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Development and Application of a Framework for Emerging Infectious Disease Intelligence in Lower Resource Settings

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Abstract

In 2005, World Health Organization member countries agreed to the revised International Health Regulations which require countries to detect, report, and respond to any event that may represent a public health emergency of international concern. Forecasting the risk posed by hazards, including incidents in animal populations, requires an intelligence-based approach. We propose an emerging infectious disease intelligence framework informed by literature from the fields of surveillance, epidemic intelligence, and military intelligence. This framework highlights the need for situational awareness and can be used to assess emerging infectious disease intelligence capacity in lower resource settings. To illustrate the utility of this framework we applied it to the Infectious Disease Surveillance and Analysis System, a mobile phone-based surveillance pilot project supplementing diagnostic laboratory-based surveillance in Sri Lanka. Application of the framework was feasible and useful in illuminating the strengths and deficits in the current surveillance infrastructure in Sri Lanka for emerging infectious disease early warning. The approach also demonstrated how a mobile phoned-based system could improve Sri Lanka's emerging infectious disease intelligence capabilities. Finally, the framework allowed us to recommend steps to take in order to strengthen Sri Lanka's emerging infectious disease early warning capacity, enabling more timely and complete identification of events in the animal population that could pose a human health risk.

Keywords: Surveillance; Intelligence; Emerging infectious disease; Infectious disease outbreaks; Animals; Health; Lower resource settings; Sri Lanka.

Abbreviations: EID: Emerging infectious disease; CDC: Centers for Disease Control and Prevention; IDSAS: Infectious Disease Surveillance and Analysis System; DAPH: Department of Animal Production and Health; VRI: Veterinary Research Institute; VIC: Veterinary Investigation Centre; FVS: Field veterinary surgeon.

Introduction

The landscape of infectious disease risk has changed dramatically over the last forty years. A number of new infectious diseases have emerged, catching the global public health community off guard. The rate of emergence has been increasing and this trend is expected to continue [1-3]. Infectious diseases are deemed 'emerging' if they have only recently arisen or if they are previously known diseases that are increasing in incidence or geographic or host range [4]. It is estimated that close to 75 percent of new emerging infectious diseases (EID) in humans have arisen in animals [2], making animal surveillance an important part of EID preparedness [5]. As the size of the global population increases so too will the forces driving the emergence and spread of EIDs [2,6-8], and therefore reliable means of forecasting the risk of future EID events are in demand [9].

When the risk of future EID events is mapped, it is highest in areas at lower latitudes where many countries range from low to middle income [2]. In many cases these countries lack the infrastructure necessary to carry out many of the surveillance techniques developed in high-income countries [10]. Therefore, EID surveillance research should focus on developing techniques and methods that are adaptable to local conditions, especially those in high-risk areas [10-12].

Surveillance in the animal health field has historically targeted submissions to diagnostic laboratories, much like in the human health field, where the aim is to make an etiological diagnosis [13]. This type of surveillance is limited with respect to identifying EID events: the etiological agent may be previously unknown, significantly delaying a diagnosis [14]; diagnostic technologies may be costly and have limited availability, particularly in rural and lower resource settings, severely restricting sensitivity of systems [15]; and clinicians may encounter new diseases that mimic common diseases and therefore attribute cases to an enzootic agent, precluding the need for diagnostic laboratory support [16]. When new pathogens are identified, often there are no data on exposure to determine the risk they pose to human health [17]. These limitations indicate that laboratory-based surveillance often fails to capture the information required to adequately forecast the risk posed by animal health-related events [17].

Due to the changing EID landscape and limitations of laboratory-based surveillance, there is a desire to develop, implement, and evaluate surveillance systems that use other forms of animal data to identify

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events that could forecast an emerging health risk to humans [18]. The reason for seeking out new data sources for animal-based surveillance is two-fold: there is a need to detect animal health events as early as possible, and there is a need to consider events in context to determine their significance as a human health risk. Identifying new sources of animal health data that satisfy these needs remains a key challenge to EID surveillance [19].

