confirmation technique	Medium: laboratory diagnostics, isolation of the pathogen is possible	High: good laboratory diagnostic tests, high sensitivity and specificity	Very high: good diagnostic tests available, clinical signs are pathognomonic and clinical diagnosis is easy and certain
Treatment in humans	Effective treatment, total recovery without relapse, rarely side-effects	Difficult treatment, cost-efficient, total recovery	Long therapy, limited efficacy, cost-intensive, side-effects possible	Long therapy, cost-intensive, side-effects	No effective treatment, antibiotic resistance

Burden of disease in animals					
Severity of disease in animals	Asymptomatic, very mild course of disease, total recovery without veterinary care	Mild clinical signs, good prognosis with or without veterinary care	Severe illness, good prognosis with treatment	Severe illness, increased abortion and infertility, poor prognosis despite therapy	Fatal, herd-level mortality >20%
Availability and effectivity of diagnostic tools in animals	None: no clinical diagnosis, no tests available, isolation of the pathogen is not possible	Low: diagnosis only by highly specified laboratories or difficult/ unreliable confirmation technique	Medium: laboratory diagnostics, isolation of the pathogen is possible	High: good laboratory diagnostic tests, high sensitivity and specificity	Very high: commercial kits at vet/farm level, clinical signs are pathognomonic and clinical diagnosis is easy and certain
Treatment in animals	Effective treatment, total recovery without relapse, rarely side-effects, no pharmaceutical residues	Difficult treatment, cost-efficient, total recovery	Long therapy, limited efficacy, cost-intensive, side-effects possible, withdrawal period, side-effects possible	Long therapy, cost-intensive, side-effects, withdrawal period	No effective treatment, no approved drugs, antibiotic resistance
Impact of disease and measures on animal welfare and biodiversity	None: no significant pain, no wild species affected, no culling, biodiversity is not affected	Unknown	Low: disease-related discomfort or disability caused in animal <5 days, emergency-slaughtered individual animals, endangered wild species may be affected	High: disease-related discomfort or disability caused in animal >5 days, limited slaughter on farms, endangered wild species affected	Very high: Stamping out, significant mortality in wild life, significant threat to animal dependent functions (e.g. pollination)

Epidemiology					
Animal species susceptible to the disease	1	2	Unknown	3	>4
Persistence in environment	No persistence: pathogen never found in wildlife or environment	Rare: pathogen occasionally found	Unknown	Constant: animal reservoir or vector, pathogen found in environment, healthy carriers	Not removable from environment, pathogen in vectors, survival time of the pathogen in the environment >1 year, wildlife is a reservoir
Epizootic potential / potential of spread to susceptible species	Seldom: direct close contact	Possible: contamination by direct contact, risk groups	Medium: transmission by direct or indirect contact, occupational risk	Moderate: transmission by direct or indirect contact, food-borne	High: Vector-borne, air-borne,
Probability of introduction, way of spread	No trade, no tourism, no presence of the disease in adjacent territories	Unknown	Restricted trade/ tourism, existing monitoring programs	High-risk flows with at least one infected or possibly infected country, existing monitoring programs	High-risk flows with at least one infected or possibly infected country, no monitoring programs
Incidence and prevalence in humans; appearance of the disease in Switzerland and in neighbouring countries	Not present in Switzerland and in adjacent territories	Sporadic, incidence <1/100'000	Endemic, incidence 1–10/100'000	Epidemic, emerging, Incidence 10–20/100'000	Epidemic, incidence >20/100’000

Epidemiology (cont'd)					
Disease trend	Diminishing incidence rates for 5 years		Stable incidence rates for 5 years		Increasing incidence rates for 5 years
Incidence and prevalence in animals including wildlife and vectors	Vector / host species are not present in Switzerland or in adjacent territories, disease is not present in Switzerland	Prevalence <10 %, incidence <1/100'000, sporadic, diminishing incidence rates for 5 years	Prevalence 10–20%, incidence 1– 20/100'000, stable incidence rates for 5 years	Prevalence 21–50 %	Prevalence >50%, incidence >20/100'000, host species have contact with humans, increasing incidence rates for 5 years
Speed of spread	Very slow, rarely contagious	Slow with or without animal movement	Unknown	Medium: rapid spread, with or without animal movement, silent spread possible	High: rapid spread without animal movement, pathogen is highly contagious
Impact of climate change on animal hosts and vectors, potential of risk change, variability of disease, change of vectors	1 type, 1 host / vector, not mutating	Few types, not mutating	Few types, not mutating, low host specificity	Numerous types, mutations possible, low host specificity, atypical forms of the disease	Numerous types, numerous vectors, mutations, low host specificity
Knowledge	Very high: aetiology, pathogenesis and epidemiology is known	High: missing details	Moderate: unknown aetiology, known epidemiology	Low: uncertain aetiology, pathogenesis and epidemiology	Limited: emerging disease, no data

