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A cooperative approach to animal disease response activities: Analytical hierarchy process (AHP) and vvIBD in California poultry

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ABSTRACT

Very virulent infectious bursal disease virus (vvIBDv) was first detected in the United States at the end of 2008. Since its detection, Federal and State animal health officials, the poultry industry and the research/academic community have led response activities through a collaborative effort. By June 2011, much still remained unknown regarding the basic epidemiology and ecology of vvIBD in California, although there were a number of potential activities to fill this information gap. Available resources limited the ability to pursue all the activities, and responsible parties and stakeholders recognized the need to prioritize the activities. The analytic hierarchy process (AHP) is a useful multi-criteria decision making methodology that incorporates qualitative information (in the form of judgments) with available quantitative information. This is especially useful when there is very limited quantitative information, such as in the situation with vvIBD in California. A commercial package that allows ready use of the AHP model was utilized for prioritizing activities, incorporating input from members from the three stakeholder groups: State and Federal animal health officials, poultry industry, and research/academia. Based on their inputs on 17 potential activities, the participants identified three priority activities; specifically determination of risk factors for re-emergence or re-introduction at affected premises, development of a laboratory diagnostic test to screen for segment B of the vvIBDV genome and surveillance of other potential reservoirs (mealworms, rodents, beetles). In order to evaluate the ability of the AHP to respond to differences, a sensitivity analysis was done in order to evaluate changes in prioritization of activities. Changes in prioritization were noted demonstrating the plasticity of the model under different conditions. However, a 50% increase or decrease in weighting was necessary to affect the order of the three highest scoring activities. The use of a tool such as the AHP enables the development of a transparent, repeatable and flexible decision process, which can be useful in certain animal health response situations including the re-emergence of a previously eliminated disease or the introduction of a foreign animal disease

1. Introduction

Infectious bursal disease (IBD), also known as Gumboro disease, is a member of the genus *Avibirnavirus* of the family Birnaviridae. The virus causes immunosuppression, disease, and mortality in young chickens (Eterradossi and Saif, 2008). Prevention of viral infection and clinical illness is primarily through vaccination of breeder flocks, subsequent maternal antibody protection of chicks and vaccination(s) of chicks. In the last 20 years, new strains of IBDv marked by hyper-virulent or very virulent forms of disease (vvIBD) have been reported in Europe, Africa, Asia, and South America (van den Berg, 2000; Eterradossi and Saif, 2008; World Organization for Animal Health (OIE), 2012).

Very virulent infectious bursal disease virus (vvIBDv) was detected for the first time in the United States in December 2008 in a California commercial poultry flock (Stoute et al., 2009). In a multi-pronged approach, State and Federal animal health officials,

Abbreviations: AHP, analytical hierarchy process; CDFA, California department of food and agriculture; IBDv, infectious bursal disease virus; MAUT, multi-attribute utility theory; MCDM, multi-criteria decision making; vvIBDv, very virulent infectious bursal disease virus.

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researchers, and the California poultry industry have worked cooperatively to conduct response activities to identify affected flocks, eliminate virus from affected premises, and to better understand the epidemiology of vvIBDv in the California poultry population. Activities included: increased statewide surveillance of domestic and wild avian species, outreach and education to commercial and backyard poultry operations, testing of archived tissues from previous years, and new vaccination and cleaning and disinfection strategies, among others.

Despite large collaborative efforts between federal, state, academia and industry since the emergence of vvIBDV in California in 2008, there was no agreed upon approach toward risk management. In June of 2011, the California Department of Food and Agriculture (CDFA) hosted a meeting to update State and Federal animal health officials, State poultry industry representatives, and IBDv researchers on vvIBDv surveillance and research. It was determined that considerable epidemiologic information was still missing in order for animal health officials and poultry producers to appropriately respond to the vvIBDv outbreak within the California poultry population. Information still unknown included understanding whether the disease arose as a result of a single or multiple introductions of the virus strain, whether current management practices are sufficient to prevent introduction into new flocks and to eradicate virus from the poultry population, and whether wildlife has a role in virus transmission. Because of this limited knowledge and anticipated budgetary limitations, it was determined that there was a need to prioritize activities associated with vvIBDv surveillance, response and research.

The need to prioritize activities when resources are limited is not uncommon. Complicating the decision process is the fact that these potential activities are evaluated on several criteria, not just one. The identification of "the best" activities to perform becomes even more complex when stakeholders, sometimes with apparently opposing views and conflicting interests, are included in the decision process.

Decision support methodologies provide the opportunity for decision makers to leverage both qualitative and quantitative criteria in making decisions around risk management. Multi-criteria decision making (MCDM) approaches can assist decision makers and stakeholders in reaching common understanding of issues and viewpoints and in making decisions that are transparent and, therefore, more acceptable to all involved. MCDM allows stakeholders to evaluate a list of alternatives, indicating the decision makers' preferences by synthesizing assessments of each alternative's performance against individual criteria – with inter-criteria information reflecting the relative importance of the different criteria (Belton and Stewart, 2002). MCDM approaches have had a variety of applications in many fields. Most were initially developed and applied in operations research, and subsequently their application has been increasingly reported in other fields, more recently including food safety (Fazil et al., 2008), human health interventions (Baltussen and Niessen, 2006), and public health (Hongoh et al., 2011).