In 1988 the Centers for Disease Control and Prevention (CDC) published the Guidelines for Evaluating Public Health Surveillance Systems to 'ensure problems of public health importance are being monitored efficiently and effectively' [20]. In those guidelines, attributes defined as necessary for the evaluation of a surveillance system included simplicity, flexibility, acceptability, sensitivity, predictive positive value, representativeness, and timeliness [20]. In 2001, the CDC published updated guidelines in part because of the need for 'changes in the objectives of public health surveillance to facilitate the response of public health to emerging health threats' [21]. They differ from the 1988 guidelines in that data quality and stability were included as additional system attributes for evaluation [21]. Updates from 2004 stressed timely data collection and analysis for detection of infectious disease outbreaks [22]. These guidelines have played a vital role in developing, implementing, and maintaining many surveillance systems [23-26]. However, they do not reflect the attributes of a surveillance system that uses data concerning animal populations to forecast risk in humans: the CDC's guidelines were based on surveillance systems that aimed to identify human cases within human data.

Surveillance systems that use animal health and disease occurrence data have been developed, in many cases by adapting methods from the human health field, however, the majority operate in high-income countries [27]. Very few have undergone a formal evaluation process, and in cases where there has been an evaluation most often only a subset of the CDC's system attributes were considered [27]. One of the challenges in evaluating these types of systems is that the purpose of using animal data for surveillance of public health risks from EIDs is to forecast risk to people.

EID surveillance that uses data other than clinical human cases can be considered risk factor surveillance [28]. Work in the area of detecting a change in risk is not limited to the field of EID surveillance. With recently heightened concerns around terrorism, there has been further research and investment in military intelligence [29]. The purpose of a military intelligence agency is to 'watch and monitor all possible sources of threats and transform that information into valuable intelligence content for implementing military operational activities' [29]. The desire of military intelligence to find unknown and difficult to quantify 'threats' is analogous to the challenge of EID risk detection. Effective surveillance systems enable decision makers to continually assess the situation and mount timely reactions to threats as they arise, or in essence 'deploy the troops' efficiently and effectively. In the military context, surveillance equates to monitoring of any data that are collected from reconnaissance, while intelligence involves analyzing that data and transforming them into usable content for planning and decision-making [29]. The same distinction between surveillance and intelligence in EID risk forecasting might have considerable value in assessing surveillance system capacity and informing future surveillance system upgrades.

In this paper we propose an EID intelligence framework informed by published literature from the fields of surveillance, epidemic intelligence, and military intelligence. The underlying premise is that there is a need for a framework separate from the CDC's Guidelines for Evaluating Public Health Surveillance Systems that reflects the objective of detecting a change in the animal population that could indicate an impending EID event of human health significance. The desired outcome is to provide a framework that can be used to assess the ability of animal health surveillance systems to provide information concerning an animal health-related event that is necessary and sufficient for public health planning and decision-making and may forecast an EID risk to people. We then apply this framework to the Infectious Disease Surveillance and Analysis System (IDSAS), a mobile phone-based animal health surveillance system that was piloted in Sri Lanka, in the context of Sri Lanka's animal diagnostic laboratory-based surveillance infrastructure, to determine its potential to contribute to EID intelligence in Sri Lanka.

Materials and Methods

Proposed framework for EID intelligence

A scoping review of primary and secondary literature from the fields of surveillance, epidemic intelligence, and military intelligence was conducted to identify common experiences, opinions, and features that would inform development of a framework for use in establishing and evaluating EID intelligence systems. Keyword searches were done in PubMed, Google Scholar, and Google using combinations of the following phrases: infectious disease surveillance, surveillance system, evaluation, epidemic intelligence, and military intelligence.

