Wildlife Pathogen Surveillance in Israel to Inform Human and Animal Infectious Disease Control: a Prioritization Exercise

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ABSTRACT

In December 2013, as a part of the establishment of the 'Israel Wildlife Diseases Surveillance'(IWDS) Program, building on the 'One Health' approach for human, livestock and wildlife disease control, a prioritization exercise using a validated risk analysis method was carried out by distributing online questionnaires to 86 relevant experts. The results were subsequently presented in the prioritization of a wildlife surveillance workshop, compiling the risk assessments of 51 pathogens by human, livestock, wildlife and total risks. The endemic diseases, brucellosis, rabies and foot and mouth disease ranked as the highest risks. The Risk Analysis method was used successfully in the prioritization exercise. Furthermore, the results combined surveillance priorities of relevant stakeholders and will be used in planning and implementing the national surveillance program.

Keywords: Surveillance; Wildlife; Pathogen; Israel; One Health; Risk Analysis; Surveillance Program.

INTRODUCTION

Emergence and reemergence of infectious diseases has occurred globally over the last decades. The majority (60%) of emerging infectious diseases in humans are zoonotic diseases and 75% of them are of wildlife origin (1).This global phenomenon is a result of varying processes. Exponential growth in human population and livestock together with habitat destruction of wildlife increased the interface between wildlife, human and their livestock. Furthermore, the increased transport of livestock and animal products, tourism, global trade, climate change and emergence of pathogens resistance to antimicrobial drugs are all contributors to this phenomenon (2).

The understanding that the health of human, livestock, wildlife and the environment are connected to each other is expressed in the 'One Health' approach (3). This approach was initiated in 2004 and subsequently adopted by the World Health Organization (WHO), World Organization of Animal Health (OIE), Food and Agriculture Organization of the United Nations (FAO), World Bank and the Wildlife Disease association (WDA) (4). According to the One-Health approach, dealing with the increment of the emerging diseases mandates ongoing nationwide wildlife surveillance (4).

Early detection of emerging diseases allows implementation of preventive measures to avoid the spread of disease in human and livestock populations (5). For example, SARS and avian Influenza epidemics were relatively contained due to rapid interventions following surveillance (6). Epidemics can

incur a heavy loss of human and animal life and also financial damage even without counting the direct effect of morbidity and mortality. SARS caused morbidity in only 9,000 people but the financial damage reached about 30-50 billion US dollars (6). Without early detection epidemics could go beyond containment and have devastating effects. For example, an Avian Influenza Pandemic could cause 71 million deaths, which is estimated to entail an economic significance of 3 trillion US dollars, which is 4.8% of the world Gross National product (GNP) (6).

As a part of the establishment of an Israeli national surveillance program for wildlife pathogens, in 2013, a steering committee including representatives from Nature and Parks Authority, Ministry of Health, Ministry of Environmental Protection and the Veterinary Services, Ministry of Agriculture held a workshop that discussed the prioritization of wildlife pathogens for surveillance for a national program. Conducting a surveillance program for wildlife is one of the recommendations of OIE Performance of Veterinary Services (PVS) evaluation report of the veterinary services of Israel (7) infectious disease threats in relation to livestock and public health.

Prioritization is a central aspect of setting up the surveillance system and decision making regarding resource allocations. Prioritization helps meeting the needs of the stakeholders, maximizes the use of limited resources (fiscal and human) and ensures that planning and resource allocation are fit-for-purpose and transparent (4, 8, 9).

Prioritization exercise in relation to zoonoses has never been performed in Israel, neither in the veterinary nor in the public health sectors. A review of possible approaches and methods was initially carried out. The methods for prioritization differ mainly by the number of criteria, scoring system and the methodology of collating results (workshops, electronically, etc.) (8, 10, 11). A published methodology for prioritizing pathogens for wildlife surveillance applicability and relevance termed 'Rapid risk analysis' was adopted. This methodology is based on the OIE framework and involves hazard identification, risk estimation and ranking of the diseases. The rapid assessment is made by using a semi-quantitative system for scoring the introduction, spread and consequences of each pathogen. The qualitative risk estimated results are then combined to a score that can be used to prioritize pathogens for surveillance (12). Rapid risk analysis was chosen mainly because of the relative ease of data collection and analysis, the ability to separate risks by different populations and adding up the populations' risks to a total risk.