The use of MCDM in animal health interventions and risk analysis is not new. The application of decision-tree analysis to animal health was explored in the 1980s and 1990s to estimate monetary values of or cash flow associated with action choices involving animal health programs (Elder and Morris, 1986; Ngategize et al., 1986; Parsons et al., 1986; Gillard and Monypenny, 1988; Bennett, 1992). Recently, MCDM approaches have been used for prioritizing diseases affecting animal health (Brookes et al., 2012; Del Rio Vilas et al., 2012; Humblet et al., 2012) and public health (Humblet et al., 2012) and to evaluate animal disease control strategies (van Asseldonk et al., 2005; Mourits and Oude Lansink, 2006; Mourits et al., 2010).

There are numerous approaches that all fall within the general definition of MCDM (Huang et al., 2011). These approaches can be divided into three main categories; multi-attribute utility theory (MAUT), outranking, and the analytical hierarchy process (AHP) (Linkov et al., 2006; Huang et al., 2011). While the approaches have many similarities they differ importantly in how values are assigned and combined. Therefore, understanding the approach is critical toward selecting the most appropriate MCDM. An MCDM approach that was not found in peer-reviewed animal health literature is AHP, which was developed by Saaty, 1980, 1990, 2008, 1987. Unlike some of the other MCDM approaches and economic and epidemiologic modeling, use of the AHP does not require special skill or significant training of the decision makers or stakeholders. Compared to other MCDM approaches (e.g., MAUT), the AHP is less data-intensive. The AHP uses a process of relative comparisons based on human judgment to derive criteria priorities. Because comparisons are relative in nature (i.e., how much more important is one factor as compared to another), AHP can effectively enable a collaborative group to make tradeoffs and establish priorities among qualitative and quantitative inputs. This is a particularly useful characteristic in an animal disease situation where much of the epidemiology is still unclear and stakeholder viewpoints may not be aligned. The AHP model and the relative tradeoffs are built on a decision process of pairwise comparisons, and it explicitly recognizes and incorporates the knowledge and expertise of participants by using their subjective judgments at every step of process (Chelst and Canbolat, 2012).

Decision Lens (Arlington, VA) is a commercial package that provides ready use of the AHP decision model. A major advantage of the this type of software package is that the platform is Web-based, thereby providing more flexible access for participants who might be unable to attend a live meeting. The web component provides the ability to see real-time results as stakeholders enter their judgments and allows easy adjustments if participants change their judgments, as well as the ability to look at the input of individual participants and/or groups. The software also allows the input of certain members, such as key policy makers or experts, to have more impact on the final scores, by allowing different weights associated with each participant's input. For example, a commercial poultry veterinarians input might be weighted twice that of a diagnostic veterinarian because of his or her increased expertise in dealing with vvIBD in commercial poultry. However, one limitation is the inability to give variable weights to an individual depending on the topic. For example, while the diagnostic veterinarian may know more about the disease they most likely would know less than a regulatory veterinarian with respect to policy. Finally, the software enables the principal decision makers to easily perform sensitivity analyses. These analyses show how the activities might score differently if stakeholder opinions changed, which might occur when new information arises or new policies are implemented.

The objectives of this paper were to present the AHP process using a real world scenario (e.g., the control of vvIBDV in California) in order to better understand the utility of this approach for animal disease control.

2. Methods

During a stakeholder meeting in June of 2011, the participants agreed to evaluate the utility of the software in order to better prioritize response actions. After a brief introduction to the AHP and to Decision Lens (Arlington, VA), the meeting participants agreed to use the software to assist in prioritizing proposed activities associated with vvIBDv in California poultry. Participants included the face-to-face meeting attendees, as well as other members iden-

Table 1
Participation of stakeholders by group. The goal, criteria and activities meeting was used to introduce the AHP process, the criteria comparison participation represents the number of respondents who did comparisons of the criteria and sub-criteria and the evaluation of activities represented the number of people who evaluated the potential activity responses. Individual training was provided to the 4 poultry industry participants who completed the criteria comparison but were not available for the goal, criteria and activities meeting.

	Invited to participate	Brainstorming: goal, criteria and activities (June 2011 meeting)	Criteria comparison participation	Evaluation of activities participation
Animal health official	12	12	8	7
Research/academia	10	7	7	6
Poultry industry	10	3	7	1
Total participation	–	22	22	14

tified by the State poultry epidemiologist (MP). Participants were then placed in one of the following three stakeholder groups, based on their affiliation: animal health official, academia/research, and poultry industry (Table 1). The animal health official group included State and Federal representatives from both livestock/poultry and wildlife agencies. The academia/research group included those in a university setting, including those in a diagnostic laboratory capacity. The poultry industry group included representatives of the State poultry industry. Based on their expertise in the California poultry industry, IBDv, and the outbreak in California, some key participants were identified; the input of these participants was given greater weight (three times) than that of their peers within their group. The weights of each participant were then re-balanced so that the total weight of each group was equal. This was done to reduce bias toward results that may occur because one group was larger or had more key participants than another.