The first author was responsible for retrieving and reviewing the articles. No attempt was made to assess the quality of the papers. English language titles and abstracts retrieved were read and articles were selected if they satisfied one of the following criteria: 1) they reviewed and synthesized findings across the subjects of surveillance, surveillance systems, surveillance system performance and evaluation, animals as sentinels, and infectious disease outbreaks; 2) they provided explanation supported by literature for essential surveillance system characteristics; 3) they detailed considerations in surveillance system design and implementation; or 4) they defined and/or detailed epidemic intelligence or military intelligence. Common objectives of early warning systems were identified as the system features of an EID intelligence system. The defining characteristics of the system features were identified as elements. For each element, common goals were sought that served as identifiable outcomes of early warning or intelligence systems. The components of the system were defined as the capacities, resources or infrastructure associated with delivery of these goals. Finally, attributes for design and/or evaluation of each component were identified as measurable features of each component that might allow one to determine if the components were in place to meet the objectives of an EID intelligence system. System features, elements, goals, components, and attributes, as well as their key references, were organized into a table to define clearly the framework, document the thematic review process, and illustrate the hierarchical structure.

The infectious disease surveillance and analysis system

The IDSAS was established in collaboration with the Department of Animal Production and Health (DAPH), the national-level body responsible for control of livestock diseases, livestock research, animal breeding, and education in animal husbandry in Sri Lanka. Veterinary services are delivered through provincial-level DAPH councils and field offices. Provinces are made up of districts, which are further divided into divisional secretariats. Each divisional secretariat division is assigned a minimum of one field veterinary surgeon (FVS) that provides animal health services. In the four participating districts in Sri Lanka (Anuradhapura, Matara, Nuwara Eliya, Ratnapura) the IDSAS employed forty FVSs to track syndromes and clinical diagnoses in cattle, buffalo, and poultry. Each survey submitted by a FVS represented one visit to a farm or one examination in a clinic of at least one of the three species. Surveys were classified by routine visits (yes/no), presence or absence of an animal health issue, location of the case (clinic/on-farm), diagnostic samples submitted (yes/no), and gross post mortem examination (yes/no). When an animal health issue was present, cases were given a syndrome group and a clinical diagnosis. FVSs were given the option of classifying the cause of the animal health issue as unknown or other, in which case comments in a free-text field could be entered. There were a total of 17 syndrome groups for cattle and buffalo and 11 for poultry. Options for clinical diagnoses were based on the syndromic grouping selected. As each FVS is responsible for a known geographical area, geographic locations could be associated with each survey down to divisional secretariat division level. FVSs were asked to submit surveys via email to a surveillance database daily. Weekly reports containing a list of cases were disseminated to project partners. See Robertson et al. 2010 for a detailed description of design and implementation of the IDSAS [30].

Diagnostic laboratory-based surveillance in Sri Lanka

The DAPH carries out surveillance for OIE-listed diseases and emerging animal diseases. The Veterinary Research Institute (VRI) operates under the DAPH and is the only national-level organization in Sri Lanka that provides veterinary diagnostic services. District-level laboratory diagnostics are provided by Veterinary Investigation Centres (VIC). They are located in fifteen of the twenty-five districts: Anuradhapura, Badulla, Hambanthota, Chillaw, Jaffna, Matara, Peradeniya, Rannala, Polonnaruwa, Ratnapura, Vaunia, Welisara, Kegalla, Nuwara Eliya, and Dambulla. One aim of the DAPH is to establish VICs in every district in Sri Lanka.

Diagnostic laboratory data are stored in paper format at the VRI and VICs. Diagnostic laboratory data from the geographical area covered by the IDSAS were compiled and digitized into a Microsoft Excel® spreadsheet. For each case, fields included: date; location from which the sample(s) were collected down to the divisional secretariat division level; species; age of the animal(s); number of animals in the flock or herd; sex; number of samples collected; type of sample(s); test(s) performed; result of the test(s); agent(s) identified; and whether the test was performed as part of a government-initiated health program. The data presented cover the period of January 1 2000 through to December 31 2009.

Diagnostic laboratory data

In order to detail ongoing diagnostic laboratory-based disease surveillance in Sri Lanka, availability of laboratory diagnostics as well as descriptive statistics are presented. The number of case submissions and laboratory tests performed for the area covered by the IDSAS, the average number of tests per year, the range, mean, and median of tests per divisional secretariat division over the 10-year period, and the percent complete for each of the submission fields were calculated. Only case submissions from the three species tracked by the IDSAS were included in order to compare the number of submissions between the two systems. Case submissions known to be from government-initiated health programs were excluded because they often entailed multiple visits to a small number of farms over a short period of time (weeks to a few months) to collect blood, fecal, and milk samples in order to test for a variety of pathogens. These programs are directed by VICs and do not reflect case submissions from FVSs.

