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Stakeholder attitudes and perspectives on wildlife disease surveillance as a component of a One Health approach in Thailand

Serena Elise George [a,*], Moniek Smink [b], Nareerat Sangkachai [c,d], Anuwat Wiratsudakul [c,d,e], Walasinee Sakcamduang [c,e], Sarin Suwanpakdee [c,d,e], Jonathan M. Sleeman [f]

[a] University of Wisconsin-Madison, School of Veterinary Medicine, 2015 Linden Dr, Madison, WI 53706, USA
[b] University of Wisconsin-Madison, Department of Computer Sciences, 1210 W Dayton St, Madison, WI 53706, USA
[c] Thailand National Wildlife Health Center, Faculty of Veterinary Science, Mahidol University, 999 Phuttamonthon 4 Road, Salaya, Nakhon Pathom 73170, Thailand
[d] The Monitoring and Surveillance Center for Zoonotic Diseases in Wildlife and Exotic Animals, Faculty of Veterinary Science, Mahidol University, 999 Phuttamonthon 4 Road, Salaya, Nakhon Pathom 73170, Thailand
[e] Department of Clinical Sciences and Public Health, Faculty of Veterinary Science, Mahidol University, 999 Phuttamonthon 4 Road, Salaya, Nakhon Pathom 73170, Thailand
[f] U.S. Geological Survey, National Wildlife Health Center, 6006 Schroeder Rd, Madison, WI 53711, USA

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ABSTRACT

Coordinated wildlife disease surveillance (WDS) can help professionals across disciplines effectively safeguard human, animal, and environmental health. The aims of this study were to understand how WDS in Thailand is utilized, valued, and can be improved within a One Health framework. An online questionnaire was distributed to 183 professionals (55.7% response rate) across Thailand working in wildlife, marine animal, livestock, domestic animal, zoo animal, environmental, and public health sectors. Twelve semi-structured interviews with key professionals were then performed. Three-quarters of survey respondents reported using WDS data and information. Sectors agreed upon ranking disease control (76.5% of respondents) as the most beneficial outcome of WDS, while fostering new ideas through collaboration was valued by few participants (2.0%). Accessing data collected by one's own sector was identified as the most challenging (50%) yet least difficult to improve (88.3%). Having legal authority to conduct WDS was the second most frequently identified challenge. Interviewees explained that legal documentation required for cross-institutional collaborations posed a barrier to efficient communication and use of human resources. Survey respondents identified allocation of human resources (75.5%), adequate budget (71.6%), and having a clear communication system between sectors (71.6%) as highest priority areas for improvement to WDS in Thailand. Authorization from administrative officials and support from local community members were identified as challenges during in-person interviews. Future outreach may be directed toward these groups. As 42.9% of marine health professionals had difficulty knowing whom to contact in other sectors and 28.4% of survey respondents indicated that communication with marine health professionals was not applicable to their work, connecting the marine sector with other sectors may be prioritized. This study identifies priorities for addressing current challenges in the establishment of a general WDS system and information management system in Thailand while presenting a model for such evaluation in other regions.

1. Introduction

Pathogens in terrestrial and aquatic wildlife populations are a critical threat to ecosystem stability, poverty alleviation, and global health security. Infectious diseases have become increasingly recognized as a major driver of wildlife population decline, highlighting the need for pathogen surveillance for wildlife conservation purposes [1,2]. At the same time, pathogen spillover to livestock and farmed aquatic organisms as well as transmission to humans are major human health and livelihood concerns [3]. The top thirteen zoonoses (at least eight of which involve wildlife) prioritized by the International Livestock Research Institute contribute to 2.4 billion cases of human illness and

* Corresponding author at: 810 S Gammon Rd, Madison, WI 53719, USA.
E-mail address: sgeorge5@wisc.edu (S.E. George).

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2.2 million human deaths annually [4]. Of the 60.3% of total emerging infectious diseases (EID) attributed to zoonotic pathogens, 71.8% of these originate in wildlife [5]. Gastrointestinal, food-borne zoonoses are of the highest priority and are expected to intensify with globalization of the food supply chain [4]. Consequently, the risk of fish and aquatic-derived bacterial, fungal, viral, parasitic, and protozoal zoonoses is expected to increase along with global expansion of fisheries and aquaculture and the increasing consumption and trade of aquatic foods [6–8]. Surveillance for pathogens in terrestrial and aquatic wildlife populations is therefore essential to the prevention, early detection, and containment of zoonotic infectious diseases.

According to the Convergence Model developed by the Institute of Medicine (US) Committee on Emerging Microbial Threats to Health in the 21st Century [9], infectious diseases arise from a complex interplay of genetic, biological, ecological, environmental, social, political, and economic factors. The Southeast Asia region (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Vietnam) is particularly vulnerable to zoonotic EIDs due to a variety of factors which increase human, livestock/domestic animal, and wildlife contact: rich mammalian and bird biodiversity, population growth and movement, high urbanization rates, land-use change and deforestation, expanding fisheries and aquaculture production, mixed crop livestock intensifying farming systems, increased demand for animal product consumption, and wildlife markets [4,6,10,11]. In recent years, Southeast Asia has experienced several emerging (avian influenza A H5N1, pandemic influenza A H1N1, severe acute respiratory syndrome (SARS), Nipah virus), re-emerging (Japanese encephalitis, rabies, *Streptococcus suis*, leptospirosis), drug-resistant (tuberculosis), and neglected tropical (various aquatic foodborne trematodiases) zoonotic diseases [8,11]. Given the complex and transboundary nature of zoonotic disease emergence, multisectoral collaboration through a One Health model which emphasizes the interconnection of human, animal, and environmental health has become increasingly implemented in wildlife disease surveillance (WDS) [12–14].