Following a standard protocol that leads decision makers and stakeholders through the AHP decision model development, the initial steps of the process required brainstorming to establish the goal(s) of the decision making process, criteria that were important in considering the activities (in this case) and identification of the activities that could be performed to attain the goals. The brainstorming session occurred during the June 2011 face-to-face meeting.

2.1. Define the decision goal(s)

Meeting participants were asked to share what they thought should be the goal of the decision model. Through discussion, the group reached consensus that the goal was to prioritize and fund activities designed to better understand the epidemiology and ecology (i.e., reservoirs of the virus) of vvIBDv to mitigate the impact of vvIBDv on the California poultry population and to efficiently contain vvIBDv in the current (geographic) locations.

2.2. Define the criteria

The meeting participants were next asked to share the important considerations in their determination of whether a proposed activity should be implemented. The ideas were ultimately summarized by three major criteria, with one criterion consisting of six sub-criteria.

They are defined as the following:

(1.) Industry support/cooperation: This criterion is used to assess the extent industry supports or accepts this activity. The willingness of industry to provide input, samples, data/information, or other items may be essential to effectively implement and complete activities.

- Containment measures: This criterion is used to assess the extent to which an activity contributes to better containment (and possibly elimination) of the virus. The sub-criteria associated with this criterion and their definitions are:

(a) Identification of cases: This sub-criterion is used to measure the extent to which better detection and efficient confirmation protocols are necessary to assure stakeholders that the disease is contained without major impact to the producer and the State.
(b) Source(s) of disease: This sub-criterion is used to assess the extent to which the activity helps identify the source of the disease. Currently, information on the emergence and introduction into flocks is limited.
(c) Disease surveillance: This sub-criterion is used to measure the extent to which this activity helps to identify the geographic extent of the disease which can affect future surveillance and containment planning.
(d) Vaccination strategies: This sub-criterion is used to measure the extent to which this activity helps provide guidance to poultry producer on vaccination strategies which may decrease the impact that the introduction of vvIBD into a flock has on that population.
(e) Cleaning and disinfection (C&D): This sub-criterion is used to measure the extent to which the activity helps assess the efficacy of C&D measures on eliminating the virus from affected premises.
(f) Biosecurity practices: This sub-criterion measures the extent to which this activity helps identify biosecurity measures needed to protect a house or premises with multiple houses from introduction and spread of the virus.

- Virus evolution: This criterion is used to assess the extent to which the activity increases understanding of the evolution of the vvIBDv strains found in California and their potential impact on poultry production with respect to ease of spread, vaccine efficacy, and other important virus characteristics.

2.3. Identify the activities

Participants were next asked to identify activities that they deemed necessary to meet the goal of understanding the epidemiology and ecology of vvIBDv in California poultry. Discussions led to the identification of the following 17 activities:

(a) Development of environmental test. Literature states that vvIBD is persistent in the environment (Eterradossi and Saif, 2008). However, the virus has not yet been isolated to confirm its persistence in litter. Developing a procedure to detect the virus in litter would confirm virus persistence in this suspected source and would help determine when new flocks can be placed in a previously affected house.
(b) Evaluation methods for C&D of vvIBD. Some chemical agents effectively inactivate IBDv (Eterradossi and Saif, 2008). This

activity would study the efficacy of these agents in field conditions against the strains of vvIBDv found in California.