Census of Agriculture data

The Agriculture and Environment Statistics Division of the Department of Census and Statistics is the national-level body responsible for collecting, processing, and disseminating information related to agriculture in Sri Lanka, including data on the livestock population by species, district and divisional secretariat division. Population estimates presented concerning cattle, buffalo, and poultry for the geographical area covered by the IDSAS were collected during the year 2008. Agricultural census data are included to illustrate the use of multiple data sources, in particular how the IDSAS and census data can be used to calculation population- and farm-level case rates.

Information flow within the government veterinary services in Sri Lanka

In order to understand how animal health data moved from the field level through to the DAPH headquarters discussions took place with individuals at all levels of the government veterinary services in Sri Lanka. The initial sample included research contacts within the DAPH and the Ministry of Livestock Development. Snowball sampling through the professional contact network of preliminary research contacts was then employed to identify other key informants. All discussions took place in person. Topics of discussion included the animal health situation in Sri Lanka, the availability of diagnostic laboratory testing and supplies, handling of suspect cases of OIE-listed diseases, sources of data, data handling, and dissemination of information.

In order to explore the contribution of the IDSAS to animal health data flow in Sri Lanka, the flow of information from the IDSAS was superimposed onto a flow diagram of existing veterinary infrastructure in Sri Lanka. Included are the VRI and VICs to illustrate how cases move through various levels of the diagnostic hierarchy, from reporting a case to a FVS, to making a clinical diagnosis, to submitting a sample for a diagnostic laboratory test, and finally reporting a result to relevant authorities.

Assessing the contribution of the diagnostic laboratory-based surveillance system and the IDSAS to EID intelligence in Sri Lanka

Data pertaining to the information collected, reporting completeness, and other features of the IDSAS and the diagnostic laboratory-based surveillance system were linked to the EID intelligence framework to explore the contribution of both systems to EID intelligence in Sri Lanka.

Results

Proposed framework for building EID intelligence

There is a large body of literature that deals with surveillance, EID events, and surveillance systems in general. Detailed evaluation was restricted to a number of critical publications that synthesized main lessons [7,11,21,31-45]. There were only a few key references available that address defining and describing epidemic intelligence [46,47] and military intelligence [29,48,49]. Common features derived from these sources indicate that EID intelligence must provide information early in the course of events and be capable of generating warning signals, and that associated with each warning signal must be some indication of risk posed by the event taking place. Table 1 presents the system features, elements, goals, components, and attributes for evaluation. Key references are provided to detail the connection between the table and the reviewed literature.

Summary of the IDSAS data

The IDSAS operated for 365 days (January 1 2009 through to December 31 2009). During this period, 5758 unique surveys were submitted to the system by participating FVSs. This is equivalent to ~144 surveys/FVS over a 12-month period (12 per FVS per month). Of the total number of surveys, 4639 cases were reported, while the remaining 1119 surveys indicated no animal health issues. Of the unique surveys, 44.71% were received on the day they were completed while 78.08% were received within five days of completion. The survey required entries in all fields prior to completion. FVSs made a clinical diagnosis in 4402 cases, of which 247 (5.61%) had a gross post mortem examination performed. In 237 cases FVSs reported the cause of the case unknown, of which 18 (7.59%) had a gross post mortem examination performed. Of the 4639 cases submitted to the IDSAS, 326 (7.03%) reported contributing a sample to a laboratory.

Cattle herds visited by FVSs participating in the IDSAS averaged 6 animals in size, ranging from 1 to 150 animals. Buffalo herds averaged 23 animals and ranged in size from 1 to 198, while poultry flocks consisted of an average of 225 birds and ranged in size from 1 to 4500.

