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ORIGINAL ARTICLE

# Risk assessment on rabies entry through hunting dog movement with semi-quantitative approach to Sumatera Island, Indonesia

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## ABSTRACT

**Objective:** The objective of this study was to assess the risk of rabies entry through the movement of hunting dog from Garut District to Sumatera Island with a semi-quantitative approach.
**Materials and Methods:** Rabies entry assessment used the standard risk analysis according to the World Organization for Animal Health, with a semi-quantitative approach referring to Australian Biosecurity. Risk estimation calculation used Microsoft Excel and probabilities were estimated using Monte Carlo stochastic simulation modeling with @Risk (Palisade Corporation).
**Results:** Risk estimation were considered as "very low" with a 0.02 (90%; 0.01–0.03) probability. The probability of undetected rabies-infected dog during Veterinary Certificate issuance [node probability (NP4)] was considered as the highest, with "moderate" likelihood and 0.63 (90%; 0.51–0.75) of probability value. The number of dog movement to Sumatera reached 27,000 heads per year which 5,050 heads of them come from Garut District. There were 2 of 100 dogs from Garut District entered to Sumatera possibly infected by rabies. The five highest parameters most determinant of the risk were dog vaccination before transported (0.66), dog obtained from other District (0.41), vaccination program (0.32), serologically test (0.27), and history of vaccination (0.23).
**Conclusion:** Risk estimation from assessing on rabies entry to Sumatera through hunting dogs movement from Garut District was considered "very low." Risk mitigation is focused on the highest parameters that contribute the most to risk based on the results of the sensitivity analysis. Semi-quantitative likelihood evaluations can consider the volume of dog traffic which is an important issue in risk analysis which is not easy to get with a simpler qualitative approach.

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Assessment; dog; rabies; semi-quantitative



## Introduction

Rabies is caused by single-stranded RNA virus that belongs to the *Lyssavirus* genus of the Rhabdoviridae family and Mononegavirale order. Many countries are endemic areas, except Australia and Antarctica [1]. Rabies is fatal viral disease in unvaccinated humans or animals [2]. Rabies virus infects domestic and wild animals [3], urban rabies type is spread chiefly by unvaccinated domestic or street dogs and cats, while sylvatic-type rabies is spread by wolves, foxes, skunks, jackals, etc [4]. Rabies spread rapid in Indonesia two to three decades after 1880. It was caused by the movement of dogs through trade, pets, and military force [5]. Rabies is endemic in 24 of the 33 Indonesian provinces [6], including the islands of Bali and Nias was reported from 2008 to 2010 [7]. The risk of introduction and reintroduction of rabies are caused by the inter-island transportation of infected dogs [7].

People on the island of Sumatera, especially West Sumatera, have a culture of hunting boar [8]. One of the reasons is to eradicate boar as a pests in their farms. Other do it for hobbies, exercise, health, recreation, tourism, social functions, or just pleasure [9]. The hunting

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dogs come mostly from Java, especially West Java. The dog from West Java is considered "smart" in hunting. Some dogs come from Garut, Sumedang, Sukabumi and several other Districts in West Java. District of Garut is the one of rabies-infected area according to the Decree of Ministry of Agriculture No.3600/Kpts/PD.640/10/2009 [10].

The government of Indonesia declares rabies free in 2030, by implementing rabies control and control strategies in the form of a minimum vaccination program of 70%, population management; movement monitoring, and other supporting activities. To free Sumatera from rabies, risk analysis is recommended. Risk assessment is a part of the risk analysis. It is required to determine the introduction of dog movement risk that will be used as the basis to determine the risk management. Risk assessment with a qualitative approach is more often used than the quantitative approach because it is easier to implemented, but it has high result of subjectivity. The quantitative approach requires more expertise and a complete and accurate of data. Semi-quantitative approach provides an intermediary degree between the textual evaluation of qualitative and the numerical evaluation of quantitative approach. The aim of this study was to assess the risk of rabies entry through the movement of hunting dogs from Garut District to Sumatera Island with a semi-quantitative approach.

## Materials and Methods

### *Entry assessment model*

Entry assessment model and risk estimation calculation method in this study were developed from the results of previous studies [11]. Rabies entry assessment used the standard risk analysis according to the World Organization for Animal Health (OIE) methodology for risk analysis [12], with a semi-quantitative approach referring to Australian Biosecurity [13]. The rabies virus in this study is limited to urban and rural cycle. The pathway investigated was limited to the legal movement of the live dog. Risk assessment consisted of risk estimation and sensitivity analysis. The risk path consists of several nodes which will be a reference for compiling a list of parameter questions (PQs). Each node consisted of several PQs with different parameter values (PVs) and was developed based on the factors in the risk assessment which referring the World Organization for Animal Health (OIE) methodology for risk analysis [12].