In Thailand, One Health was adopted in 2012 by the Thai Cabinet in its National Strategic Plan for Emerging Infectious Disease, which was prompted by the highly pathogenic avian influenza H5N1 outbreak in 2004 and the H1N1 pandemic influenza in 2009 [15]. In 2014, the National Committee on EID Preparedness and Response instituted the Coordinating Unit for One Health to centralize One Health collaborations and to serve as a community outreach and resource center [16]. Since its establishment, four main challenges to the implementation of One Health in Thailand have been identified: 1) balancing routine work duties with continuous intersectoral collaboration, 2) awareness and interpretation of, attitude toward, and commitment to One Health, 3) information sharing challenges related to lack of mutual trust, contrasting priorities, and administrative and legal restrictions, and 4) sustained funding [16].

One program that may help to address the challenges of implementing One Health in Thailand is the World Organization for Animal Health (WOAH, founded as OIE) Laboratory Twinning Programme, which was established in 2006 with the goal "to improve global capacity for disease prevention, detection, and control, through capacity building and networking" [17]. The United States Geological Survey National Wildlife Health Center (U.S. Geological Survey NWHC) and the Thailand National Wildlife Health Center (Thailand-NWHC)/ Monitoring and Surveillance Center for Zoonotic Diseases in Wildlife and Exotic Animals (MoZWE) have established a cross-institutional collaboration through this program. The twinning involves exchange of expertise in wildlife disease risk assessment, monitoring and surveillance, and diagnostic tools capacity building to further develop a general WDS system and establish a WOAH Collaborating Centre for Wildlife Health and Zoonotic Diseases for the Asia-Pacific region in Thailand. Creation of an interoperable data system that connects Thailand with countries throughout the Asia-Pacific region will ultimately work toward the quadripartite vision of, "A world better able to prevent, predict, detect and respond to health threats and improve the health of humans, animals, plants and the environment while contributing to sustainable development" outlined in The One Health Joint Plan of Action (2022–2026) [18].

A needs assessment of Thailand-NWHC/MoZWE was performed in October 2019, which identified the establishment of a general WDS network and associated data and information management system as priorities. To direct the further development of the network and associated information management system, an online survey and in-person interviews with key stakeholders in Thailand were conducted. The first objective of the survey was to understand the perceived importance and value of conducting WDS as part of a One Health surveillance system in Thailand to better characterize how and by which health sectors WDS systems are used in daily work. The second objective of the survey was to understand the current capabilities of wildlife disease data collection, data management, and collaboration across health sectors in order to optimize wildlife disease prevention. Participants were surveyed about perceived impediments to successful WDS as a component of One Health surveillance, their recommendations for solutions, and their motivations for making improvements. To gather more detailed information on perceived impediments and challenges to the implementation of WDS as a component of One Health surveillance, key informants were interviewed. This approach collected location-specific information to optimize resource use and prioritize capacity-building efforts in Thailand, while presenting a model for the evaluation of WDS as part of a One Health system in other regions. Ultimately, the study aims to contribute to the improvement of EID detection and response efforts in the Asia-Pacific region and to safeguard global health through strengthening the WOAH network.

2. Materials & methods

2.1. Online survey

An online survey in English and Thai was generated using Microsoft Forms (Microsoft, Richmond, Washington; see Supporting Information List S1). The survey contained a mixture of eight multiple choice, three ranking, four 5-point Likert scale, and six free response questions that collected demographic information and information on the current use, value, efficiency, and effectiveness of WDS as part of a One Health surveillance system in Thailand [19–21]. The following governmental organizations/health sectors (henceforth referred to as "sectors") were defined: public health, wildlife health, marine animal health, livestock/domestic animal health, zoo animal health, and environmental/ecosystem health. Subject matter experts peer reviewed and pre-tested the online survey before final distribution to partners of the Thailand-NWHC/MoZWE. Following approval by Institutional Review Board, Mahidol University, the survey was delivered in Thai via email by Mahidol University to 183 persons representing multiple health sectors (List S1). A project description and participant information sheet were attached to the official letter invitation with the request for the Director General/Director/Dean to distribute the online survey to colleagues. Entry into a prize raffle was offered by Mahidol University as incentive for participation. The survey remained open for two months. All responses were kept confidential.

Data were originally formatted in Microsoft Office Excel (Excel version 2205, 2018), then statistical analysis and figures were completed in R: A Language and Environment for Statistical Computing (version 4.0.3, 2020; R Foundation for Statistical Computing; Vienna, Austria). For statistical analysis, responses were assigned "high" and "low" values based on answer distribution. Through bivariate analysis, logistic regressions determined statistically significant associations (95% confidence level) between high or low question response and sector of survey respondent. Any relationship with a 90% confidence interval was noted. Free-text responses were translated from Thai into English and analyzed for common themes created during the reading of the responses. Responses were categorized into none, one, or multiple of

the themes, depending on the content of the response. The number of responses placed in each theme was recorded.

2.2. In-person interviews

After collection of online survey results, purposive sampling was used to conduct in-person, semi-structured interviews consisting of six open-ended questions that further explored aspects of the online survey results (List S2) [22]. Based on the preference of the interviewee, interviews were conducted in Thai or English with the aid of three translators. All interviewees signed a written consent form before questioning and received a small cash compensation provided by Mahidol University. Interviews were recorded with permission. Clarification and follow-up questions were asked as necessary, and all interviewees were given the opportunity to add any comments that they felt were not addressed in the interview questions. At the conclusion of the interview, interviewees were presented with a list of potential impediments related to WDS categorized into four classes (physical resources; human resources; administrative and legal issues; other) and asked to rank from each category the top three most difficult impediments faced in their health sector (List S2) [20,21].

The interviewees' response to each question was summarized, then all response summaries were compared and qualitatively analyzed for common themes among other interviewees and for similarities with online survey results. For the list of potential impediments presented to interviewees, the frequency of an impediment being listed among interviewees' top two-three choices was recorded.

3. Results

3.1. Online survey

In total, 102 responses were collected from representatives of the following health sectors: wildlife (40.2%), marine (13.7%), livestock/domestic animal (34.3%), public health (8.8%), and other (2.9%) (Table 1).