(c) Stakeholder driven development of a best management practices (BMP) for disease control.
(d) Identification and dissemination of recommended IBD vaccination strategies for backyard and commercial production flocks.
(e) Evaluation of IBD vaccine strategies for parent flocks in order to maximize innate immunity in chicks.
(f) Development of case definition for vvIBD in order to have an agreed upon case definition of vvIBD.
(g) In order to improve the diagnostic specificity; development of a laboratory diagnostic rapid RT-PCR test to screen for unique regions of both segments of the vvIBD genome.
(h) Development of laboratory protocols that enable the tracking of changes in the vvIBD genome in order to follow the evolution of the virus which may provide insights into vaccination and pathogenicity.
(i) Voluntary surveillance at and around known affected commercial poultry premises.
(j) Voluntary surveillance of commercial poultry premises in the Central Valley and other parts of the State not known to have vvIBD.
(k) Voluntary surveillance and outreach to backyard flock owners in proximity to affected premises.
(l) Voluntary surveillance and outreach to backyard flock owners throughout the State.
(m) Sentinel surveillance using the strategic placement of day-old chicks in backyards poultry premises within the "buffer zone" surrounding the known affected areas to ascertain the geographic containment of vvIBDv.
(n) Evaluation of vvIBD strains using specific pathogen-free (SPF) birds in order to better understand differences in mortality associated with the detected strains of vvIBDv.
(o) Surveillance of wild bird populations geographically linked to affected commercial poultry premises. vvIBDv has been isolated or detected by PCR in tissues of wild birds in Korea and Africa (Jeon et al., 2008; Kasanga et al., 2008). This activity also includes sampling wild birds not linked to affected premises to establish background prevalence levels. This information could help assess whether virus containment and/or elimination are feasible goals.
(p) Surveillance of other potential reservoirs (e.g., mealworms, rodents, beetles). The available literature has shown the potential of other non-avian reservoirs (Snedeker et al., 1967; Okoye and Uche, 1986; McAllister et al., 1995; Park et al., 2010). Results would be used to determine the need for further studies, such as research on the ability of these species to transmit IBDv to poultry.
(q) Determination of risk factors to identify re-emergence vs. re-introduction at affected premises. Two of the companies affected had undergone extensive C&D and found virus again at a later time, while others have not (Pitesky et al., 2013). Under this activity, management practices and other potential risk factors will be evaluated to determine whether these cases represent re-emergence or re-introduction of the virus onto the premises. This may provide useful information to improve C&D, biosecurity, and other management practices.

2.4. Pairwise comparison

Stakeholders were next asked to provide input in the form of pairwise comparisons, whereby the parent criteria are compared to each other and the sub-criteria (of containment measures) are then compared to each other. For each comparison, each stakeholder was asked: In his or her opinion, which of the two criteria was more important and by how much, using a scale of 1–9 where 1 indicates that the two criteria being compared are of equal importance and 2 through 9 representing increased preference for one criterion over the other from moderate to extreme (Table 2). With 3 major criteria and 6 sub-criteria, 18 comparisons were entered by participants: 3 major criterion-to-criterion comparisons and 15 sub-criterion-to-sub-criterion comparisons.

Table 2
Scale used in criteria comparison, as defined by Saaty (1980). Scores input by participants indicate the level of importance of one criteria over another.

Score	Definition for score
1	Equal importance. The two criteria are equally important to the objective.
3	Moderate importance of one criterion over another.
5	Essential or strong importance.
7	Very strong importance.
9	Extreme importance. The importance of one criterion is of highest possible order over another.

Participants were introduced to the pairwise comparison via an initial conference call and/or in face-to-face meetings with the State poultry epidemiologist (MP) to learn more about entering their judgments into the software package. In some cases, stakeholders provided input on paper, and these judgments were hand-entered into the program.

The software provides real-time calculations as participants' judgments are entered, including an "average judgment" based on the geometric mean of participant judgments for each pairwise-comparison. These calculations are utilized by the software to establish weights of each criteria and sub-criteria, indicating their overall importance in making the decision, using a pairwise comparison matrix with each criterion represented in both rows and columns, as described in Saaty (1990). By definition, all diagonal entries equal one, as they represent the comparison of a criterion to itself. The corresponding comparison of one criterion to another, using the geometric mean of each participant's input, is entered into the matrix. Because AHP interprets the score scale (1–9) in a ratio sense, if criterion A is preferred to criterion B with strength of preference of P, then the comparison of criterion B with criterion A is the reciprocal (or 1/P). The principal eigenvector of the matrix is then determined and serves to represent the priorities of the criteria that comprise the matrix. In addition to the priority weights, the software calculates two indices: inconsistency ratio and alignment index. The inconsistency ratio allows the model facilitator to evaluate the logical consistency of the group's judgments to ensure participants followed a logical thought process during the pairwise comparisons, as opposed to entering their judgments at random (e.g., inconsistency ratio of 90%). A threshold of 10% in the inconsistency ratio ensures confidence in the logical consistency of judgments. Methodology and equations to establish the inconsistency ratio are described elsewhere (Saaty, 1987; Ragsdale, 2008; Chelst and Canbolat, 2012) and, therefore, are not presented here. The second index that the software provides is the alignment index, which is an indicator between 0 and 100% that demonstrates the extent to which participants agree on their pairwise comparison judgments. Unlike the inconsistency ratio, there is no goal or target. One usually can expect the alignment index to be in the 40 to 80% range. Very high alignment may suggest decision making that discourages creativity or individual opinions (i.e., "groupthink"); low alignment may represent lack of coordinated direction or strategy. No action is required to raise or lower alignment values.

2.5. Evaluate the activities

In this step, stakeholders are asked to evaluate to what extent each proposed activity helps to meet the objectives described in each criterion or sub-criterion. Input was provided using scales that

Table 3
Scales used in the evaluation of the activities and their contribution to each of the criteria and sub-criteria.