Summary of the diagnostic laboratory data

The current laboratory diagnostic capabilities of the government veterinary services in Sri Lanka are presented in Table 2. Diagnostic laboratory data was stored in paper format at VICs and the VRI and therefore had to be manually reviewed and digitized in order to be made accessible. During the 10-year study period 1208 laboratory tests were performed on 1101 cases at the VRI and relevant VICs. This is equivalent to ~3.02 laboratory tests/divisional secretariat division/year (0.25 tests per month). The tests per divisional secretariat division ranged from 0 to 305 over the 10-year period, with a mean of 30.2 and a median of 7.5. There was no standardized data collection platform for diagnostic laboratory data: digitization required that information be pulled from laboratory reports with varying formats. Measures of diagnostic laboratory data completeness are presented in Table 3. The first diagnostic samples were processed at the VIC in Anuradhapura in January 2008; in Matara in February 2001; in Nuwara Eliya in June 2009; and in Ratnapura in November 2007. The number of diagnostic laboratory submissions by year and test location is given in Figure 1. During 2009 the VRI received samples from 28 cases and the VICs received samples from 308 cases.

Merging of the IDSAS and census of agriculture data

Table 4 provides an example of population and on-farm rates for

System features	Elements	Goals	Components	Attributes for design and/or evaluation	Key references
Early	Timely awareness	To effectively communicate understandable information in a rapidly accessible manner to people with ability and authority in order that they interpret the information and act	A communications system that is regular, reliable, and multidirectional	Features of data acquisition and dissemination Traceability of individual cases through the system	[11,21,29,31-37,46,48,49]
			People with the ability to interpret the data centrally and locally	Ability and willingness of stakeholders to access and view data appropriately	[11,21,31-33, 35,38]
			An understandable and meaningful input format	Feedback from data providers regarding properties of the data collection platform	[11,21,29,33,39,48,49]
Warning	Meaningful event information	To provide information to help forecast population-level prognosis	Data to fill the diagnostic hierarchy	Number of cases at various points in the system	[21,40,41]
			Data to define the magnitude of the problem	Ability to calculate population rates Ability to calculate farm-level rates	[21,37,41]
			Contextual information on the problem of interest or unusual occurrence	Case characteristics accompany submissions	[21,33,37,42]
		To provide peri-event information to help provide context	Concurrent health events	Ability to document other health-related events	[11,21,40,32,33,38,48,49]
			Local environmental variability	Ability to incorporate environmental data	[7,39,40,43,46,47]
Risk	Unusualness	To recognize an event as unusual	Local knowledge	Ability to collect and integrate local knowledge from farmers and data providers	[7,34,38,39,42,46]
			Create/access historical trend development (species, disease, location)	Inventory of historical trend data or ability to generate trend data	[11,21,31,32,39,40,44,48,49]
			Analytical capacity	Ability to analyse data from multiple sources to detect an event and determine its significance	[11,21,29,31,32,34,40,46-49]
	Risk to the human population	To demonstrate the potential for human exposure	Document animal location and use with respect to the population of concern	Ability to collect and integrate agricultural and human census data, animal locations and movements	[7,34,41-47]

Table 1: Proposed components of an emerging infectious disease intelligence system supported by published evaluations and criteria.

Location	Diagnostic capabilities	Confirmable condition (if applicable)
Field offices	Clinical examination Gross post mortem examination California Mastitis Test* Microscopy (+/- stain)*	 Mastitis Blood-borne parasites
VICs	California Mastitis Test Microscopy (+ stain) and fecal flotation Aerobic bacterial culture Antibiotic sensitivity testing Rose Bengal plate agglutination test Rapid antigen detection	Mastitis Blood-borne parasites, intestinal parasites Bacterial infection Bacterial drug resistance Brucellosis Highly pathogenic avian influenza
VRI	California Mastitis Test Microscopy (+ stain) and fecal flotation Aerobic and anaerobic bacterial culture Antibiotic sensitivity testing Histopathology Complement fixation test Milk ring test Antigen detection enzyme-linked immunosorbent assay Enzyme-linked immunosorbent assay Reverse transcription-polymerase chain reaction Pathogen isolation by egg inoculation Serology	Mastitis Blood-borne parasites, intestinal parasites Bacterial infection Bacterial drug resistance Brucellosis Brucellosis Foot and mouth disease Classical swine fever Highly pathogenic avian influenza Newcastle disease Infectious Bursal Disease Infectious Bronchitis Reovirus infection Infectious laryngotrachitis
*Only select offices have these diagnostic capabilities.		