3.2. WDS in the context of One Health

The majority of respondents (92.2%) reported applying One Health in their work, and a smaller majority (74.5%) reported using WDS data and information in their work. The most frequent users of WDS data were the wildlife and marine sectors; 92.7% and 78.6% of respondents from these health sectors reported using WDS data, respectively, while some livestock (62.9%) and less public (33.3%) health sector respondents reported using WDS data. Public health was viewed as the sector that benefited most from WDS based on 67.6% of all respondents selecting the public health sector in their top two areas chosen that most benefitted from WDS (Table S1). Otherwise, respondents perceived that their own sector benefited most from WDS data and information (Table S1, Fig. S1). Survey respondents from the wildlife and marine health sectors were significantly less likely to perceive WDS data as a benefit to marine health when compared to respondents from the public health sector ($p_{Wildlife} = 0.001$, $p_{Marine} = 0.004$). Respondents ranked the most beneficial outcome of WDS as disease control (76.5% of respondents placed this category in their top three of ten outcomes), while fostering new ideas through collaboration (2.0%), collection and exchange of information for research (4.9%), and improving general knowledge and skills through information exchange (5.9%) were the least valued outcomes of WDS (Fig. 1). In general, answers did not vary significantly by sector (Table S2).

3.3. Communication among health sectors

In general, all health sectors were considered adequate at communication; there was no health sector where the number of neutral and dissatisfied responses outnumbered the number of satisfied responses (Table 2, Fig. S2). While health sectors were generally satisfied with communication within their own sector, some differences in satisfaction with intersectoral communication emerged (Table 2). Most notably, the wildlife health sector reported a significantly higher level of satisfaction for communication with the zoo sector as compared to the livestock ($p = 0.002$) and marine health ($p < 0.001$) sectors (Table 2). Communication with the marine, environmental, and zoo sectors was considered not applicable to 28.4%, 16.7% and 12.7% of all respondents, respectively (Table 2). Of the three free response questions related to the improvement of WDS (33% average response rate), 47 out of the 99 comments contained references to the challenge of coordinating and communicating among health sectors (55% of comments for Q12; 40% for Q14; 50% for Q16; see List S1). Suggestions for improving the communication among sectors included a central database for resources such as data, laboratory results, and information in general (9 responses), regular meetings between sectors (5 responses), and a systematic collaboration framework (11 responses).

Table 1
Online survey demographics. Count of online survey respondents in each demographic category, grouped by health sector.

	Health sector of survey respondent					
	Public (n = 9)	Wildlife (n = 41)	Livestock (n = 35)	Marine (n = 14)	Other (n = 3)	Total (n = 102)
Gender						
Male	4	14	17	4	1	40
Female	5	27	17	10	2	**61**
Other	0	0	1	0	0	1
Age						
25–34	4	19	22	10	2	**57**
35–44	4	19	8	1	1	33
45–54	1	2	5	2	0	10
55–64	0	1	0	1	0	2
Location[†]						
Central	6	11	16	2	1	**36**
Northern	0	4	6	0	0	10
Northeastern	1	14	5	0	1	21
Eastern	0	5	1	4	0	10
Southern	1	6	3	8	0	18
Western	1	1	4	0	1	7
Education[‡]						
Bachelor's	4	20	17	10	2	**53**
Master's	1	9	12	2	0	24
Professional (DVM, MD)	0	8	3	2	0	13
PhD	4	4	3	0	1	12
Work Experience[§]						
0-5 years	6	25	16	10	2	**59**
6–10 years	3	9	12	1	1	26
11–20 years	0	7	5	2	0	14
21–30 years	0	0	2	0	0	2
31+ years	0	0	0	1	0	1

[†] Geographical location within Thailand.
[‡] Highest level of education attained.
[§] Years in current position.

3.4. Evaluation of current WDS system

Table 3 summarizes online survey results about 13 aspects of WDS in a format comparable to Berezowski et al. [20], and complete information can be found in Tables S3-S5. The following aspects of WDS were most frequently perceived as “often” or “very often” a challenge: 1) having easy access to field and lab data collected by one's own health sector (50.0% of all respondents), 2) having legal authority to conduct surveillance (44.1%), 3) having adequate physical resources (i.e. equipment, laboratory facilities, etc.) (41.2%), and 4) communicating data to stakeholders (38.2%) (Fig. 2, Table 3, Table S3). Health sectors