All criteria and sub-criteria, except Industry support/cooperation	Score
Clearly contributes	1.00
Some contribution	0.67
Little contribution	0.33
No contribution	0
Industry support/cooperation criteria	
Full support/cooperation	1.00
Mostly supportive/cooperative	0.75
Some support/cooperation	0.50
Little support/cooperation	0.25
No support/cooperation	0

Table 4
Geometric means of each pairwise comparison of criteria and sub-criteria. Criteria or sub-criteria found more important in each pairwise comparison is listed first

Comparisons of Criteria	Geometric mean
Industry support/cooperation vs. containment measures	1.012
Industry support/cooperation vs. virus evolution	1.305
Containment measures vs. virus evolution	1.526
Comparisons of sub-criteria	
Source(s) of disease vs. identification of cases	1.197
Source(s) of disease vs. disease surveillance	1.681
Source(s) of disease vs. cleaning and disinfection	1.786
Source(s) of disease vs. vaccination strategies	2.4
Disease surveillance vs. vaccination strategies	1.471
Cleaning and disinfection vs. disease surveillance	1.3
Cleaning and disinfection vs. vaccination strategies	1.709
Identification of cases vs. disease surveillance	1.142
Identification of cases vs. cleaning and disinfection	1.577
Identification of cases vs. vaccination strategies	1.735
Biosecurity practices vs. source(s) of disease	1.199
Biosecurity practices vs. identification of cases	1.246
Biosecurity practices vs. cleaning and disinfection	1.414
Biosecurity practices vs. disease surveillance	1.435
Biosecurity practices vs. vaccination strategies	2.495

described the contribution and are translated into values between 0 and 1 (Table 3). The software calculates the arithmetic mean of each participant's judgment for each activity under each criterion. Using the criteria weights established in the previous step, weighted averages of each activity are then calculated to provide an overall score for each activity. Sensitivity analyses were performed by modifying criterion weights in order to evaluate resultant changes in prioritization of activities. These sensitivity analyses consisted of changes to the weights of criteria that could result as the virus evolves, disease pathogenicity changes, and other epidemiologic characteristics of the virus are better understood. This new information may result in different overall scores of the activities, thereby identifying different priority activities.

3. Results

A total of 32 stakeholders were asked to participate in the decision process. Table 1 provides information on the participation level of stakeholders, broken down into the three stakeholder groups.

3.1. Pairwise comparison

Stakeholders were able to provide input online through the software based Web site or via paper over the course of two months to ensure adequate time to become comfortable with the software and subsequently provide their judgments. Input was received by 22 of the 32 (69% response rate) participants. The geometric mean of each pairwise comparison is provided in Table 4. For example, in the comparison of containment measures and industry support/cooperation, the participants as a group believe they are of equal importance, while they have moderate preference for containment measures as compared to virus evolution. The final priority weights given to each criterion and sub-criterion as calculated from the input matrices are presented in Table 5. Overall, containment measures and Industry support/cooperation were deemed more important than virus evolution. Among the containment measures sub-criteria, Biosecurity practices and source(s) of disease were considered more important. If one looks at the weights of criteria by participant group, one can see differences in priorities. Among the animal health officials, Industry support and containment measures were considered more important. For the poultry industry group, containment measures was far more important than either of the other two criteria, and source(s) of disease the most important sub-criteria. For the research/academia group, virus evolution and industry cooperation/support were more important criteria, and identification of cases the most important sub-criteria. Based on these results, there was very low inconsistency and relatively low alignment, overall and by stakeholder group.

3.2. Evaluate the activities

The final scores of the activities are presented in descending order in Table 6, based on the overall weights of the criteria and the ratings of each alternative against each criterion. Based on these scores, the top-ranking activities are: Determination of risk factors for re-emergence or re-introduction, development of a laboratory diagnostic test to screen for segment B, and surveillance of other potential (non-avian) wildlife reservoirs. Table 6 shows how the activities would have ranked by participant group; the activities could not be prioritized for the poultry industry group due to inadequate participation of this particular group in this stage of the process.

The sensitivity analyses were conducted with alterations in two aspects: weights of participant input and priority weights of criteria.

3.2.1. Participant weights

An evaluation of the effect of participant weights was performed (data not shown). In one scenario, every participant's input was weighted equally, without balancing of weights across groups. In the second scenario, key participants were given increased weight (triple) but were divided into two groups (animal health officials/academia/research and poultry industry) and the weights balanced so that total weight of both groups were equal (so industry was not outweighed by the sheer number of people in the other group). Regardless of the weighting, the top three activities remained the top three priorities, and the bottom five activities remained the bottom five priorities, with minor changes in the rankings of activities in between.

3.2.2. Priority weights of criteria

The priority weights of criteria were adjusted to see how judgment changes due to new information or other influencers might impact the priorities. Manual changes were made only to the containment measures criterion, the virus evolution criterion, or both; the software adjusted the remaining criterion weight(s), but maintained the relative priority of these remaining criteria so as not to lose their relationship to one another. Adjustments of up to 20% increases in one or both of the manually adjusted criteria did not result in any major shifts in priorities (not shown); the top four activities remained in the top four and the bottom four remained in the bottom four, with very minor changes in rank of the remaining activities. An increase in priority weight of either or both of those criteria by at least 50% was needed to create noticeable shifts in pri-

Table 5
Comparison of priority weights of the criteria among stakeholder groups as calculated from the input matrices. The inconsistency ratio reflects the calculated eigenvector and is used to measure the integrity of the measurements. The alignment index reflects the extent to which participants agree on their pairwise comparison judgments. Alignment indexes are typically between 40 and 80 percent. Low alignment may represent lack of coordinated direction or strategy.