Deliberate release of pathogens was not considered in the prioritization exercise. Malicious introductions are dependent on complex variables some of which are profoundly different from those associated with natural occurrence of infections due to transmission routes of pathogens. Thus man-made and natural incidents are difficult to prioritize one against the other. Additionally, deliberate release involves a range of stakeholders that is somewhat different from those represented in the current process.

The ultimate goal of the prioritization exercise was to produce a list of wildlife pathogens that will be included, after critical review, in the future Israeli national surveillance program for wildlife related pathogens.

MATERIALS AND METHODS

The 'Rapid Risk Analysis' method was chosen by the steering committee after reviewing different options for the prioritization exercise (8, 10, 11, 12). The chosen method included three consecutive steps: hazard identification, risk assessment and ranking of pathogens.

For hazard identification, a list of 51 diseases (Table 1) was formulated by the steering committee of the surveillance program. The list was based on literature review and reportable animal (OIE disease lists) and human diseases (per national public health laws). The majority of the diseases were zoonotic or affecting livestock. A disease card was prepared for each disease based on various sources (13, 14, 15, 16, 17, 18).

The risk assessment, the scoring system of which is presented in Table 2 utilized a semi-quantitative approach to score pathogens and included (12):

- **Probability of entry (POE) to Israel:** The POE is the release assessment. The POE depends on various factors: route of transmission, the existence of environmental conditions that allow the survival of the vectors and the natural hosts of the disease. The responders were asked to consider all the potential paths that can enable the entrance of the pathogen into Israel, including paths by which wildlife are not involved (sick humans, transportation, imported livestock, food, etc.). Scoring of POE had six options: 0.2, 0.4, 0.6, 0.8, 0.9 and 1. The scores of 0.2-0.8 represent the probability of a pathogen to enter Israel and scores of 0.9 and 1

Table 1: Diseases list (in alphabetical order)

	Disease
1	Anthrax
2	Aujeszky's disease
3	Avian influenza
4	Avian mycoplasmosis
5	Bluetongue
6	Bovine spongiform encephalopathy
7	Bovine tuberculosis
8	Bovine viral diarrhea
9	Brucellosis
10	Campylobacteriosis
11	Canine distemper
12	Caprine arthritis/encephalitis and Maedi-visna
13	Chronic wasting disease
14	Classical swine fever
15	Congo-Crimean Hemorrhagic fever
16	Cryptosporidiosis
17	Dengue fever
18	Ebola haemorrhagic fever
19	Echinococcosis
20	Epizootic haemorrhagic disease
21	Foot and mouth disease
22	Glanders
23	Hantavirus disease
24	Human granulocytic anaplasmosis
25	Human monocyticehrlichiosis
26	Japanese encephalitis
27	Leishmaniasis
28	Leptospirosis
29	Listeriosis
30	Lumpy skin disease
31	Lyme disease
32	Middle East respiratory syndrome coronavirus
33	Morbillivirus
34	Newcastle disease
35	Nipah virus encephalitis
36	Old World screwworm
37	Ovine chlamydiosis
38	Pasteurellosis
38	Porcine cysticercosis
40	Psittacosis
41	Q fever
42	Rabies
43	Ranavirus disease
44	Rift valley fever
45	Salmonellosis
46	Spotted fever (Rickettsiosis)
47	Swine influenza
48	Toxoplasmosis
49	Trichinellosis
50	Tularemia
51	West Nile fever

represent pathogens that are likely to be already present in Israel or known to be present, respectively.

- **Likelihood of spread (LOS):** The LOS is the exposure assessment. The likelihood that the pathogen will become established in Israel was evaluated separately for each of the three groups: human, livestock and wildlife. The responders were asked to consider the transmission patterns (routes) (animal to animal, animal to human, human to human, or via an arthropod vector), population dispersal, survival of pathogen in the environment, morbidity, virulence, and the rate of spread. Scoring of LOS ranged from 1 to 4, where 1 represented a very low LOS and 4 a very high LOS.
- **Consequences of spread (COS):** The COS is the consequence assessment. The COS was also evaluated for each of the three affected groups (human, livestock and wildlife). The responders were asked to consider the disease incidence, morbidity and mortality (case fatality rate), public health impact (ability to infect humans, the ability of transmission from human to human, the ability to control spread among humans), economic effects on production and trade, international consequences, the ability to control the spread (diagnosis, vaccination, treatment), and the public perception of the disease. Scoring of COS had 4 options from 1 to 4, where 1 represented minor COS and 4 severe COS.
- **Risk estimation:** For each disease and each target group (human, livestock, wildlife) the risk was estimated as follows:

$$\text{Risk (group)} = \text{POE X LOS X COS}$$

The score of a disease risk could range between 0.2 (minimal) to a maximal score of 16.