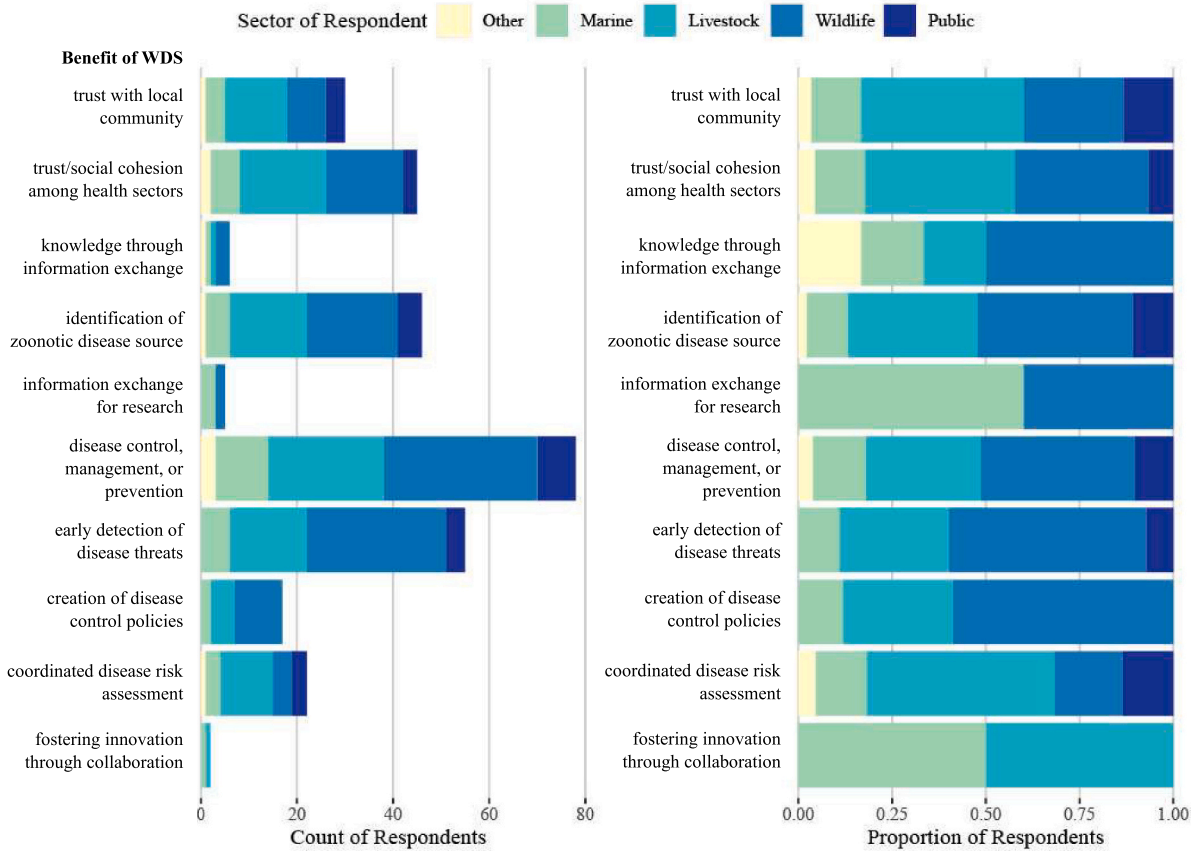

Fig. 1. Perceived benefits of WDS. Online survey results to a ranking question where participants (n = 102) were presented with ten possible outcomes of wildlife disease surveillance (WDS) and asked, "In your health sector, do you think that wildlife disease surveillance is of benefit to you in the following areas ("1" represents "MOST beneficial" and "10" represents 'LEAST beneficial')?". Total count of respondents (left) and proportion of respondents (right), that ranked an area as first, second, or third most benefitted by WDS is depicted, colored by sector of respondent.

Table 2
Evaluation of communication among health sectors. Online survey results to a 5-point Likert scale question where participants (n = 102) were presented with the below six health sectors and asked, "Please rate your ability to share and receive information with each of the below sectors." Count and percentage of respondents' satisfaction with ability to share and receive information with sectors are tabulated.

Satisfaction with communication	Health sector to be communicated with											
	Public		Wildlife		Livestock[†]		Marine[‡]		Zoo[§]		Environmental[¶]	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Very Satisfied	26	25.5	20	19.6	27	26.5	11	10.8	21	20.6	10	9.8
Satisfied	39	38.2	46	45.1	46	45.1	30	29.4	41	40.2	35	34.3
Neutral	20	19.7	23	22.6	19	18.6	25	24.6	23	22.5	30	29.4
Dissatisfied	6	5.9	7	6.9	4	3.9	4	3.9	2	2.0	7	6.9
Very Dissatisfied	3	2.9	3	2.9	4	3.9	3	2.9	2	2.0	3	2.9
Not Applicable	8	7.8	3	2.9	2	2.0	29	28.4	13	12.7	17	16.7

[†] Respondents from the livestock health sector were noted as more likely to be satisfied with the ease of communication with the livestock health sector than respondents from the marine health sector ($p = 0.087$).

[‡] Respondents from the livestock health sector were significantly less likely to be satisfied with the ease of communication with the marine sector than respondents from the marine health sector ($p = 0.049$), and were noted as less likely to be satisfied with the ease of communication with the marine health sector than respondents from the wildlife sector ($p = 0.093$).

[§] Respondents from the wildlife health sector were significantly more likely to be satisfied with the ease of communication with the zoo sector than both the livestock and marine health sectors ($p = 0.002$, $p < 0.001$, respectively). Respondents from the marine health sector were noted as less likely to be satisfied with the ease of communication with the zoo animal health sector than respondents from the public health sector ($p = 0.092$).

[¶] Respondents from the public health sector were noted as more likely to be satisfied with the ease of communication with the environmental health sector than respondents from the livestock health sector ($p = 0.099$).

differed on which aspects of WDS were perceived as most often challenging. In general, the marine sector perceived topics such as having a timely communication system among health sectors, having the ability to interpret data from other sectors, and knowing whom to contact in other sectors as significantly more often a challenge than other sectors (Table S3). Having the legal authority to conduct WDS was perceived as significantly more often a challenge by survey respondents from the marine ($p_{Public} = 0.041$, $p_{Wildlife} = 0.057$) and livestock/domestic animal ($p_{Public} = 0.036$; $p_{Wildlife} = 0.028$) sectors than by those in the public and wildlife health sectors (Table S3). Of the free response questions related

Table 3
Perceived challenges and priorities of current WDS system. Online survey results to 5-point Likert scale questions where participants (n = 102) answered questions about 13 aspects of wildlife disease surveillance (WDS). The percentage of total respondents who categorized each aspect of WDS as "often" or "very often" a challenge; "difficult" or "very difficult" to improve; and "very important" are tabulated, with the highest and lowest values for each dimension bolded and underlined, respectively.

Surveillance Capability	Is this a challenge in your jurisdiction?	How difficult would it be to make improvements?	What priority is making improvements in your jurisdiction?
	Often or Very Often	Difficult or Very Difficult	Very Important
	(%)	(%)	(%)
Having a clear, comprehensive, and timely communication system between sectors	30.4	32.4	71.6
Knowing whom to contact in other sectors to assess/ respond to risks	21.6	23.5	60.8
Having easy access to data collected by own sector	**50.0**	11.7	64.7
Having easy access to data collected by other sectors	22.5	43.1	48.1
Having the skills to analyze and interpret data from other sectors	20.6	45.1	43.1
Having the skills to utilize data to promote health and research efforts	28.4	20.6	51.0
Having adequate budget	26.5	**51.9**	71.6
Having adequate physical resources (i.e. equipment, labs, etc.)	41.2	29.4	64.7
Having sufficient/ efficient allocation of human resources	34.3	42.2	**75.5**
Communicating surveillance data to stakeholders	38.2	23.5	55.9
Knowing and addressing concerns of local communities	28.4	25.5	52.9
Having legal authority to conduct surveillance	44.1	28.4	54.9
Having a committee/ group to coordinate among sectors	29.4	24.5	53.9

to improving challenging aspects of WDS, 16 out of the 99 comments related to lessening bureaucracy and streamlining the chain of command for WDS. Respondents suggested lessening the impact of bureaucracy to increase efficiency of work (6 comments), reducing paperwork load (4), and increasing support for and understanding of the practitioner level by the administrative and executive levels (2). Increasing transparency and honesty was highlighted in four responses.