Table 2: Veterinary diagnostic capabilities in Sri Lanka.

Field	Number of completed fields	Total number of cases	% of cases
Type of sample	1203	1208	99.6
Result of test	1193	1208	98.8
Type of test performed	1204	1208	88.7
Number of samples submitted	525	1208	43.5
Age	336	1208	27.8
Sex	134	1208	11.1
Number of animals in herd or flock	106	1208	8.8
Number of positive samples given a positive test result	264	859	30.7
Number of positive samples given a positive test result where the number of samples submitted was supplied	262	405	64.7

Table 3: Measures of diagnostic laboratory data completeness in Sri Lanka, 2009.

the most commonly encountered syndrome by FVSs in cattle and poultry for two districts.

Flow diagram of animal disease data in Sri Lanka

An overview of existing disease surveillance infrastructure in Sri Lanka is merged with the IDSAS in Figure 2. The flow of data through levels of government veterinary services was derived from field-level interviews. Though the IDSAS enabled FVSs to report sample submission to a laboratory, the system did not allow individual samples from FVSs to be tracked to the VICs or VRI as indicated by the dashed lines in Figure 2.

Applying the EID intelligence framework to the IDSAS and the diagnostic laboratory-based surveillance system in Sri Lanka

In Table 5 the performance of the IDSAS in Sri Lanka is summarized based on the proposed framework in Table 1.

Discussion

There remains uncertainty as to how to operationalize an EID early warning system. In this paper we propose and apply a framework

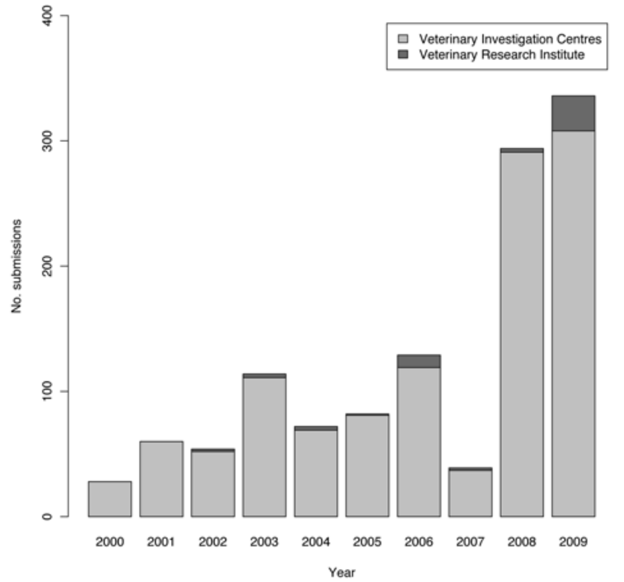

Figure 1: The number of diagnostic laboratory submissions by year and testing facility.

Syndrome and species	Nuwara Eliya			Matara		
	Cases	Population case rate	Farm-level case rate	Cases	Population case rate	Farm-level case rate
Cattle: Decreased feed intake/milk production	853	853/29823[1] 2.860%	853/3217[2] 26.515%	317	317/9286[1] 3.413%	317/1316[2] 24.088%
Poultry: Decreased egg production/weight gain/appetite	121	121/151676[1] 0.07978%	121/1239[2] 9.766%	14139	14139/100722[1] 14.038%	14139/30069[2] 47.022%

[1]Denominators derived from the 2008 Census of Agriculture
[2]Denominators derived from the IDSAS database

Table 4: Case counts, population and on-farm rates for selected syndromes and districts in Sri Lanka.