Prevention and control measures					
Prevention in humans	High: effective prevention tools or there is no need for prevention		Medium: prevention tools are not very effective or difficult to implement or not established		Low: no prevention tools available or prevention tools are not effective, strong need for further research on preventive measures
Prevention in animals	High: diva vaccine, simple control of animal movement, effective bans, measures efficient	Medium: effective vaccine, effective bans, special movement measures	Low: vaccine preventing carriage and excretion, bans difficult to implement (wildlife) but specific movement measures effective	Very low: vaccine is only limiting clinical expression, no completely immune protection, bans difficult to implement, movement control difficult	None: no vaccine, bans not effective, movement control difficult or ineffective
Effectiveness of control measures and surveillance in animals	High: clinical or pathological surveillance easy, sensitive and specific tests, DIVA vaccine, zoning <1 km	Moderate: clinical surveillance difficult, pathological surveillance possible, sensitive and specific tests, no DIVA vaccine, zoning 1–10 km	Low: clinical and pathological surveillance difficult, tests not sensitive, zoning >10km	Very low: clinical surveillance impossible, pathological surveillance difficult, tests not sensitive or specific, zoning >>10 km	None: clinical and pathological surveillance impossible, no reliable test, zoning not possible
Biosafety	High: simple measures (cleaning, disinfection, limiting and		Low: needs complex measures or useful but moderate		None: unpreventable risk, measures ineffective

	control of contact between animals and the public, isolation of sick and parturient animals)		effectiveness or availability		

Economy					
Direct economic losses: cost for each human case	No loss due to disease, no control measures needed, no increase of the health expenditures, no lack of work	Unknown	Increasing health expenditures, medium costs for control measures, lack of work <5 days		High health expenditures, high costs for control measures, lack of work >5 days
Indirect economic costs	No loss in price, no impact on consumption	Unknown	Low loss in price, low impact on consumption	Price reduced <30% (local)	Loss in price >40%, high impact on consumption, no tourism
Impact on (international) trade in animals and animal/food products	Restrictions only at animal level, no hindrance to movement of animals and animal products, no particular measures for the trade	Restrictions at herd level	Restrictions at zone level, no loss of official status	Zone standstill, loss of official status, short recovery period	Possible nationwide ban / standstill, official disease status, status difficult to recover
Economic damage in animal reservoir: costs per year	<100'000 Swiss Francs: only few animals get ill, control is done at the level of the animal itself, production not affected		100'000–500'000 Swiss francs: farm animals can get ill, control is done at the level of the farm itself, production reduced by less than 5%		500'000-1 Mio. Swiss francs: farm animals can get ill, control is done at national or international level, production reduced by more than 5%

Society					
Public awareness	Low public awareness, low political priority	Low public awareness, informal political expectations	Medium public awareness, informal political expectations	High public awareness, explicit political agendas	High public awareness, international duties, explicit political agendas
Social perception of the disease	Unknown disease	Familiar disease, low level of concern, risk groups	Familiar disease, medium level of concern, risk groups	Familiar disease, high level of concern	Dreaded disease, emerging disease, very high level of concern
Potential impact on media	No recent occurrence of the disease reported in the media, subject discussed positively in the media	Low	Unknown	Disease reported in the media in the last 5 years	Subject under public discussion

S2: The 16 zoonoses that were selected for the ranking process, as classified by the Swiss Animal Health Ordinance (Swiss Federal Chancellery, 2013).

Notifiable Diseases				**Emerging Diseases**
Highly infectious diseases	**Diseases that need to be eradicated**	**Diseases that need to be controlled**	**Diseases that need to be monitored**	
Avian Influenza	Rabies	Leptospirosis	Campylobacteriosis	Nipah Virus Encephalitis
New Castle Disease	Bovine Tuberculosis	Salmonellosis	Echinococcosis	
	Bovine Spongiform Encephalopathy	Avian Chlamydiosis	Listeriosis	
	Glanders		Toxoplasmosis	
			West Nile Fever	
			Q-Fever	

Prioritization of Zoonoses in Switzerland using Conjoint Analysis: A Comparison of Expert and Student opinion

Stebler, N.[1], Schuepbach-Regula, G.[1], Braam, P.,[2] Falzon, L.C.[1]

[1]Veterinary Public Health Institute, University of Bern, Switzerland.

[2]Federal Food Safety and Veterinary Office, Switzerland.

Corresponding author:

Laura C. Falzon; email: laura.falzon@vetsuisse.unibe.ch; tel: +4131 631 5733

Abstract

Disease prioritization exercises have been used by several organizations and national research groups to inform surveillance and control measures, while optimizing resource allocation. Though most methodologies for disease prioritization are based on expert opinion, it is now recognized that health experts and lay people may perceive risks differently. Hence, the objective of this study was to compare the weights assigned to disease criteria, and the consequent prioritization of zoonotic diseases, by both experts and students in Switzerland using a Conjoint Analysis (CA) questionnaire.

The expert group comprised experts from the Federal Food Safety and Veterinary Office, Federal Office of Public Health, cantonal physicians and cantonal veterinarians, while the student group comprised first year veterinary and agronomy students. Eight criteria relevant for disease prioritization were selected following a literature search and expert elicitation. These 8 criteria, described on a 3-tiered scale, were evaluated through a choice-based CA questionnaire with 25 choice tasks. Questionnaire results were analyzed to obtain importance scores (for each criterion) and mean utility values (for each criterion level), and these were then used to rank notifiable or emerging diseases in Switzerland.

The most important criterion for both groups was “Severity of the disease in humans”. For the experts, the criteria “Economy” and “Treatment in humans” were considered the next most important, whereas for the students the criteria “Treatment in humans” and “Incidence of the disease in animals” were ranked in the second and third position, respectively. Regarding the criterion “Control and Prevention”, experts tended to prioritize a disease when the control and preventive measures were described to be 95% effective, while students prioritized a disease if there were almost no control and preventive measures available. Overall, there was a good agreement in the ranking of the diseases based on expert and student opinion, particularly when the importance scores were used. Moreover, Bovine Spongiform Encephalitis was ranked as the most important disease for control and prevention in Switzerland in all ranking lists, regardless of the weighting score or stakeholder opinion used.