The following areas of WDS were most often perceived as "difficult" or "very difficult" to improve: 1) adequate budget (51.9% of all survey respondents), 2) ability to interpret others' data (45.1%), 3) having easy access to field and laboratory data by other sectors (43.1%), and 4) sufficient and efficient allocation of human resources (42.2%) (Table S4). The areas that were most often perceived as "easy" or "very easy" to improve include: 1) having easy access to field and laboratory data by own sector (41.2% of all respondents), 2a) having legal authority to conduct surveillance (28.4%), and 2b) having a committee for sector coordination (28.4%) (Table S4). Sectors generally agreed on which topics they perceived as most difficult/easy to improve, with one significantly different exception (Table S4). From the wildlife sector, 41.5% of respondents reported "having legal authority to conduct surveillance" would be "difficult" or "very difficult" to improve, while 42.9% of respondents from the livestock/domestic animal sector reported it would be "easy" or "very easy" to improve ($p = 0.003$, Table S4).

Respondents generally considered the improvement of all surveillance capabilities presented in the survey to be important; there was not a single improvement that >7% of respondents considered an aspect as "not at all a priority" or "slightly important" (Table S5). The areas perceived as highest priority by all sectors included: 1) sufficient and efficient allocation of human resources (75.5% of all respondents chose this area to be "very important"), 2) adequate budget (71.6%), and 3) having a clear communication system between sectors (71.6%) (Table S5). No statistically significant differences were detected between sector of respondent and assigned level of priority.

To address the perceived challenges of WDS, respondents reported the following interventions to be most important: 1) increasing human resources (52.9% of all respondents ranked this intervention among the top three most important interventions), 2) providing training and continuing education (51.0%), and 3) providing necessary equipment (45.1%) (Fig. S3). Sectors tended to agree on the importance of each intervention. When asked "What training/continuing education needs do you have?" (91.1% response rate), 42% of responses mentioned epidemiology, with 5% specifically interested in risk assessment, and 4% specifically interested in field epidemiology (Fig. S4). Other training and education needs expressed included: pathology (15%); wildlife health (15%); disease surveillance (17%); data management and information technology skills (13%); animal specimen collection, management, and analysis (12%); and collaboration and communication between organizations (8%) (Fig. S4). Of the 31 free responses regarding improvements in WDS, 39% related to improving the collaboration and networks between organizations, 23% related to inclusion and relations with the public, and 10% related to improving and clarifying the policies surrounding the import and export of animals.

4. In-person interviews

With the exception of stakeholders from one wildlife non-governmental organization who could not be interviewed due to COVID-19 travel restrictions, all WDS professionals solicited for participation accepted the request for in-person interviews. The following sectors were represented with a total of 12 interviews: marine (3 professionals), local Department of National Parks (DNP) from location one (DNP1; 3), local DNP from location two (DNP2; 3), central DNP (2), university (1).

4.1. WDS in the context of One Health

All interviewees viewed WDS as important, citing a variety of benefits including establishment of an early warning system, data support for new policies, efficient use of money by preventing outbreaks, and protection of health. Comments about health generally focused on disease transfer between humans, animals and livestock/domestic animals, while environmental health impacts were not emphasized. Multiple interviewees cited personal connection and collaboration across sectors as key outcomes desired through WDS, which was less emphasized in survey results. One Health initiatives were viewed as an opportunity for this desired collaboration, which would increase efficiency and success