System features	Strengths	Limitations	Opportunities for development
Early	Timely Regular Reliable Acceptable Understandable Meaningful Interpretable Adaptable based on user and stakeholder feedback	Unidirectional No traceability Unsustainable Limited data dissemination Limited ability for stakeholders and users to access and view data	Incorporation of diagnostic laboratory data
Warning	Detailed information on individual cases Supplemented the diagnostic hierarchy Documented other health-related events	Disconnect between the level of the FVS and the diagnostic laboratories	Calculation of population- and farm-level rates Incorporation of environmental data
Risk	Provided case location data Inventoried historical trends on syndromes and endemic disease Collection and integration of local knowledge from FVSs	Limited local analytic capacity Limited ability to collect and integrate local knowledge from farmers	Collection and integration of agricultural and human census data, animal locations and movements Analysis of data from multiple sources

The table describes the Infectious Disease Surveillance and Analysis System as it was implemented in Sri Lanka in terms of its strengths, limitations, and opportunities for development

Table 5: Proposed system features of the emerging infectious disease intelligence framework and the Infectious Disease Surveillance and Analysis System in Sri Lanka.

for EID intelligence that includes key elements and specific system attributes against which existing surveillance systems can be compared. It was based on the premise that recent changes in the landscape of EID risks necessitate an approach that considers risk more broadly and places emphasis on the context in which animal health-related events take place, and within which animal-health related information is used by decision makers. Application of the framework was feasible and useful in illuminating the strengths and deficits of the IDSAS and current diagnostic laboratory-based surveillance infrastructure in Sri Lanka for EID early warning. The framework helped to identify steps that could be taken to strengthen the IDSAS (Table 5).

Given the diagnostic capacity in Sri Lanka and the small number of case submissions, the diagnostic laboratory system cannot serve solely as the basis for EID surveillance, and on its own, is unable to adequately identify and characterize the breadth of animal health-related events relevant to EID early warning. If the proposed EID intelligence framework is accepted as sufficiently supported by current literature, we demonstrate how the IDSAS could facilitate a shift from diagnostic laboratory-based surveillance to EID intelligence in Sri Lanka.

Frontline mobile phone-based reporting has the potential to contribute to EID intelligence as shown by the IDSAS which was able to help describe the context in which animal health-related events occur. The IDSAS has the ability to greatly increase the number of case submissions and reports that are readily available to high-level officials. As the IDSAS is based on submissions from FVSs, it provides more opportunities to observe change within the animal population: FVSs visit farms, interact with farmers, and can gather ancillary data. FVSs are often the first to observe animal health-related events. In addition, as the IDSAS requires completion of all data fields prior to survey submission, the contextual information more accurately reflects the animal health situation as encountered by FVSs.

Utilization of the EID intelligence framework also revealed important weaknesses and deficits in the IDSAS. There was no way to trace cases through the IDSAS up through to the level of the diagnostic laboratories. Information flow was entirely unidirectional. Stakeholders did not receive information in a timely enough fashion, nor were they able to access data independently of researchers. While the ability to incorporate and analyze additional information sources, including environmental data, relevant subsets of the agricultural and human census, and animal locations and movements, was inherent in the IDSAS, this capacity was never utilized within the pilot system.

The pilot stage of the IDSAS in Sri Lanka serves as proof of concept. It is important to note that the IDSAS was never designed to become part of ongoing EID disease surveillance efforts in Sri Lanka, though early on it became clear that the IDSAS was in fact very efficient and effective at collection of data that details the domestic animal population served by FVSs in Sri Lanka. While it remains highly praised at the DAPH and the DAPH remains motivated to deploy mobile phones for targeted projects as they saw the value in this approach, a long-term plan for the IDSAS in Sri Lanka is still pending at the time of writing. This situation highlights one of the challenges to surveillance –it takes considerable time and energy to develop and implement novel approaches to surveillance. Current funding and project structuring do not allow for timelines sufficient for surveillance system design, implementation, and integration with pre-existing surveillance activities, and realization by researchers and government of the added