Criteria/sub-criteria	Everyone	Animal health official	State poultry industry	Research/ academia
Virus evolution	0.262	0.163	0.199	0.414
Industry support/cooperation	0.361	0.421	0.197	0.425
Containment measures:	0.377	0.416	0.604	0.161
Identification of cases	0.181	0.156	0.114	0.267
Source(s) of disease	0.221	0.120	0.399	0.204
Disease surveillance	0.138	0.116	0.116	0.164
Vaccination strategies	0.092	0.093	0.080	0.083
Cleaning and disinfection	0.145	0.119	0.147	0.142
Biosecurity practices	0.223	0.396	0.145	0.140
Criteria comparisons				
Inconsistency ratio	0.3%	0.3%	0.7%	2.4%
Alignment index	27.9%	35.9%	20%	48.5%
Sub-criteria comparisons				
Inconsistency ratio	0.6%	1.6%	3.3%	1.9%
Alignment index	27.6%	30.2%	17.4%	44%

Table 6
The scores of proposed activities prioritized in Decision Lens, based on stakeholder participation in criteria comparison and evaluation of the activities against each criterion. Activities have been presented in decreasing order of scores, and therefore prioritization. The final score shows the comparison of the ranking of activities (based on the output scores of the decision model, from highest score to lowest score) among stakeholder groups. Due to the limited input from the California poultry industry representatives, ranking of the activities for this group could not be performed.

Activity	Everyone	Animal health officials	Research/ academia	Final score
Determination of risk factors for re-emergence or re-introduction at affected premises	1	1	3	0.766
Development of laboratory diagnostic test to screen for segment B of the vvIBD genome	2	8	1	0.734
Surveillance of other potential reservoirs (mealworms, rodents, beetles)	3	2	10	0.726
Evaluation of vvIBD strains using specific pathogen-free (SPF) birds	4	4	4	0.713
Surveillance of wild bird populations geographically linked to affected commercial poultry premises	5	6	5	0.692
Voluntary surveillance of commercial premises in the Central Valley and other parts of the State not known to have vvIBD	6	5	9	0.686
Development of best management practices (BMP) disease control program	7	3	14	0.682
Voluntary surveillance at and around known affected commercial premises	8	11	8	0.679
Development of laboratory protocols that enable the tracking of changes in the vvIBD genome	9	15	2	0.671
Development of environmental test	10	14	6	0.664
Voluntary surveillance and outreach to backyard owners in proximity to affected premises	11	10	7	0.657
Voluntary surveillance and outreach to backyard owners throughout the State	12	9	12	0.649
Evaluation methods for cleaning and disinfection (C&D) of vvIBD	13	7	15	0.617
Sentinel surveillance using backyard birds	14	17	11	0.565
Development of case definition for vvIBD	15	16	13	0.561
Evaluation of IBD vaccine strategies for parent and production flock	15	13	17	0.561
Identification of recommended IBD vaccination strategies	17	12	16	0.554

orities. Presented in Table 7 are the resulting changes from more dramatic changes in weights (50 to over 100% increases) in one or both. As can be seen in the figure, the bottom four activities remained the lowest scoring activities.

4. Discussion

The general purpose of the MCDM is to serve as an aid to decision making and not to make the decision. Values provided by the software including the calculated inconsistency ratio and alignment index for the whole group provides interesting insights into the participants' different perspectives which can be used by the decision maker to facilitate a decision. For example, the combination of the very low inconsistency ratio, indicating that the logic and judgments were sound, with the relatively low alignment index suggests that there were well-considered key differences in thoughts and that they were consistently not in agreement (Table 5). While MCDA techniques are relatively new to disease response, these types of stakeholder group differences and inconsistencies values are consistent with previous studies (Havelaar et al., 2010; Mourits and Oude Lansink, 2006). However, the priorities in these studies and others are more generic in nature than in the present study (Hurley et al., 2010 Humblet et al., 2012).

Observation of the criteria weights differed by group (animal health official vs. research/academia vs. poultry industry) (Table 5). However, it is interesting to note that even within each group there was still low inconsistency and relatively low alignment. This lack of agreement may in part be a reflection of the limited knowledge about vvIBDv in California. However, it is interesting to note the differences that arose when comparing the top activities identified by each group, with the animal health official group inputs more toward epidemiologic and management-related activities and the research/academic group inputs favoring those that were diagnostic laboratory testing methodology. It is unfortunate that participation of poultry industry representatives was low during the evaluation of activities stage, as this would have provided useful insight into what that group would have thought to be priority activities and how they might differ from the other two groups. This low participation is likely a reflection of the time commit-

Table 7
Sensitivity analyses to show changes in prioritization of activities when the priority weights of criteria were changed. Adjustments to the weight of criterion of interest was made manually, with the weights to the remaining criteria adjusted automatically by Decision Lens. The manual changes in priority weight for a criterion scenario are as follows: A. Containment weight doubled; B. Containment weight increased 50 percent; C. Virus evolution weight doubled; D. Virus evolution weight increased 50 percent; E. Containment weight increased 20 percent and virus evolution weight increased to equal weight of containment.