For each disease a total risk was estimated as follows:

$$\text{Total Risk} = \text{Risk (Humans)} + \text{Risk (Livestock)} + \text{Risk (Wildlife)}$$

The score of a total risk could range between a minimal score of 0.6 to a maximal score of 48.

- **Ranking of pathogens:** After collecting questionnaire results and calculating group risks and total risks for all the diseases, ranking was carried out for each target group, by total risk and by exotic and endemic diseases (low and high POE).

Table 2: Scoring system framework based on the 'Rapid risk analysis' method (12)

Probability of entry to Israel (POE)	Likelihood of spread (LOS) and Consequences of spread (COS)					
	Humans		Livestock		Wildlife	
	LOS (1-4)	COS (1-4)	LOS (1-4)	COS (1-4)	LOS (1-4)	COS (1-4)
1-Known to be Present	1- Extremely unlikely	1- Minor	1- Extremely unlikely	1- Minor	1- Extremely unlikely	1- Minor
0.9- Likely to be present but undetected	2- Moderately unlikely	2- Moderate	2- Moderately unlikely	2- Moderate	2- Moderately unlikely	2- Moderate
0.8- Very likely to enter	3- Moderately likely	3- Major	3- Moderately likely	3- Major	3- Moderately likely	3- Major
0.6- Moderately likely to enter	4- Extremely likely	4- Severe	4- Extremely likely	4- Severe	4- Extremely likely	4- Severe
0.4- Moderately unlikely to enter						
0.2- Very unlikely to enter						

The questionnaire was generated on Google forms™ platform and was distributed electronically to 86 relevant experts representing key stakeholders whom were chosen by the steering committee of the surveillance program. The questionnaire was open for response from 12/11/13 till 12/12/13. For each responder personal information was collected (name, institute, job title, academic degrees). Partial response was allowed. The questionnaire summary was presented at the prioritization of wildlife surveillance workshop daywhich was held at the Kimron Veterinary Institute, Bet Dagan Israel on the 17th of December 2013.

The workshop itself was held between the 15th to the 20th of December 2013 and engaged the steering committee of the national surveillance program and three international experts of wildlife diseases: Dr. Paolo Calistri (Istituto G. Caporale, Campo Boario, Teramo, Italy), Dr. Paul Duff (Project leader of Diseases of Wildlife Scheme, AHVLA Penrith, United Kingdom(and Dr. William B. Karesh (Executive Vice President for Health and Policy at EcoHealth Alliance, New York, USA). The expert mission was funded by TAIEX (Technical Assistance and Information Exchange Instrument of the European Commission). Based on the Prioritization questionnaire results and the workshop, the experts created a policy paper with recommendations for initiation of a national surveillance program in Israel.

RESULTS

Of the 86 experts approached, responses were received from 38 (44% response rate). The majority of the responders were veterinarians (n=27) and 15 of them held advanced degrees (PhD/MPH/MSc/specialist). The rest were medical doctors (n=5) and researchers (n=4). The majority of the responders held governmental positions (n=24) and the rest were based at universities (n=6), hospitals (n=3), zoos (n=3) and other organizations (n=2). The specialization of the responders included public health (n=10), research specialties (n=7), wildlife (n=6), human health (n=5), livestock (n=3), pathology (n=3), bacteriology (n=3), poultry (n=2) and other areas (n=1).

The risk estimates of the pathogens and their rankings according to the risk assessment are presented in Table 3. The ranking of the twenty highest risk estimates of pathogens according to the Human risk, Livestock risk and Wildlife risk are presented in Figures 1-3. Figure 4 presents the upper twenty Total Risks of non-endemic pathogens which were defined by POE as 0.6-0.8.