### *Definition of risk pathways*

The risk pathway was developed based on the biological pathways by which rabies might be introduced from dogs' movement from Garut District to Sumatera Island. The risk pathway followed the path of inter-area dog movements in Indonesia through legal transportation. Scenario tree in this study was developed from the results of previous studies [11]. The scenario tree for rabies entry assessment through hunting dog consisted of five nodes (Fig. 1) which are: Node 1, probability of dog infected in the area of origin. This node represents the probability of dogs have been infected by rabies in Garut District before being moved. Node 2, probability of dog infected by rabies in trader facilities. This node is used to assess the probability that uninfected dog in origin area, becoming infected at the trader facilities. Node 3, probability of dog was not vaccinated before transported. This node represents the probability of dog was not vaccinated by trader before moved. Node 4, probability of rabies-infected dog was not detected while the issuing process of Veterinary Certificate (VC). This node used to assess probability that infected dog not detected by the government veterinarians in Garut District before transported to move. Node 5, probability of rabies-infected dog was not detected in exit point of the Agricultural Quarantine Service (AQS). This node used to assess the probability that infected dogs were not detected in the exit point of AQS before permitted to move Sumatera Island.

### *Risk estimation and model outputs*

Each node consisted of several PQs with different values. The value from all PQs in a node is 1. The approach used in this study was semi-quantitative, so the opportunities of each event were assumed to follow uniform distribution. The likelihood of each parameter answer in each parameter question was converted to a semi-quantitative approach that referring to Australian Biosecurity [13]. The qualitative category was quantified into uniform distribution referring to Australian Biosecurity [13]. Risk estimation was calculated using Microsoft Excel (Windows

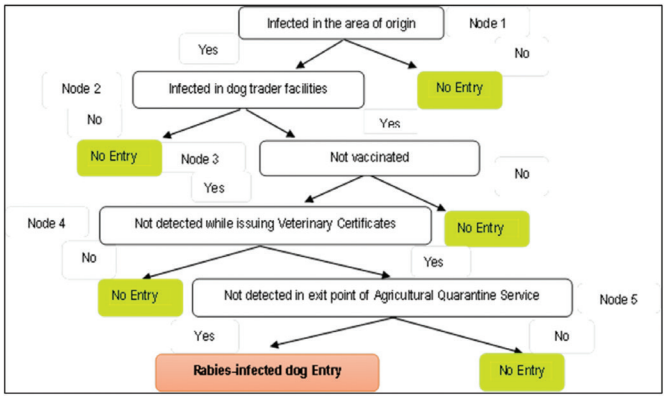


**Figure 1.** Scenario tree of entry assessment on rabies to Sumatera through hunting dogs movement from Garut District, West Java, Indonesia.

2016) and probabilities were estimated using Monte Carlo stochastic simulation modeling with @Risk 7.5 Student Version (Palisade Corporation). The consistency of assessments was maintained using 1,000 iterations as a basis for simulation. Results of model outputs are presented as mean (10% percentile, 90% percentile).

The parameter probability (PP) was obtained from the multiplication of input value of probability (P) for each parameter answer (PA) with the PV of the PQ. The each NP was based on the sum of each parameter probability in the node. An alphabetical list of parameters used in the model is: NP, input value of P, PA, PP, PQ, and PV. The formulas of the probability of rabies entry assessment on each node are as follows:

Node 1: NP1 = PP1 + PP2 + PP3 + PP4 + PP5
= (PV1 * P1) + (PV2 * P2) + (PV3 * P3) + (PV4 * P4) + (PV5 * P5)

Node 2: NP2 = PP1 + PP2
= (PV1 * P1) + (PV2 * P2)

Node 3: NP3 = PP1 + PP2
= (PV1 * P1) + (PV2 * P2)

Node 4: NP4 = PP1 + PP2 + PP3 + PP4
= (PV1 * P1) + (PV2 * P2) + (PV3 * P3) + (PV4 * P4)

Node 5: NP5 = PP1 + PP2 + PP3 + PP4 + PP5 + PP5
= (PV1 * P1) + (PV2 * P2) + (PV3 * P3) + (PV4 * P4) + (PV5 * P5) + (PV6 * P6)

The estimated risk value was obtained from the multiplication of all the probability of the node in the risk pathway. Risk estimation on rabies entry to Sumatera through hunting dog movement from Garut District is: Risk Estimation = NP1 * NP2 * NP3 * NP4 * NP5.