Activity	Original	A	B	C	D	E
Determination of risk factors for re-emergence or re-introduction at affected premises	1	1	1	4	2	3
Development of laboratory diagnostic test to screen for segment B of the vvIBD genome	2	7	3	1	1	1
Surveillance of other potential reservoirs (mealworms, rodents, beetles)	3	2	2	5	5	5
Evaluation of vvIBD strains using specific pathogen-free (SPF) birds	4	11	8	3	4	4
Surveillance of wild bird populations geographically linked to affected commercial poultry premises	5	4	4	7	6	7
Voluntary surveillance of commercial premises in the Central Valley and other parts of the State not known to have vvIBD	6	10	9	9	8	11
Development of Best Management Practices (BMP) disease control program	7	5	6	12	11	12
Voluntary surveillance at and around known affected commercial premises	8	5	7	10	9	10
Development of laboratory protocols that enable the tracking of changes in the vvIBD genome	9	12	12	2	3	2
Development of environmental test	10	3	5	11	12	9
Voluntary surveillance and outreach to backyard owners in proximity to affected premises	11	9	11	6	7	6
Voluntary surveillance and outreach to backyard owners throughout the State	12	8	10	8	10	8
Evaluation methods for cleaning and disinfection (C&D) of vvIBD	13	15	13	14	13	15
Sentinel surveillance using backyard birds	14	13	14	13	14	13
Development of case definition for vvIBD	15	14	15	15	15	14
Evaluation of IBD vaccine strategies for parent and production flock	15	16	16	16	16	16
Identification of recommended IBD vaccination strategies	17	17	17	17	17	17
Containment weight	0.377	0.749	0.565	0.241	0.31	0.452
Industry support weight	0.361	0.145	0.252	0.234	0.297	0.1
Virus evolution weight	0.262	0.106	0.183	0.524	0.392	0.448

ment required of participants for every evaluation. Participants were asked to provide 153 judgments in this stage (17 activities × (3 major criteria + 6 sub-criteria)). Future use of the software for such a study will likely need to utilize the voting assignment tool which specifies which criteria and/or activities an individual is responsible for assessing against.

The results of the sensitivity analyses are interesting to note. With even a 20% increase in the weighting of containment measures and/or industry support/cooperation, the three highest scoring activities and the four lowest scoring activities remained the same. Given that more information has been gained since June 2011, it was anticipated that the priority weights would probably have changed since participants provided their input into the software in late 2011. As a result of 2011–2012 surveillance activities, genetic changes in the virus genome and increased incidence of the disease in backyard flocks, relative to commercial flocks, were reported. These findings likely would have increased the perceived importance by participants of the virus evolution relative to the other two criteria.

The scenarios tested in the sensitivity analyses were attempts to evaluate how the ranking of activities might have changed as a result of the new knowledge. It is interesting to find that unless there were dramatic changes in the priority weights, the top priority activities would not have changed much. Given the analytic methodology behind the AHP, it seems unlikely that all or most of the participants would have changed their judgments significantly enough to result in the dramatic changes in the criteria weights needed to change the top scoring activities. It was also interesting to note that even with dramatic changes, the lowest scoring activities remained the lowest scoring. This indicates that overall, participants did not view these activities as contributing much to meeting the goal of better understanding of vvIBD epidemiology and ecology in California. However, having the ability to test alternative scenarios is an important aspect of this approach. In the future combining this approach with indirect weighting techniques which ranks or scores test scenarios against real scenarios may be beneficial (Brookes et al., 2012). In addition, an approach by Ge et al. (2010), termed epidemic–economic modeling supports dynamic decision making during epidemic control as opposed to a static approach based on pre-defined static control strategies . These approaches maximize the ability of the model to adapt to dynamic changes in disease control.

As demonstrated in this study, the use of AHP can provide assistance in prioritizing activities when knowledge and resources are limited. Using this kind of decision-support tool provides the opportunity to incorporate qualitative (and, when available, quantitative) information in the form of stakeholder judgments in order to prioritize where resources should be directed. Commercial applications like Decision Lens can be useful to decision makers, in that the application calculates scores and identifies inconsistent entries in real time, enabling a proficient user to evaluate and revise entries immediately. In addition, while not used in this study, the software is capable of integrating the cost of the proposed activities into an overall budget which is based on the relative ranking and cost feasibility of each alternative. Because of the software's ease of use, any number of stakeholders can provide judgments without requiring human-driven re-tabulation of data with late-comers and enables easy comparison of inputs of stakeholder groups to compare similarities and differences in opinions. The software's Web suite makes the application even more useful, as it enables stakeholders to provide input at their convenience, as opposed to a designated day and time that is convenient for all or most stakeholders.