DISCUSSION

The objective of the prioritization exercise was to prepare for the conception of a national surveillance system for wildlife pathogens in Israel (IWDS). The IWDS program aims to promote disease control in humans, livestock and wildlife. Such an approach has never been carried out in Israel, neither in the veterinary nor in the health sector. We adopted an existing method of prioritization which has already been validated (12), with certain modifications.

Human risks ranking placed Brucellosis and Leishmaniasis the first and second highest risks. Most of the top twenty ranked diseases are endemic to Israel. Other diseases like Congo-Crimean hemorrhagic fever

Table 3: Ranking of the 51 wildlife pathogens according to Total risk in descending order.

	Disease	POE[a]	Human risk	Livestock risk	Wildlife risk	Total risk[b]
1.	Brucellosis	1.0	9.7	11.0	5.4	26.1
2.	Rabies	1.0	7.7	8.4	9.7	25.9
3.	Foot and mouth disease	1.0	1.0	12.8	8.1	21.9
4.	Salmonellosis	1.0	7.4	7.1	5.8	20.4
5.	Leishmaniasis	0.9	9.6	2.6	8.0	20.2
6.	Leptospirosis	1.0	7.0	7.8	5.2	19.9
7.	Anthrax	0.9	5.1	8.6	6.0	19.8
8.	Newcastle disease	1.0	1.3	11.7	6.2	19.1
9.	Avian influenza	0.8	5.6	8.2	5.0	18.8
10.	Campylobacteriosis	0.9	7.3	7.6	3.6	18.5
11.	Bluetongue	0.9	1.1	10.1	7.2	18.5
12.	Listeriosis	1.0	8.0	5.8	4.5	18.3
13.	Q fever	0.9	6.8	5.1	4.0	15.9
14.	West Nile fever	0.9	7.0	4.1	4.3	15.4
15.	Echinococcosis	0.9	6.1	5.0	3.9	15.0
16.	Toxoplasmosis	0.9	5.6	4.8	4.1	14.6
17.	Trichinellosis	1.0	4.4	4.4	5.3	14.1
18.	Cryptosporidiosis	0.8	4.4	5.9	3.5	13.7
19.	Lumpy skin disease	1.0	1.0	10.2	2.5	13.7
20.	Rift valley fever	0.6	4.3	5.6	3.5	13.4
21.	Classical swine fever	0.8	1.0	6.0	6.3	13.3
22.	Psittacosis	0.9	5.3	3.8	3.8	12.8
23.	Congo-Crimean Hemorrhagic fever	0.7	4.7	3.9	3.2	11.8
24.	Avian mycoplasmosis	1.0	1.3	5.4	4.7	11.5
25.	Pasteurellosis	0.9	3.2	5.1	3.0	11.3
26.	Ovine chlamydiosis	0.8	2.3	4.7	2.8	9.8
27.	Spotted fever (Rickettsiosis)	0.9	4.0	1.7	2.6	8.3
28.	Canine distemper	0.9	1.4	2.3	4.4	8.2
29.	Middle East respiratory syndrome coronavirus	0.7	3.9	2.3	1.8	8.0
30.	Epizootic haemorrhagic disease	0.7	0.9	4.5	2.2	7.6
31.	Bovine viral diarrhea	0.8	1.0	4.8	1.8	7.6
32.	Bovine tuberculosis	0.5	2.7	2.6	2.3	7.5
33.	Dengue	0.6	5.5	0.8	0.8	7.1
34.	Swine influenza	0.6	2.4	2.5	2.1	7.0
35.	Caprine arthritis/encephalitis and Maedi-visna	0.8	1.0	3.3	2.2	6.6
36.	Tularemia	0.5	2.9	1.6	1.9	6.4
37.	Human monocyticehrlichiosis	0.8	4.1	1.0	1.1	6.2
38.	Porcine cysticercosis	0.7	1.8	2.4	1.8	5.9
39.	Hantavirus disease	0.4	3.0	1.4	1.2	5.7
40.	Bovine spongiform encephalopathy	0.4	1.6	2.5	1.1	5.2
41.	Lyme disease	0.5	2.0	1.6	1.5	5.1
42.	Glanders	0.4	1.4	1.7	1.2	4.3
43.	Aujeszky's disease	0.4	0.8	1.6	1.4	3.8
44.	Nipah virus encephalitis	0.3	1.1	1.5	1.1	3.8
45.	Ebola haemorrhagic fever	0.3	2.3	0.6	0.8	3.7
46.	Ranavirus disease	0.5	0.7	0.7	2.0	3.5
47.	Human granulocytic anaplasmosis	0.5	1.9	0.7	0.9	3.5
48.	Morbillivirus	0.5	1.4	0.7	0.9	3.0
49.	Japanese encephalitis	0.3	1.8	0.4	0.4	2.6
50.	Chronic wasting disease	0.2	0.3	0.7	0.7	1.7
51.	Old World screwworm	0.2	0.4	0.6	0.6	1.5