Findings from this study indicate that, while experts and students agreed on the weighting of certain criteria such as “Severity” and “Treatment of disease in humans”, they disagreed on others such as “Economy” or “Control and Prevention”. Nonetheless, the overall disease ranking lists were similar, and these may be taken

into consideration when making future decisions regarding resource allocation for disease control and prevention in Switzerland.

Keywords: choice-based Conjoint Analysis; disease risk perception; zoonotic diseases; health professionals; health priorities; stakeholder opinion

1. Introduction

Disease prioritization exercises have been used by several organizations and national research groups to inform surveillance and control measures, while optimizing resource allocation (e.g. World Health Organization (WHO), 2006; Balabanova et al., 2011; Ng and Sargeant, 2012a). These priority setting exercises are a multi-dimensional task as they need to take into consideration several factors which may sometimes be difficult to compare. These factors include clinical factors such as severity of the disease, epidemiological factors such as incidence of the disease, and economical parameters (Morgan et al., 2009; Balabanova et al., 2011).

Most described methodologies for disease prioritization are based on expert opinion (e.g. Horst et al., 1998; WHO, 2003; Krause et al., 2008; Balabanova et al., 2011; Cox et al., 2012, 2013; Del Rio Vilas et al., 2013). In recent years, however, a number of groups have recognized the fact that different stakeholders perceive risks differently, leading to different priorities (Jensen et al., 2005; Wauters and Rojo-Gimeno, 2014). This is of particular relevance when considering the perception of zoonotic diseases, as these may have a large impact on numerous life sectors, including health and economy. Moreover, human behavior may largely affect the cause, spread, prevention, and control of these diseases (Wauters and Rojo-Gimeno, 2014). Consequently, future refinement of priority setting techniques for zoonoses should also incorporate general public values within their assessment (Lomas et al., 2003), particularly of those stakeholders who are directly affected, such as veterinarians and farmers (Ng and Sargeant, 2012a).

A few working groups have already included multiple stakeholder opinions within their zoonotic disease prioritization exercises. In the Netherlands, Havelaar et al. (2010) included both experts, and medicine and veterinary medicine students, in their quantitative priority setting method. More recently, Ng and Sargeant (2012a, 2012b, 2013) included experts and the general public in both the qualitative focus groups to elicit information on which criteria were relevant for disease prioritization, and this was followed by an online Conjoint Analysis (CA) questionnaire to weight these criteria.

Conjoint Analysis is a quantitative method which was first described for the field of marketing and consumer research (Luce and Tukey, 1964). It allows researchers to collect information on people's preferences by asking them to select between products or scenarios described using different levels of relevant attributes, such as price or color. This method has also been used in the veterinary field (Horst et al., 1996; van Schaik and Dijkhuizen, 1998), as it offers the advantage of providing a more precise estimate compared to qualitative methods such as expert panels or focus groups, as a consequence of the larger study groups involved (Ng and Sargeant, 2012b).

In Switzerland, the Swiss Food Safety and Veterinary Office (FSVO) and the cantonal veterinary offices described the need to prioritize zoonotic diseases in the recently published document “Animal Health Strategy 2010+” (Swiss Food Safety and Veterinary Office, 2010). As the prioritization should reflect the opinion of Swiss policy makers and other Swiss stakeholders, thus incorporating the local situation, results published by other countries could not be extrapolated to Switzerland. Priorities in Switzerland might differ from other countries, because herd sizes are smaller compared with other European countries (Swiss Federal Statistical Office, 2010), and because there are many animal movements in consequence of the alpine pasturing (Parker, 1985; Voelk et al., 2014). Moreover, Switzerland is declared as officially free from diseases such as bovine Tuberculosis or Glanders, though the risk of introduction due to the intensive international trade and tourism still persists. It is therefore important to take these differences into consideration when prioritizing diseases for control and surveillance in Switzerland. The aim of this study was to weight disease criteria based on Swiss expert and student opinion obtained through a CA questionnaire, and to use these weighting scores to rank 16 notifiable or emerging diseases in Switzerland.

2. Materials and Methods

2.1. Selection of the criteria used in the prioritization process

The methods for criteria selection have been described by Stebler et al. (submitted), and are summarized schematically in Figure 1. Briefly, 6 main and 28 sub-criteria relevant for disease prioritization were identified following a thorough literature search. These 34 criteria were evaluated and weighted by 6-7 experts in a modified Delphi panel, where each expert was asked to weight the criteria along a paper arrow, based on their assumed importance. All weightings and suggestions made by the experts were noted.

In a second step, 8 of these 34 criteria were selected for inclusion in a Choice-Based Conjoint Analysis (CBC) questionnaire (Table 1). These criteria were selected, either because they were weighted highly by the experts in the modified Delphi panel (e.g. “Incidence of the disease in humans” and “Severity of the disease in humans”), or because they encompassed several of the original 28 sub-criteria (e.g. “Control and prevention”). For each of these eight criteria, a three-tiered measurement scale was developed. As an example, the criterion “Severity of the disease in humans” was classified as: (1) Fatality in humans <1% (2) Fatality in humans = 20%; and (3) Fatality in humans >30%.