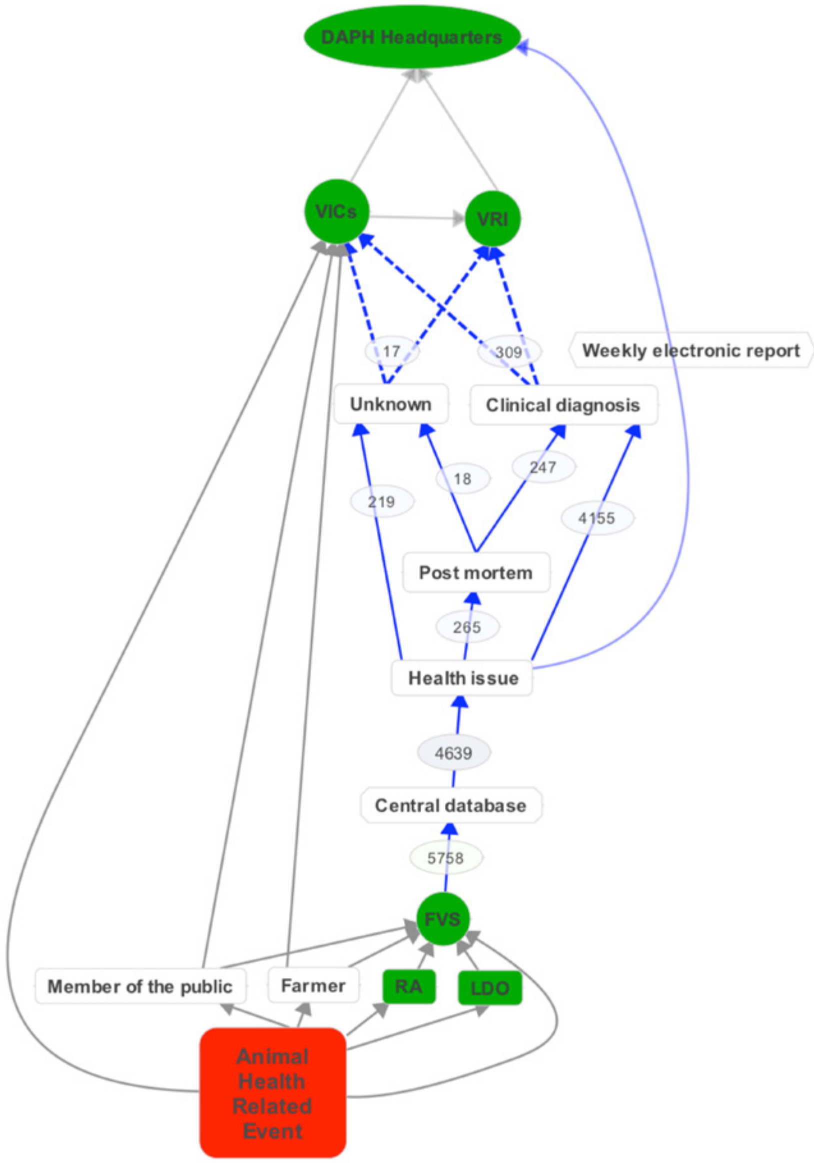

Figure 2: Structure and flow of data concerning animal health-related events in Sri Lanka from 1 Jan 2009 to 31 Dec 2009, in addition to the IDSAS as it relates to existing disease surveillance activities. Green-filled shapes represent hierarchical levels within the government veterinary services of Sri Lanka. Green-filled circles represent sources from which data was collected. Arrows represent the flow of information: blue arrows representing case flow through the IDSAS; grey arrows indicate known flows of data which could not be quantified; dashed arrows represent loss of traceability of data. The numbers quantify case counts at various levels in the diagnostic hierarchy. (RA – Research Assistant, LDO – Livestock Development Officer, FVS – Field Veterinary Surgeon, VICs – Veterinary Investigation Centres, VRI – Veterinary Research Institute, DAPH – Department of Animal Production and Health).

value provided by the information generated [50]. The next steps in developing the IDSAS would have included facilitation of data access by stakeholders at all levels, incorporation of additional data sources, exploration and automation of statistical surveillance methods, incorporation of ongoing diagnostic laboratory-based surveillance into the IDSAS database, and transference of administration of the IDSAS to the DAPH.

Local knowledge from frontline health care workers in lower resource settings remains an untapped resource [34,51]. Using existing technological capacity enables conversion of this knowledge into accessible and available data that can help achieve EID intelligence [11]. Future systems need to incorporate means of signal follow up that enable a response in advance of an etiological diagnosis and explore means of ongoing engagement of stakeholders [34]. This approach will permit more rapid identification and response to animal health-related events that may, in turn, mitigate emerging risks to humans.

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