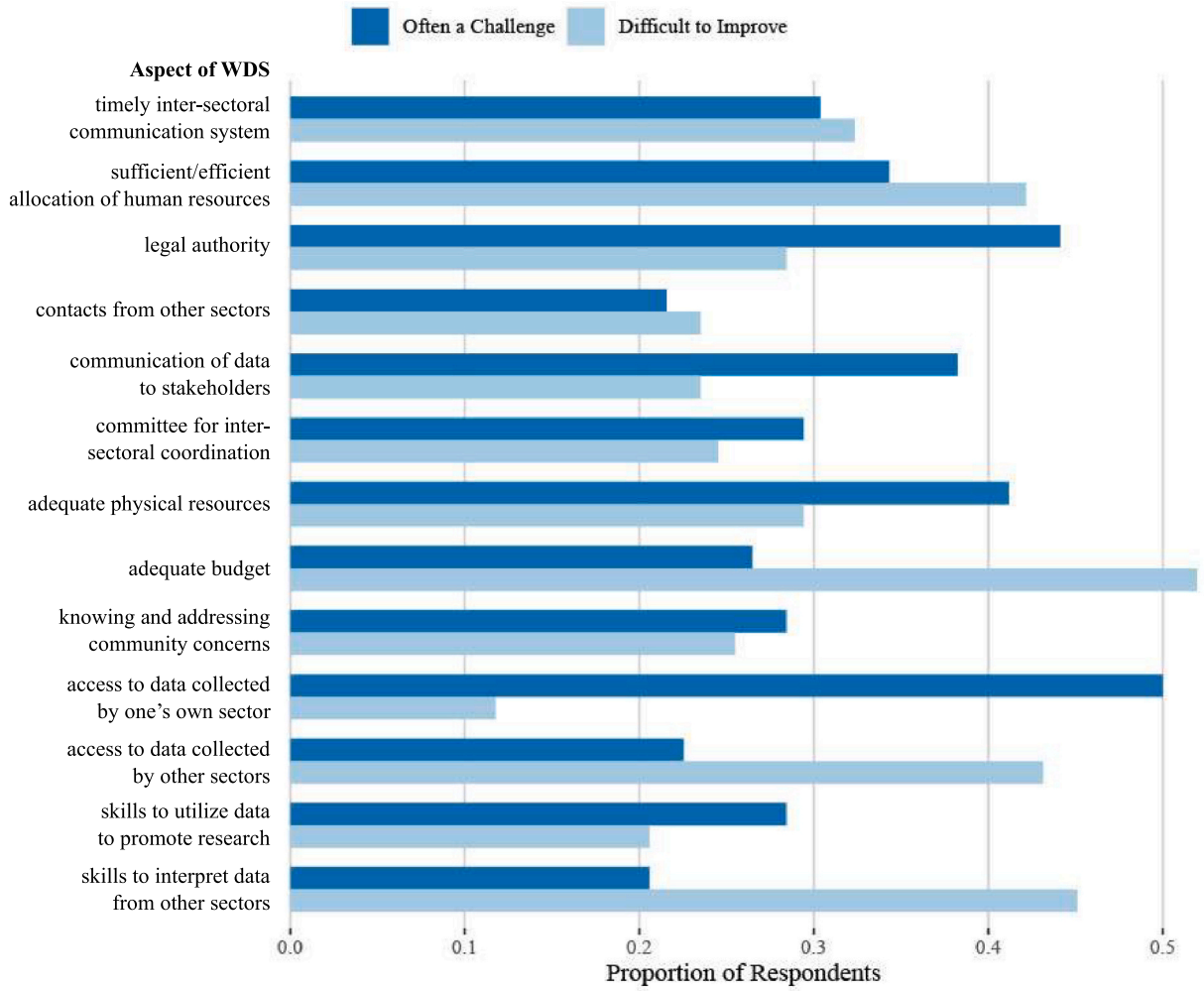

Fig. 2. Perceived challenges of current WDS system. Online survey results to two 5-point Likert scale questions where participants (n = 102) answered questions about 13 aspects of wildlife disease surveillance (WDS) in terms of how often each aspect was a challenge and how easy/difficult it would be to make improvements. Depicted is the proportion of respondents who categorized each aspect of WDS as "difficult" or "very difficult" to improve and "often" or "very often" a challenge.

of health management.

Interviewees generally defined One Health as the interconnection and sharing of resources between human, animal, and environmental sectors. The Field Epidemiology Training Program and the Thailand One Health University Network were mentioned as examples of One Health training opportunities in Thailand; however, not all interviewees were aware of such programs. Interviewees across departments expressed interest in One Health training at the administrative, veterinary, and animal care levels as this would help organizations function more efficiently as a team. However, having the personnel to participate in/deliver this training was perceived as a challenge. In particular, marine sector interviewees expressed concerns that not all employees have a clear understanding of One Health and that it was unknown how to start One Health training in the marine sector because no model of One Health for marine resources currently exists. Interviewees interpreted this lack of One Health training as it relates to WDS in the marine sector to stem from higher authorities having little concern of crossover between human and marine diseases. Instead, interviewees believed authorities focus budget and human resources on what may be considered "terrestrial" rather than "coastal" problems. One interviewee mentioned feeling a lack of connection between the marine sector and other organizations due to a sense of "separation between land and sea." These details collected during in-person interviews may elucidate why the largest percentage of online survey respondents (28.4%) considered communication with the marine sector to not be applicable to their work (Table 2).

4.2. Communication among health sectors

With the exception of employees from local DNP1, all interviewees perceived challenges to WDS collaborations. Interviewees commonly cited differences in professional values, priorities, responsibilities, concerns, and/or experiential knowledge as challenges to cross-institutional collaboration. For example, economic versus human health versus conservation concerns may conflict with each other. Collaborating with social psychologists was suggested to develop skills in cross-cultural/institutional interactions. Based on the perception of successful WDS collaborations at local DNP1, establishing a work culture that employees have a sense of loyalty to may be a helpful goal. For example, the employees of local DNP1 all shared a strong culture of building trust, having faith in a mission, and following the motto, "look forward and walk together."

Interviewees provided several concrete examples that may elucidate why 47.5% of free response comments in the online survey referenced the challenge of coordinating and communicating among health sectors. While formal WDS collaborations do exist, not all interviewees were aware of them. Two interviewees from different departments commented that collaborations are initiated only after a problem is detected. While central DNP workers explained that time is managed so that all who ask the central DNP for help receive it, this was not consistent with

the experience of local DNP workers. "Lack of knowing whom to contact in other sectors to conduct research" was emphasized as a major problem and source of confusion for marine sector interviewees, which again confirms online survey results (Table S3) and reflects the disconnect of the marine sector with other health sectors.

4.3. Evaluation of current WDS system

Table 4 presents the highest ranked impediments to WDS identified by all interviewees (results with full list of impediments presented to interviewees can be found in Table S6). The most commonly identified resource impediment selected by 91.6% of interviewees was "having a surveillance system to jointly assess and respond to risk of transmission

Table 4
Perceived resource impediments to WDS. In-person interview results to a ranking question where interviewees (n = 12) were presented with ten Physical, five Human, ten Administrative, and four Miscellaneous Resource Impediments. Count and percentage of interviewees who ranked an impediment in their top three most often faced Resource Impediments in their line of work is tabulated for the three highest ranked impediments of each category.