2.2. Questionnaire development

A partial-profile CBC questionnaire was developed using Sawtooth Software CBC version 8.2.4. The partial-profile survey allows one to only assess part of the criteria in each choice task, while ensuring that all criteria are equally represented. The questionnaire contained 25 choice tasks, each comparing 2 fictitious diseases (Disease A and Disease B) which were described in a narrative form using 4 out of the 8 criteria. The disease criteria and levels assessed varied in each choice task, and participants were asked to select the disease they considered had the higher priority for surveillance and control. The questionnaire was first pre-tested to assess the number and clarity of choice tasks, and any suggestions were incorporated into the final version. All questionnaires were in German, and they were administered as a paper-and-pencil survey. The strength of design (D-efficiency) calculated for 200 respondents was 806.76604 (relative to a full-profile orthogonal design, where all attributes appear an equal number of time), with a standard error <0.05 for each criterion level. The questionnaire is available from the corresponding author upon request.

2.3. Survey population

The questionnaire was administered to two respondent groups: experts and students.

Specifically for the experts, the questionnaire was administered in person to experts at the Federal Office of Public Health (FOPH) and Federal Food Safety and Veterinary Office (FSVO). In addition, the questionnaire was sent by mail to all German-speaking and bilingual (French- and German-speaking) Swiss cantonal official veterinarians and cantonal official physicians.

The students were represented by first year veterinary students from the Vetsuisse Faculty (at both the University of Bern and University of Zurich), as well as first-year agronomy students from the School of Agricultural, Forest and Food Sciences in Bern. A presentation explaining the purpose of the research project and questionnaire preceded the distribution of the questionnaire. In order to assess whether veterinary training influences the students' opinions regarding priorities, fourth-year veterinary students specializing in Veterinary Public Health were also asked to fill in the questionnaire. All questionnaires were kept anonymous, and a 10 Swiss Francs (8€) voucher was offered as an incentive to all the students who completed the questionnaire.

2.4. Statistical analyses

The responses of the completed questionnaires were entered into two separate Excel spreadsheets (Microsoft Office Excel©, 2007), for the expert and student group respectively, and saved as comma-separated-values-files. These files were then imported into Sawtooth Software CBC/HB version 8.2.4 which uses a Hierarchical Bayes (HB) model to estimate part-worth utility values (ß) and importance scores based on which of the two diseases described in each choice task was selected for prioritization, and the attributes and levels used to describe that disease.

The HB model has an upper- and lower-level model; the former models the variation in preference between respondents (between variation) and serves as a prior information, while the latter models the variation between questions answered by the same respondent (within variation), and provides a likelihood. The model then determines posterior probability values based on the most optimal weight of the upper- and lower-level models, and these are equivalent to the part-worth utility values. These final individual-level parameter estimates represent the relative influence each criterion level had on respondent choices, with higher values indicating a stronger influence on choice.

The importance scores are then calculated by dividing the range between the highest and lowest Mean Utility Value (MUV) of each criterion, by the sum of all MUVs ranges across all criteria. The larger the range between the lowest and highest MUV assigned to a criteria, the larger the importance score and, consequently, the more influence that criterion had on the participants' prioritization choice.

The goodness-of-fit of the model was based on the expected percent certainty and root likelihood (RLH). The expected percent certainty is 0% for a chance model, and 100% for a perfect model, while the expected RLH is 0.5 for a chance model (1 divided by the number of choice tasks, which in this study was 2), and 1.0 for a perfect model.

2.5. Selection and scoring of zoonoses for disease prioritization

As described in Stebler et al. (submitted), 16 zoonoses which represented either one of the four categories of notifiable diseases or the category of emerging diseases in Switzerland (Swiss Federal Chancellery, 2013) were selected for evaluation in this study. These diseases were selected either because of their current status in Switzerland and in neighboring countries, or due to their relative importance in other recently published ranking lists (Havelaar et al., 2010; Humblet et al, 2012; Ng and Sargeant, 2012a).

Each of these 16 zoonoses was evaluated using the 28, 5-tiered, sub-criteria originally developed for the modified Delphi panel (Section 2.1). Scoring was done independently by two of the authors (NS and LCF), and supported by recently published articles on the topic (e.g. O'Brien and Delavergne, 2012; Ng and Sargeant, 2012a), official web-sites (FSVO, 2013; FOPH, 2013; OIE, 2013) and a textbook (Palmer et al., 2013). The severity scores assigned to each criterion, for each disease, were compared during a consensus process between the two authors, and any disagreement was resolved through discussion.

2.6. Ranking of the zoonoses for the disease prioritization exercise

Four zoonotic disease ranking lists were created using the importance scores and MUVs obtained from the CBC questionnaires administered to the expert and student groups, respectively.

For the importance scores, a final disease score was obtained by multiplying the importance score of each of the eight criteria, with the severity score assigned to that criterion for that disease by the authors. Since some of the eight criteria evaluated in the CA questionnaire were represented by several of the original 28 sub-criteria, a mean severity score was first created by adding the severity scores assigned to each of the relevant sub-criteria, and then dividing this by the number of criteria assessed. This mean severity score was then multiplied by the importance score obtained from the CA for that criterion. The sum of the eight criteria were then added together to obtain a final disease score.

For the MUVs, a final disease score was created by taking the MUV for the level that closest matched the severity score (or standardized severity score for those criteria represented by several sub-criteria) assigned to the eight criteria, for each disease. As a three-tiered scale was used in the CA questionnaire, while the diseases were scored on a five-tiered scale, the next highest MUV was assigned for the intermediate severity scores “2” and “4”. As an example, if “Incidence of the disease in humans” for Salmonellosis was assigned a severity score of “4”, the MUV for the highest level of that criterion (i.e. Incidence of disease in humans in the last 5 years is >1000 persons) was selected. The 8 MUVs were added up to create a final disease score, which was then used to rank the 16 zoonotic diseases.