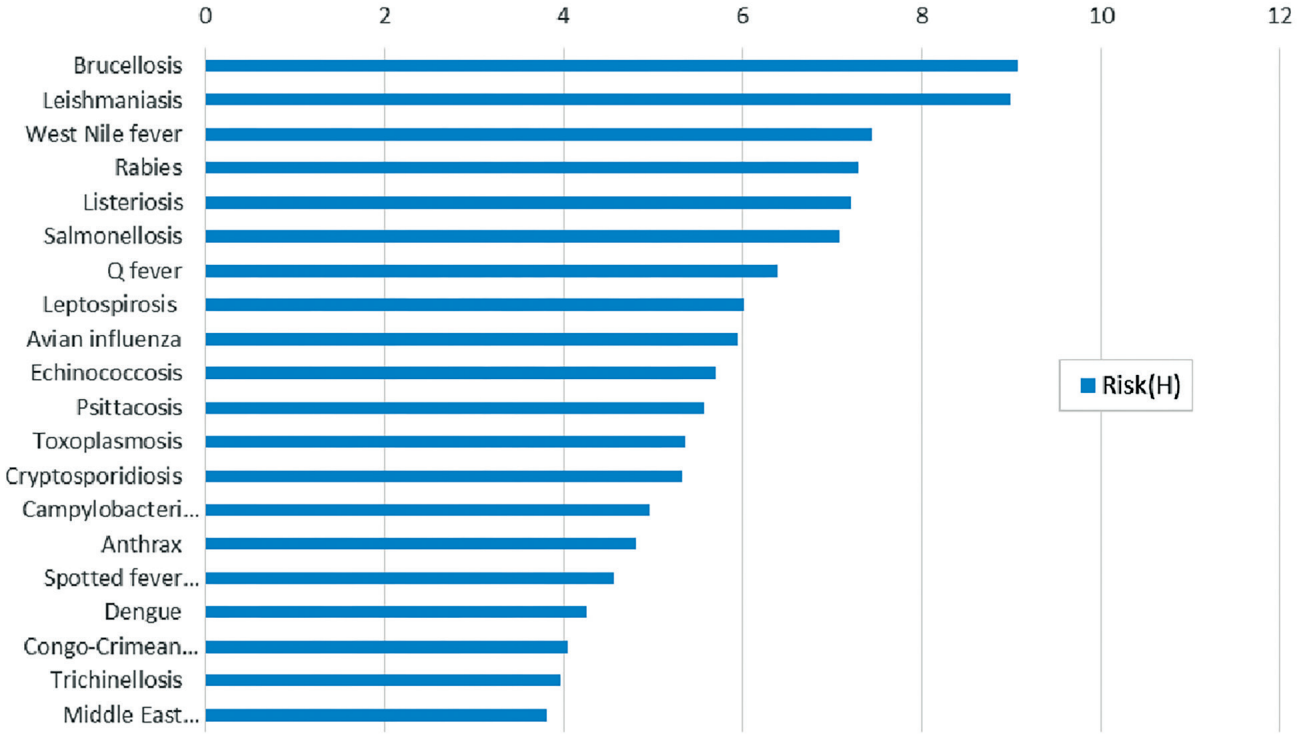

Figure 1. Top 20 Human risks. Risk(H)=Human risk

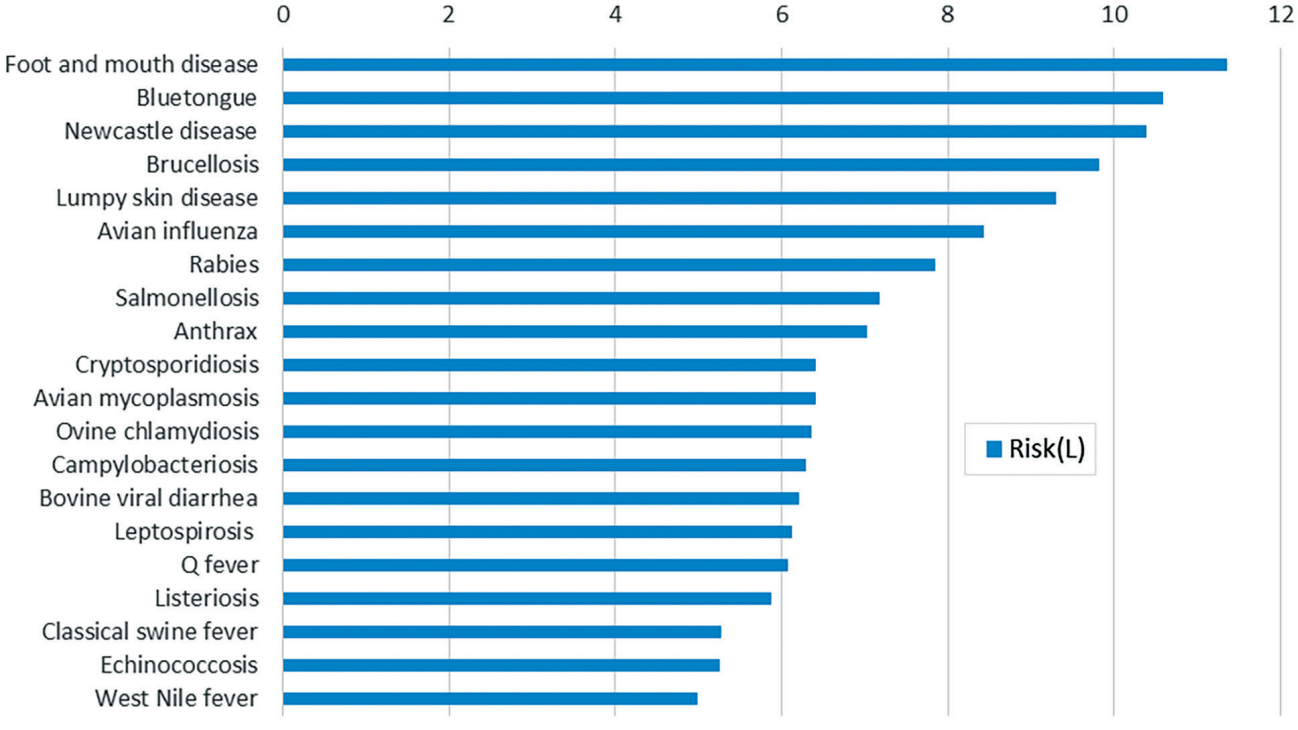