Physical Resource Impediment	Count of Interviewees who placed PRI as:					
	First		Second	Third	Top 3	
	Count	%	Count	Count	Count	%
Having surveillance system to jointly assess and respond to risk of transmission across sectors in a timely manner	6	50.0	2	3	11	91.7
Having improved infrastructure	2	16.7	5	2	9	75.0
Having sufficient budget to implement future conservation and research efforts	1	8.3	0	4	5	41.7
Human Resource Impediment	Count of Interviewees who placed HRI as:					
	First		Second	Third	Top 2	
	Count	%	Count	Count	Count	%
Having the skills to integrate, analyze and interpret data from other sectors	5	41.7	3	2	8	66.6
Having proper training	4	33.3	3	1	7	58.3
Having sufficient human resources	2	16.7	3	2	5	41.7
Administrative/Legal Impediment	Count of Interviewees who placed ALI as:					
	First		Second	Third	Top 3	
	Count	%	Count	Count	Count	%
Knowing and addressing concerns of local community	3	25.0	4	2	9	75.0
Exchanging information with investigators from other sectors in a clear and comprehensive format	3	25.0	3	0	6	50.0
Legal issues	1	8.3	1	2	4	33.3
Miscellaneous Impediment	Count of Interviewees who placed MI as:					
	First		Second	Third	Top 2	
	Count	%	Count	Count	Count	%
Having support/awareness among public	6	50.0	2	3	8	66.6
Difficulty of duties (difficulty in handling wild animals, etc.)	3	25.0	3	5	6	50.0
Possible transmission of diseases/other safety concerns	1	8.3	5	3	6	50.0

across sectors in a timely manner." Interviewees elaborated upon each of the top four important interventions identified by online survey respondents (Fig. S3). In regard to increasing human resources, one marine sector interviewee explained that while a sufficient amount of data is being collected, there is no position dedicated to sorting, analyzing, or interpreting this data. As a result, multiple people at different centers analyze the same data, but may interpret it differently, thereby leading to inefficiency and consequent work overload/lack of sufficient human resources. Concerning training and continuing education, there was consensus by local DNP2 interviewees on the importance of sample collection and wildlife first aid training, and it was emphasized that this should be organized in the local area. Two of the three interviewees from local DNP1 expressed the need for training in basic health checks. Interviews highlighted more specific training needs as compared to the online survey, which expressed the need for epidemiology training broadly. Regarding the importance of providing necessary equipment, one university interviewee proposed the establishment of a local or mobile laboratory with basic capabilities/animal-side diagnostic tests as well as training for veterinarians in proper data collection. In reference to the importance of including sample collection in routine duties, one interviewee explained that if WDS is not perceived as directly relevant to routine duties, the human resources needed to carry out WDS would not be provided. This perceived lack of relevance along with limited human resources may be contributing factors for the 25.5% of online survey respondents that did not report using WDS data and information in their work.

Throughout interviews in all departments, the importance of community involvement was emphasized (Table 4). For example, when describing the public hearings required for marine sector professionals to work with the endangered dugong (*Dugong dugon*), one interviewee said, "If the public says ok, your job is halfway done!" The banteng (*Bos javanicus*) rehabilitation and release program was also cited as one example of the power of social pressure over laws. It was described that the king's support for banteng conservation led to the local community's respect and compliance with the conservation project because released bantengs were considered the king's "property." Local DNP1 interviewees, especially, reiterated the importance of investing the time to form personal connections with community members so that the public believes in the mission of and feels connected to the project. Online educational platforms were suggested as a tool for community engagement and knowledge sharing. Local DNP interviewees suggested clearer communication with the public as to the community's role in WDS surveillance (i.e. which wildlife should be reported when a mortality is found), and monetary incentives were suggested as a possible way to increase public engagement. Overall, interview responses in regard to raising support and awareness among the public were consistent with the free responses from the online survey.

The 16% of free responses from the online survey citing bureaucracy as a challenge to WDS were further supported by interviewees, who commonly perceived rules and regulations as barriers to collaborations across institutes and even within departments. Specifically, formal letters sent from departments through the chain of command to the Central DNP (the authority for nature and wildlife) were described as inefficient. It was noted by local DNP workers that requests made to the Central DNP or to universities often receive a delayed response. Additionally, time-sensitive morbidity and mortality information must be sent to the Central DNP through official letters up the chain of command. Inconsistencies between required event-by-event reports and optional monthly summary reports were described. An interviewee from local DNP1 felt that the paperwork and legal procedures involved for collecting samples for WDS prevent real-time diagnoses (i.e. legal permits for investigation may take months to acquire).

Local DNP1, local DNP2, and university interviewees expressed a need for more practical policies. It was described that the current "top-down" administration structure makes it difficult for higher authorities to understand what is realistic for departments to carry out and what

local communities need. Interpretation of laws was described as difficult by marine and local DNP1 interviewees due to movement of animals between areas that fall under the jurisdiction of different organizations, and as one interviewee noted, "everyone has different interpretations of the law." Interviewees from all departments mentioned that the ability of departments to participate in WDS depends on higher authorities. Local DNP1 interviewees were not aware of explicit policy or funding given from the Central DNP to support One Health and WDS activities. The perceived reason for this was that the monetary benefits of WDS and One Health collaborations are not clear to higher authorities. In line with online survey responses, it was explained that administration must first be convinced of the value of One Health before budget and approval to conduct WDS will be granted.

5. Discussion

The results of this study confirm the importance and value of WDS as a component of a One Health system in Thailand and provide direction for future management efforts. In person interviews corroborated and elaborated upon online survey results, and several common themes emerged. Most notably, access to data collected by one's own sector was identified as a key priority. Additionally, the marine health sector stood out as a key sector to focus One Health networking and training efforts on to address the current disconnect between terrestrial and coastal WDS. Community members and administrative officials were identified as target audiences for future One Health and WDS outreach, which should emphasize the practical and economic value of WDS. Professionals in Thailand perceived WDS to be beneficial for its primary purpose of disease control, management and prevention, though placed less value in the potential collaborative benefits of cross-sector cooperation. Future One Health trainings may promote these benefits by emphasizing/encouraging the knowledge and innovation that can result through exchanging expertise among health sectors.