As sensitivity analysis the 95% lower and upper confidence intervals were applied to the MUVs, and any changes in the ranking lists were noted.

3. Results

3.1. Survey population

Thirty two experts participated in this study. These included four experts from the FOPH and six experts from the FSVO. Additionally, the questionnaire was completed and returned by 6 out of 19 (32%) German-speaking cantonal official physicians, 14 out of 15 (93%) German-speaking cantonal veterinary officers, 1 expert from the FOPH who could not be present on the day of the questionnaire administration, and 1 expert in Virology and Immunology who expressed a direct interest in completing the questionnaire. Of these 32 experts, 21 (66%) were male and 11 (34%) were female. The mean age of this group was 52.2 years (range=35 to 65 years).

A total of 215 students completed the questionnaire. Of these, 136 (63%) were first-year veterinary students (of which 60 and 76 students were from the University of Bern and the University of Zurich, respectively), 68 (32%) were first-year agronomy students, 8 (4%) were fourth-year veterinary students specializing in Veterinary Public Health. Of the 212 students, 49 (23%) were male and 163 (77%) were female. The mean age was 21.4 years (range=18 to 37 years).

3.2. Disease criteria Importance Scores and Mean Utility Values based on Expert opinion

The three highest-weighted criteria by experts were “Severity of the disease in humans” (importance score=16.52), followed by “Economy” (importance score=16.41), and “Treatment in humans” (importance score=14.66), while the criterion “Transmission” was the least influential (importance score=8.42) (Table 1).

Twenty-four mean utility values were estimated (3 levels for each of the 8 criteria), and these values ranged from -71.51 to 67.80 (Table 1). Seven of the eight criteria were more likely to be selected when described using the third level, compared to when they were described with the first or second level. Taking “Treatment in humans” as an example, a disease was selected by more experts when it was described using the third level of this criterion (i.e. “Treatment lasts for more than four weeks”; MUV=67.80), compared to when it was described using the first (i.e. “Treatment lasts less than a week”; MUV=-41.15) or second level (i.e. “Treatment lasts two weeks”; MUV=-26.66). The only exception was the criterion “Control and prevention”, where a disease was more likely to be selected by the experts if it was described using the first level of this criterion (i.e. “Measures are 95% effective”; MUV=32.75), as opposed to when it was described using the second (i.e. “Measures are 50% effective”; MUV=9.01) or third level (i.e. “Measures are 5% effective; MUV=–41.76).

The overall fit of the model using expert data was above satisfactory, with a percent certainty fit of 83.6% and an RLH of 0.85.

3.3 Disease criteria Importance Scores and Mean Utility Values based on Student opinion

The three criteria that were weighted highest by the student group were “Severity of the disease in humans” (importance score=17.95), followed by “Treatment in humans” (importance score=15.15), and “Incidence of the disease in animals” (importance score=13.67), while “Economy” was the least influential criteria (importance score=7.80) (Table 1).

The MUVs for the 24 levels ranged from -78.21 to 69.54 (Table 1). For all criteria, the third level always had the highest MUV, suggesting that priority was given to those diseases that were described using the third level. Unlike the experts, this was also the case for the criterion “Control and prevention”, whereby students were more likely to prioritize a disease if it was described using the third level (i.e. “Measures are 5% effective”; MUV=12.37), rather than with the first (i.e. “Measures are 95% effective”; MUV=–14.43) or second level (i.e. “Measures are 50% effective”; MUV=2.06)

For the student group, the model fit was also above satisfactory, with a percent certainty fit of 79.9% and an RLH of 0.8.

3.4. Scoring and ranking of the zoonotic diseases

Table 2 presents the ranking list of the 16 zoonotic diseases based on the importance scores from the expert and student group, and the respective difference in rank. For both groups, the top two diseases were Bovine Spongiform Encephalopathy (BSE) and Rabies, followed by Nipah Virus Encephalitis or Echinococcosis for the expert and student group, respectively. Overall, 4 of the 16 zoonoses had the same rank in both groups, while the remaining 12 zoonoses were ranked within a maximum of two positions of each other.

The ranking list based on the MUVs from the expert and student group, and the respective difference in rank, is presented in Table 3. For both groups, the three most important diseases were BSE, Echinococcosis and Rabies, though the position of the latter two varied depending on the group; Rabies was ranked second based on students' opinion, and third based on expert opinion. Toxoplasmosis was ranked last for both groups. Overall, 3 of the 16 diseases had the same rank in both groups, while 11 diseases were ranked within three positions of each other. For the student group, Nipah Virus Encephalitis ranked four positions lower, and Glanders ranked five positions higher, when compared with the expert group.

When the upper and lower 95% confidence intervals were applied to the MUVs based on expert opinion, 9 of the 16 diseases did not change their position in the ranking list, 6 diseases moved one or two positions, and only 1 disease (Rabies) was ranked 4 positions lower. When the 95% confidence intervals were applied to the MUVs based on student opinion, none of the diseases changed their position in the ranking list.