Figure 2. Top 20 Livestock risks. Risk(L)=Livestock risk

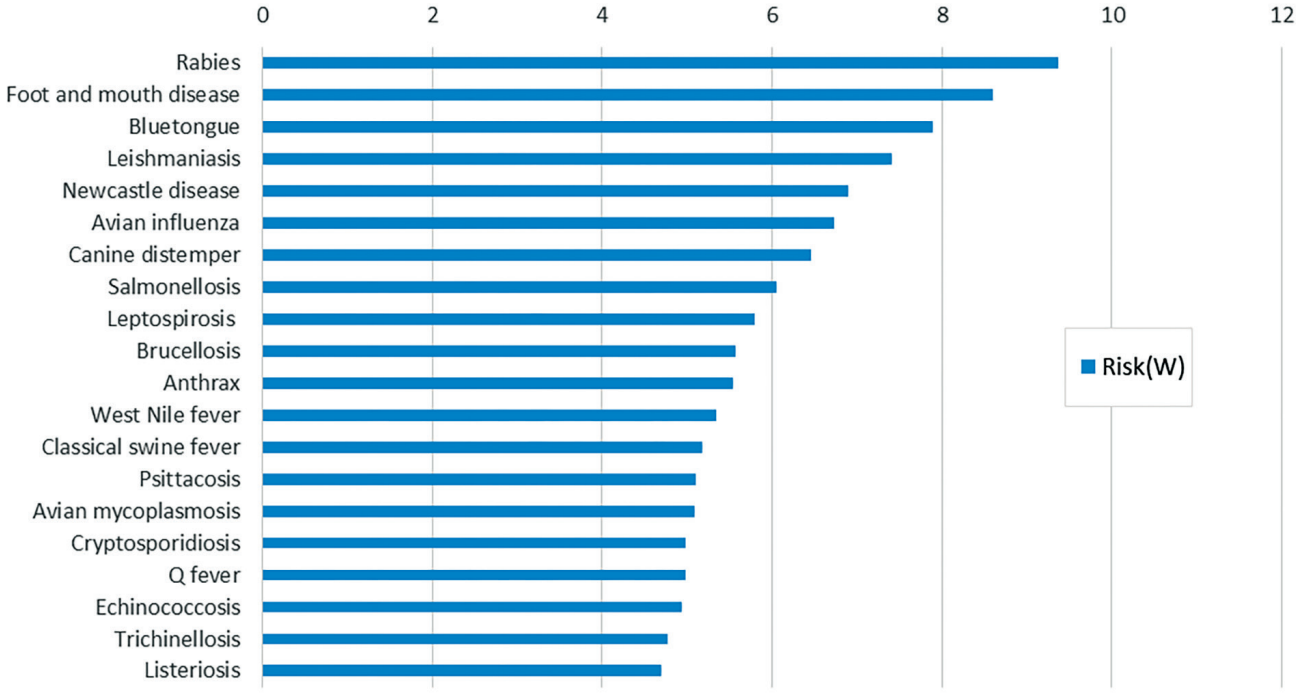

Figure 3. Top 20 Wildlife risks. Risk(W)=Wildlife risk