Lack of a formal and networked WDS system was perceived as a primary impediment by online survey respondents and emphasized as a priority by interviewees in all departments, which reinforces the value of establishing such a system in Thailand. A survey by Berezowski et al. [20] identified effective data management as a critical component to addressing challenges associated with One Health surveillance implementation. Access to data collected by health sectors outside of one's domain was perceived as most challenging and difficult to improve, and the ability to send and receive electronic data was considered the highest priority for improvement [20]. In contrast to these results of Berezowski et al. [20], having easy access to data collected by one's own sector was perceived as the most frequently challenging yet the least difficult to improve in Thailand. This is an encouraging result as improved internal data sharing is a prerequisite for having a streamlined communication system among health sectors that enables secure, up-to-date, complete, and accessible records.

The differences noted in online survey responses among sectors highlight key groups to focus future WDS and One Health outreach efforts. For example, though the public health sector was perceived as the sector that benefits most from WDS data, only 33.3% of public health sector respondents reported using WDS data. These results suggest that accessibility of WDS data to public health professionals should be assessed, though interpretation of these results would benefit from a more robust representation of the public health sector in the online survey and interviews. A previous survey by Berezowski et al. [20] identified access to data and contacts from other sectors to be particularly difficult for animal health professionals. Based on survey results and interview conversations, communication for animal health professionals within the marine sector specifically appears to be the most difficult in Thailand. Future One Health networking and training efforts may benefit from incentivizing participation from the marine sector; emphasizing the interconnection of marine ecosystems, terrestrial ecosystems, and human health [23–25]; and considering the development of a model of One Health for marine resources that could guide future programs [26].

The online survey and interviews identified community members and administrative officials as key groups of people to which One Health and WDS outreach is needed in Thailand. The power of community engagement in One Health work has been portrayed through first-hand accounts in our interviews, as well as the literature [16,27]. Tangwangvivat et al. [16] concluded that One Health commitment in Thailand depends heavily upon the structure and priorities of an organization and its programs. Conveying the value of WDS to administrative professionals will likely be a continued challenge that, if addressed, may be critical for alignment of policy with field worker and community needs. Working with administration to build WDS and One Health work into an organization's goals and structure may encourage proactive rather than reactive collaboration. Additionally, defining common values and goals within a workplace may improve social cohesion as demonstrated by DNP1 interviewees. As suggested by one interviewee, the expertise of social psychologists may help improve skill development in cross-cultural/institutional interactions and demonstrate the potential benefits of health professionals collaborating across disciplines. Dialogue among data scientists, social scientists, policy makers, and other sector professionals would allow for a more holistic approach to WDS.

The limitations and inherent bias in voluntary surveys and interviews should be considered when interpreting the results of this study. Due to the small sample size which may be unavoidable for countries with small health professional communities, building a program to search for keywords in free response and interview summaries was impractical, and the ability to conduct robust statistical analysis was limited. This potentially allowed for more subjectivity in the interpretation of free response and interview data. However, the consistency between online survey and interview responses allowed for more confidence in the results of this study. Additionally, distribution of the survey via email led to uncertainty in the response rate because the survey invitation may have been forwarded to an unknown number of other health professionals. Key subject matter experts in the fields of zoo, environmental and public health were underrepresented in the survey and not represented in the interviews. The methods used to request participation may have led to participation bias as Thailand-NWHC has more contacts established in the wildlife health sector than other sectors. Lack of participation by environmental health sector professionals in this online survey may reinforce previous findings of a particular lack of engagement with environmental health sectors in One Health initiatives [20,28]. Alternatively, this may be explained by participation bias, or the description "environmental health sector" may not have been clear to survey participants. It is recommended that future studies use more specific language such as "forestry" or "land management" when describing the environmental health sector in order to provide more context to survey participants. Expanding the "livestock/domestic animal health sector" to explicitly include aquaculture health may also benefit future studies.

6. Conclusion

The online survey was a valuable tool to compare differing needs among health sectors, while in-person interviews provided important context to trends observed in the online survey. Results gathered critical information to guide the development of the general WDS system and network in Thailand, which is what the WOAH Laboratory Twinning Programme aims to create. Common challenges of the implementation of One Health surveillance previously described in the literature were reiterated in this study, with data management, administrative outreach, cultural competencies and training needs specific to Thailand being emphasized. The Twinning Programme's development of a data and information management system is currently focused on establishing intra-sectoral communication for wildlife and marine health

professionals. Redistributing this survey after implementation of a general WDS in Thailand would evaluate the effectiveness of Twinning Programme efforts. This study's reported disconnect of the marine sector from other health sectors in Thailand emphasizes the importance of developing an inclusive network with a governance structure. At the same time, online survey responses from professionals across all health sectors demonstrate the need for a comprehensive One Health surveillance data and information management system, which suggests a willingness to support future development of the data and information management system into a larger One Heath network accessible by all health sectors in Thailand. Analyzing differences in responses among health sectors proved beneficial to creating a more tailored approach to One Health as this revealed the unique challenges and the individual needs of each sector. Future studies may encourage participation by zoo, environmental, and public health professionals, and may additionally include surveying community members and stakeholders to evaluate the general public's perspective on WDS. Ultimately, the combination of an online survey and in-person interviews was productive for the collection of ideas for improvement in wildlife disease risk assessment, monitoring and surveillance, diagnostic tools and data management, as well as the identification of priority needs for information, training and resources.

Ethics statement

The authors confirm that the ethical policies outlined on the journal's author guidelines page have been adhered to and the appropriate ethical review committee approval has been received. This work was completed as part of a Memorandum of Understanding between U.S. Geological Survey and Mahidol University. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

CRediT authorship contribution statement

Serena Elise George: Conceptualization, Methodology, Investigation, Writing – original draft, Funding acquisition. **Moniek Smink:** Formal analysis, Visualization, Writing – original draft. **Nareerat Sangkachai:** Investigation, Project administration. **Anuwat Wiratsudakul:** Investigation, Project administration. **Walasinee Sakcamduang:** Investigation, Project administration. **Sarin Suwanpakdee:** Investigation, Writing – review & editing, Supervision, Project administration. **Jonathan M. Sleeman:** Conceptualization, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

All authors declare that they have no conflicts of interest.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2023.100600.

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