4. Discussion

In this study, eight criteria related to zoonotic disease prioritization were weighted by health experts and veterinary and agronomy students, using a CBC-questionnaire. For both groups, the criterion "Severity of the disease in humans" was weighted highest. However, other criteria were weighted differently by the two groups: the experts considered "Economy" more important compared to students, while the latter gave more importance to "Incidence of the disease in animals" and "Severity of the disease in animals". A marked difference was also noted in the perception of "Control and Prevention measures" between the two groups. Despite these differences in criteria weighting, the top three ranked diseases were similar, regardless of the group or weighting score used.

Both groups considered "Severity of the disease in humans" as the most important criterion when prioritizing diseases, followed by the criterion "Treatment in humans" (second important criterion for students, and third for experts). The criterion "Severity of the disease in humans" is also highly weighted in several other studies (Cardoen et al., 2009; Havelaar et al., 2010; Cediel et al., 2013, Ng and Sargeant 2012b; 2013), and this is likely because it is a criterion which most people can relate to, regardless of their background or expertise. On the other hand, the weighting of the criterion "Treatment in humans" varies considerably in different studies: it is rated highly in a study from Belgium (Cardoen et al., 2009), in the midrange in a study from Canada and the USA (Ng and Sargeant, 2012a), and as of negligible importance in a study from Colombia (Cediel et al., 2013). The perceived importance of treatment might vary between countries as a consequence of differences in health care systems and accessibility to treatments, or due to differences in societal organizations and institutions as a whole.

Experts weighted "Economy" as the second most important criterion (importance score=16.41), while for the students, it was the least influential criterion (importance score=7.80). This difference between the two groups is not surprising, as experts involved in disease control tend to be more aware of the economic implications of a disease outbreak, compared to the general public or students. Moreover, research has shown that experts often take an objectivist approach to risk management, using quantifiable concepts such as costs to assess and measure risk (Hansen et al., 2003). Therefore, economic components related to disease control would play a more important part in an experts' decision to prioritize a disease or not, compared to other stakeholders, such as students.

On the other hand, students considered "Incidence of the disease in animals" and "Severity of the disease in animals" more important, compared to experts, and these criteria were weighted third and fourth, respectively. We recognize that the population surveyed in this study is skewed, and not necessarily representative of the general population. However, it does offer some insight into how future veterinarians and farmers, both important stakeholders in decisions regarding zoonoses prioritization, may perceive disease control and management strategies. Research has shown that, while some control strategies such as culling may be more economically feasible, their implementation has sometimes failed because farmers might prefer more expensive strategies that safeguard their animals' wellbeing, such as vaccination (Cohen et al., 2007). Therefore, control strategies that do not take the difference in priorities given by different stakeholders and proper risk communication into consideration, might have less support from the general public (Cohen et al., 2007).

Interestingly, experts in this study tended to prioritize a disease when the control and preventive measures were described to be 95% effective, while the students prioritized a disease if there were almost no control and preventive measures available. This further highlights how different stakeholders perceive risks. Experts often take a more managerial and objective stance to risk management, focusing on well-defined and quantifiable criteria to calculate risk rationally. On the other hand, lay people tend to have a more subjectivist perception of disease risk, focusing on those risks that are unknown or not controllable. It is therefore important that experts engage in a two-way communication with, and understand the concerns of other stakeholders involved, to overcome the possible barriers created by different risk perceptions (Hansen, 2014).

Four different ranking lists were created based on the importance scores and MUVs from the expert and student group, respectively. Using the importance scores (Table 2), the top two diseases for both groups were BSE and Rabies, and all the other zoonotic diseases were ranked similarly by both groups, with a maximum rank difference of two positions. This may be explained by the fact that, with a few exceptions (e.g. "Economy" and "Incidence of disease in animals"), the importance scores assigned to the criteria by both groups were similar. Likewise, the top three ranked diseases with the

MUVs (Table 3) were BSE, Rabies and Echinococcosis for both experts and students, and most of the other zoonoses were also ranked similarly. Only Nipah Virus Encephalitis was ranked four positions lower, and Glanders ranked five positions higher, by the student group compared to the expert group. These differences may be attributable to the high weighting given by the students to the criteria related to the severity and incidence of disease in animals.

In general, the ranking lists cannot be compared with the results of other disease prioritization studies. As an example, in this study, Toxoplasmosis was ranked 12th or 16th, respectively. This may be due to the low disease burden in humans and animals reported in the literature (Palmer et al., 2013). In other studies, the position of Toxoplasmosis vary: it is ranked highly by Cardoen et al. (2009), Havelaar et al. (2010), Balabanova et al. (2011) and Cediel et al. (2013), in the middle by Ng and Sargeant (2012b, 2013), and low by the WHO (2003).

One of this study's limitations was the relatively small sample size of the expert group, compared to the student group. Nonetheless, the statistical analysis of a CA using HB models can still be effective for small sample sizes (Sawtooth Software Inc., 2013), and this was demonstrated by the overall fit of the model, which was above satisfactory for both groups. Another limitation is that the student group only comprised veterinary and agronomy students. An attempt was made to recruit students from other disciplines; however, the response rate was very low and the few responses obtained were not analyzed further given the small sample size. Moreover, we recognize that the inclusion of practicing veterinarians and farmers would have been beneficial to the study, but this was not possible due to logistical and financial constraints of this study.

Overall, this study provided information on which criteria are relevant for disease prioritization, and their respective weighting based on both expert and student opinion. The study results indicate that while some criteria were weighted similarly by both groups (e.g. "Severity of the disease in humans" and "Treatment of the disease in humans"), the weighting of other disease criteria (such as "Economy" and "Incidence of disease in animals") varied considerably. Moreover, the perception of "Control and Prevention" measures was dissimilar between the two groups. Nonetheless, the ranking of diseases was similar, especially for the top three diseases, regardless of the weighting score or group. These findings may help with future allocation of resources for disease control and prevention measures.