A major down-side identified by the authors was the time (4 months) to work through the whole process. This time period can vary, depending on a number of factors, including: the number of goals, criteria, and activities; Internet connectivity; and familiarity and comfort levels of stakeholders with its use. This limitation means that the time from start to finish can take anywhere from days to months, thereby limiting the use of AHP in the emergency response efforts. Although the use of software was intended to help prioritize activities for 2011–2012, the decision process took approximately 4 months until the model could be integrated into a comprehensive, integrated response plan. During that time, a 'business as usual' response plan focused on continued outreach and education and voluntary surveillance of commercial and backyard birds in California. The long time period could be one reason the poultry industry had relatively low participation (Table 1). It is important to note that while the initial AHP decision process can be time-consuming, it provides a repeatable decision approach. This characteristic provides a longer-term benefit. As decisions are revisited with the emergence of new information or changes in resource availability, informed decision making could be performed more quickly. For example, with each new iteration of the decision, the previous model can be copied and then archived. The newest version of the model captures the most current input and data. The older iterations provide insight like: who participated, the relative weights of the criteria based on the perceived facts on the ground at that time, and how the alternatives were impacted by the criteria weights. This increases the overall transparency of the process in that the decision time line is easily accessible.

While MCDM is still relatively unique in animal disease response, the approach has been explored in zoonotic disease response with respect to prioritizing emerging zoonoses in the Netherlands and for evaluating quarantine disease strategies for foot and mouth disease, classical swine fever and avian influenza (Havelaar et al., 2010; Breukers et al., 2008). In order to be further utilized in disease response, efficiencies in time need to be addressed. One approach to reduce the time could include a pre-developed model with criteria already identified and priority weights determined may be possible in certain animal health response situations such as detecting the re-emergence of a previously eliminated disease (e.g., bovine brucellosis or tuberculosis) or the introduction of a foreign animal disease (e.g., foot and mouth disease) that call for dramatic actions such as herd depopulation and local/regional movement restrictions. This approach could be a valuable component of contingency planning when dealing with these types of situations. However, such an application still requires reflection before use to ensure its applicability to the current emergency situation.

With the above described advantages and disadvantages of an AHP, the question of overall utility of a structured AHP approach in comparison to a more simplistic “traditional” in-person voting process is relevant. Therefore, while not directly comparable, it is of interest to note the differences in activity priorities when comparing the outcome of the software model and the in-person voting performed at the June 2011 meeting. At the meeting, each participant was asked to select their top two priority activities from the following list of seven options: continued surveillance (targeted or otherwise) of commercial poultry flocks, development of PCR screening test for segment B, determination of prevalence in targeted backyard flocks, development of best methods for cleaning and disinfection (C&D), development of PCR assay for sequence data to track changes, vaccine efficacy studies, and wildlife studies to determine risk. With 14 participants voting and therefore 28 votes cast, the activity considered by far the most important was continued surveillance in poultry, which received 12 votes. Next in priority was the development of a PCR screening test with seven votes, determination of prevalence in targeted backyard flocks with six votes, the development of best methods for cleaning and disinfection with two votes and development of a PCR assay to track evolutionary changes with one vote. The perceived importance of continued surveillance, as shown by the votes, is not reflected by the results of the software model – in neither the final model nor in any of the scenarios run were the poultry surveillance activities in the top four activities, and the wildlife studies to determine risk received only one vote while surveillance of other potential wildlife reservoirs consistently remained in the top three to five activities in the software model. Besides the differences in the alternatives under consideration both at the face-to-face meeting and during the software based component, the differences in the results are likely also due to how participants provided input, picking their top two activities as opposed to providing ranking (or some other scoring) of all seven activities. Had participants been able to rank all seven activities, perhaps some similarities in results to those from the software model would have emerged.

As noted it is important to recognize that the “traditional” approach (i.e., decisions based on informal voting) is most often used in responding to an emerging disease. While every outbreak is different with respect to the agent, host and environment, understanding how other investigators identified and established priorities compared to the AHP process for vvIBD is relevant. One of the inherent advantages of the MCDM approach is the structured nature of the results which provides opposing stakeholders not only differences and similarities but also the underlying logic and judgment of that decision (i.e., inconsistency ratio). This information is essential toward bridging differences between stakeholder groups (Mourits and Oude Lansink, 2006).

Although the activities were ranked based on participants' judgments, it is important to remember that methods like AHP are only decision support tools. AHP is not intended to replace human thinking in the final decision making, but rather is leveraged to facilitate better informed decisions. MCDM tools like the commercial software here are helpful by promoting discussion among stakeholders and decision makers. The learning and understanding that result from engaging in the overall process often prove to be more important than the actual results.

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