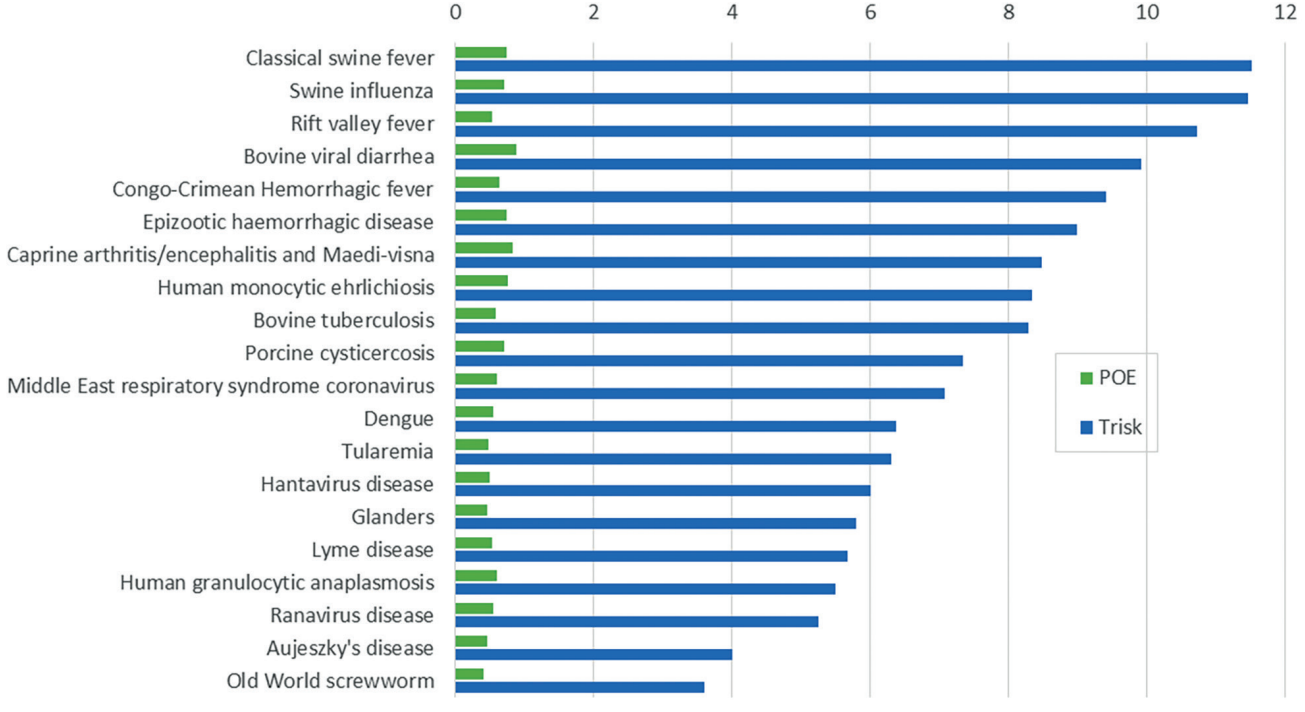

Figure 4. Top 20 total risks (Trisk) of non-endemic pathogens (POE=0.6-0.8).
Trisk=Total risk; POE=Probability of entry