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Conflict of interest:

The authors declare no conflict of interest.

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Tables

Table 1: The eight criteria (and the three levels used to describe them) included in a Choice-Based Conjoint Analysis questionnaire on zoonotic disease prioritization in Switzerland, and the Rank (based on Importance Score), the Importance Score (and Standard Deviation) and the Mean Utility Values of each criterion level, assigned by the expert and student groups, respectively.

	Experts			Students		
Criteria (and the three levels used to describe them)	**Rank**	**Importance Score (Standard deviation)**	**Mean Utility Value**	**Rank**	**Importance Score (Standard deviation)**	**Mean Utility Value**
Severity of the disease in humans	1	16.52 (6.39)		1	17.95 (5.37)	
Fatality in humans<1%			-71.51			-78.21
Fatality in humans=20%			14.86			13.69
Fatality in humans>30%			56.66			64.52
Economy	2	16.41 (5.25)		8	7.80 (3.78)	
No impact on trade			-67.59			-28.46
Slight restrictions			5.65			2.08
Stand-still			61.93			26.39
Treatment in humans	3	14.66 (4.96)		2	15.15 (5.64)	
Lasts less than 1 week			-41.15			-45.78
Lasts for 2 weeks			-26.66			-23.76
Lasts more than 4 weeks			67.80			69.54
Incidence of the disease in humans	4	13.00 (3.87)		5	12.50 (3.58)	
Incidence in humans in the last 5 years in Switzerland <50 persons			-56.54			-57.29
Incidence in humans in the last 5 years in Switzerland=500 persons			22.45			17.66
Incidence in humans in the last 5 years in Switzerland >1000 persons			34.10			39.63
Control and prevention	5	11.78 (5.26)		6	10.41 (5.66)	
Measures are 95% effective			32.75			-14.43
Measures are 50% effective			9.01			2.06
Measures are 5% effective			-41.76			12.37
Severity of the disease in animals	6	10.53 (4.39)		4	13.00 (4.40)	
Fatality in animals <1%			-44.70			-54.96
Fatality in animals=20%			17.42			8.51
Fatality in animals >30%			27.28			46.45
Incidence of the disease in animals	7	8.67 (5.34)		3	13.67 (5.96)	
Incidence in animals in the last 5 years in Switzerland<50 animals			-32.44			-55.62
Incidence in animals in the last 5 years in Switzerland=500 animals			13.22			5.25
Incidence in animals in the last 5 years in Switzerland>1000 animals			19.22			50.36
Transmission	8	8.43 (4.05)		7	9.53 (4.71)	
By direct contact			-17.61			-23.14
By indirect contact			-10.78			-6.63
Air-borne			28.39			29.78

Table 2: The 16 notifiable zoonoses which were ranked using the Importance Scores obtained from a Choice-Based Conjoint Analysis questionnaire administered to both experts and students, and the relative rank difference, in a study on prioritization of zoonoses in Switzerland.

Rank	**Ranking based on Importance scores from Experts**	**Ranking based on Importance scores from Students**	**Difference in rank (relative to Experts)**
1	Bovine Spongiform Encephalopathy	Bovine Spongiform Encephalopathy	0
2	Rabies	Rabies	0
3	Nipah Virus Encephalitis	Echinococcosis	1
4	Echinococcosis	Glanders	2
5	Avian Influenza	Nipah Virus Encephalitis	-2
6	Glanders	Listeriosis	1
7	Listeriosis	Avian Influenza	-2
8	Campylobacteriosis	Bovine Tuberculosis	1
9	Bovine Tuberculosis	Campylobacteriosis	-1
10	Salmonellosis	Q-Fever	1
11	Q-Fever	Salmonellosis	-1
12	Toxoplasmosis	Toxoplasmosis	0
13	West Nile Fever	West Nile Fever	0
14	New Castle Disease	Avian Chlamydiosis	1
15	Avian Chlamydiosis	Leptospirosis	1
16	Leptospirosis	New Castle Disease	-2

Table 3: The 16 notifiable zoonoses which were ranked using the Mean Utility Values obtained from a Choice-Based Conjoint Analysis questionnaire administered to both experts and students, and the relative rank difference, in a study on prioritization of zoonoses in Switzerland.

Rank	Ranking based on Mean Utility Values from Experts	Ranking based on Mean Utility Values from Students	Difference in rank (relative to Experts)
1	Bovine Spongiform Encephalopathy	Bovine Spongiform Encephalopathy	0
2	Echinococcosis	Rabies	1
3	Rabies	Echinococcosis	-1
4	Avian Influenza	Avian Influenza	0
5	Listeriosis	Salmonellosis	1
6	Salmonellosis	Q-Fever	1
7	Q-Fever	Bovine Tuberculosis	1
8	Bovine Tuberculosis	Listeriosis	-3
9	New Castle Disease	Glanders	5
10	Campylobacteriosis	West Nile Fever	3
11	Nipah Virus Encephalitis	New Castle Disease	-2
12	Leptospirosis	Avian Chlamydiosis	3
13	West Nile Fever	Campylobacteriosis	-3
14	Glanders	Leptospirosis	-2
15	Avian Chlamydiosis	Nipah Virus Encephalitis	-4
16	Toxoplasmosis	Toxoplasmosis	0

Figure

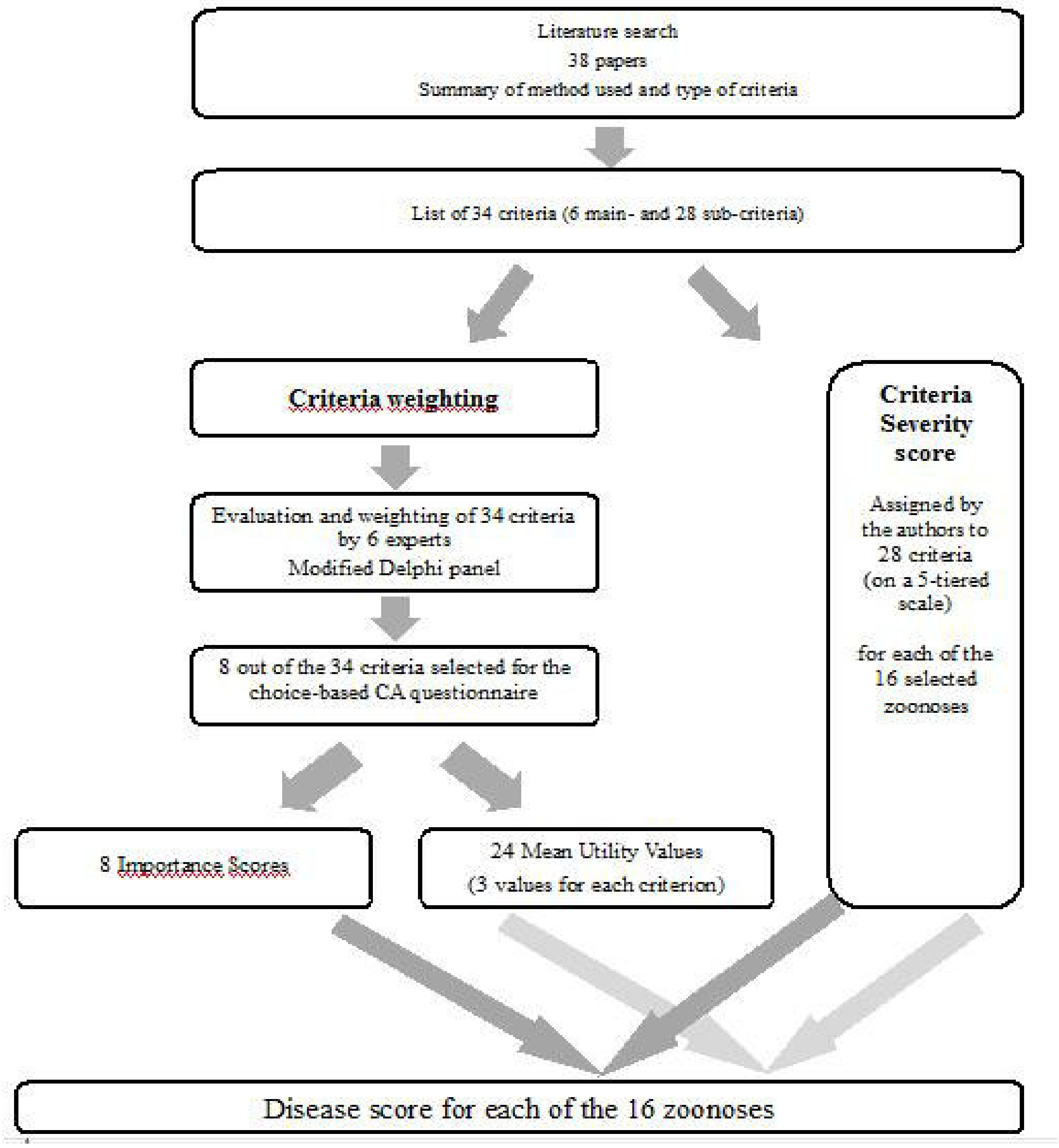

Figure 1: A schematic diagram to illustrate the weighting and prioritization process used for prioritization of zoonotic diseases based on expert and student opinion in Switzerland. The disease score for each zoonosis was obtained by multiplying the severity scores assigned by the authors, with the weighting scores (importance scores or mean utility values) obtained from a choice-based Conjoint-Analysis questionnaire.

Curriculum vitae

Persönliche Daten

Name, Vornamen:	Stebler, Nadine Sylvie
Geburtsdatum:	01.03.1988
Geburtsort:	Basel, BS
Nationalität:	Schweiz
Heimatort:	Zullwil, SO

Schulische Ausbildung

1994-1995	Primarschule, Guilford Primary School, Greensboro, USA
1995 – 1999	Primarschule Allschwil, Schweiz
1999 - 2003	Sekundarschule Allschwil, Schweiz
2003 - 2006	Gymnasium Oberwil, Schweiz
2006	Matura, Gymnasium Oberwil, Schweiz
2007 – 2012	Studium der Veterinärmedizin, Vetsuisse Fakultät Bern, Schweiz
Januar 2013	Staatsexamen als Tierärztin, Vetsuisse Fakultät Bern, Schweiz
März 2013 – November 2014	Anfertigung der Dissertation unter Leitung von Dr. Laura Falzon am Departement Veterinary Public Health der Vetsuisse Fakultät Unitversität Bern. Leitung: Prof. Dr. G. Schüpbach-Regula

Berufliche Tätigkeiten

Juli 2014	Teilzeit-Assistenztierärztin in Tierarztpraxis Allemann, Attiswil, Schweiz