which have never been diagnosed in Israel are ranked lower. For the Livestock risks, Foot and Mouth, Bluetongue, and Newcastle diseases were ranked the highest and included diseases from the top twenty which are endemic in Israel or which have appeared in the in recent times (19). For the Wildlife risks, Rabies, Foot and Mouth and Bluetongue diseases were ranked the highest and also here in the top twenty the majority are those diseases that are endemic to Israel.

Total risk ranking, which is the combination of Human, Livestock and Wildlife risks, placed Brucellosis, Rabies and Foot and Mouth diseases as highest risks. Brucellosis, which is a highly transmissible disease that is caused by several Brucella species and affects a variety of mammals including humans, is endemic in Israel but the epidemiology of the disease in wildlife is not well known, therefore the high ranking of the disease seems reasonable (20,21). Rabies, a well-known viral disease that can affect all mammals is also endemic in Israel. The prevalence of this disease in wildlife is well studied but the mortality rate of the disease caused the disease to be ranked high in the questionnaire (21,22). Foot and mouth disease is also a well-known viral disease that affects livestock and can have major economic impact. Despite this, there are still gaps in knowledge regarding wildlife epidemiology in Israel where the disease exists (21,23).

Seventy five percent (15 diseases) of the top 20 Human risks and 85% (17 diseases) of the top twenty Livestock Risks were included in the top twenty Total risks.

As a project that involves four governmental offices, the fact that the top risks combined Human and Livestock risks represented complementarily of purpose and actually strengthened the project as a One-Health targeted venture. Nonetheless, risk scores can be used for ranking pathogens within One-Health sector or across all sectors which can help to target specific issues and diseases.

The probability of entry (POE) has major influence on the risk estimation. As a national surveillance program, it was envisaged that exotic pathogens would also be monitored. The top twenty exotic pathogens, which were defined by a POE between 0.6 to 0.8 (moderately likely to highly likely to enter), showed some variance. From diseases like Classical Swine Fever that have been circulating in the past in Israel (19) to Middle East Respiratory Syndrome coronavirus that is a newly emerging disease in bordering countries (24) and to the Rana virus which is restricted to amphibians and has never been reported in Israel. The ability to differentiate between endemic to exotic pathogens risks will aid in decision making concerning the relative weight of exotic pathogens versus endemic pathogens in the surveillance program.

A notable limitation of this study may have been a lack of balance between different One Health disciplines among the group of responders. In addition, some of the responders are not involved in policy making and thus further critical validation of the risk assessments was required by the steering committee. This is important as a means to provide credibility to the results and ensure acceptability (12).

The next stage will be to consider costs and practicability of surveillance systems for the high-priority pathogens. Each of the high priority pathogens will be discussed by the steering committee and the stakeholders and decisions will be made regarding the inclusion in the surveillance program. For example: Foot and Mouth disease is a well-known disease but the role of wild boars in the epidemiology of the disease is not well understood and thus it is highly likely that this disease will be included in the surveillance program. On the other hand, campylobacteriosis is ranked high in the total risk but the source of the disease being poultry is already well-known and is already surveyed in other programs and thus it is unlikely that this disease will be included in the surveillance program. In addition, wildlife sampling is logistically demanding and sampling for different pathogens simultaneously is expected to improve the efficiency of the surveillance (12).

In conclusion, using a modification of the Rapid Risk Analysis method for prioritization of pathogens, the Israel Wildlife Diseases Surveillance (IWDS) program steering committee successfully performed the first prioritization exercise in Israel. The questionnaire results showed a good representation of Human and Livestock risks by grading diseases that are both zoonotic and livestock related and thus strengthening the program as a 'One-Health' orientation. The results will be further discussed and decisions will be made by the steering committee and stakeholders as to which pathogens will be included in the surveillance program with emphasis placed on pathogens of public and livestock health importance.

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