### *Sensitivity analysis*

Sensitivity analysis is the process of calculating the impact of variations in individual inputs on output in a quantitative risk assessment model and used to identify the most influential parameters in the quantitative model [14,15]. Probability input parameters were evaluated from 0 to 1 in a simulation of 1,000 iterations. The sensitivity of the outputs of the model to some of the input parameters was evaluated using the Sensitivity Analysis @Risk 7.5 Student Version (Palisade Corporation). Sensitivity analyses were conducted for the overall outputs of the entry assessment models to identify which input parameters were the most influential to the output probabilities.

### *Data collection for variable input*

Primary data collection techniques were done using expert opinion, in-depth interviews, questionnaire, and direct observation in the field. Secondary data were obtained from scientific publications and unpublished data. Respondents were rabies experts, quarantine veterinarians, government veterinarians, veterinary disease investigators, dog traders, the shipping driver, dog nurses, and the animal hunters.

## Results and Discussion

### *Probability of dog infected with rabies in the origin area (PN1)*

The probability of rabies-infected dog in Garut District was assessed by evaluating the area status associated with rabies (PQ1), vaccination programs (PQ2), the result of antibody titers surveillance (PQ3), rabies positive case reports (PQ4), and dog keeping system (PQ5). The results are shown in Table 1.

District of Garut is an endemic rabies area, which recorded six people death victims in 2005–2016 based on the data from Health Services of West Java. The probability of dog infected in the Garut District related to the area status assessment (P1) was considered "high" between 0.7 and 1.0 (Table 1). The disease incidence gives a direct estimate of the probability or risk of the disease [16]. There is no difference with the statement of Kwan et al. [17], the probability that dogs infected with rabies in the origin area can be considered by the reported cases.

Based on the data from the District Livestock Services of Garut, the number of dog population in 2017 was estimated at 18,853 heads in 42 sub-districts in which 30% of them had been vaccinated against rabies. The probability of dog infected in the Garut District related to the vaccination programs assessment (P2) was considered as "moderate" between 0.3 and 0.7 (Table 1). The risk was considered as "moderate" because the coverage was below 70%. Vaccination coverage, at least 70% of the dog population, could prevent the spread and transmission of rabies to humans for at least 6 years [18,19]. Vaccination coverage that reaches at least 70% will be effective for rabies against and have contribution to eliminate even in highly dynamic populations with rapid turnover and extremely high growth rates [20].

Low vaccination coverage in this District was caused by lack of vaccines, cold chains, and human resources. This was likely due to insufficient funding, infrastructure limitations, and lack of data system management training. These issues are also found in Bali Regency based on the results of research from Putra et al. [21]. Accuracy of dog population data are required to the planning of vaccination programs and properly evaluate the vaccination coverage [22,23]. Arief et al. [24] stated that the low vaccination coverage can also be caused by high population and rotation or movement of dogs. The composition of dog population

**Table 1.** Results summary of entry assessment.

| No | Node (*N*) | | PQ | PV | PA | Input value of probability (P) | Data source |
|---|---|---|---|---|---|---|---|
| 1 | Probability of dog was infected in the origin area | 1 | What is the status of rabies disease in the origin area (District/city/province) of the dog? | 0.2 | Infected or endemic area | Height: U (0.7–1.0) | Kepmentan No. 3600 (2009) |
| | | 2 | How is the vaccination program in the origin area of the dog? | 0.4 | There is vaccination program with coverage less than 70% with antibody titer test | Moderate: U (0.3–0.7) | Disnak Garut (2017) |
| | | 3 | What is the result of surveillance of serological test for rabies antibodies or rabies vaccination evaluation? | 0.1 | Protective antibody titer is more than 70% | Extremely low: U ($1.0x10^{-6}$–0.001) | BVet Subang (2017) |
| | | 4 | Has case report of rabid dog been found in the area of origin for the past 2 years? | 0.1 | No | Very Low: U (0.001–0.05) | BVet Subang (2017) |
| | | 5 | How does the generally dog keeping system in the origin area? | 0.2 | Free-roaming | Height: U (0.7–1.0) | Interview and observation |
| 2 | Probability of dog was infected in facilities of dog trader | 1 | How is the dog enclosure system in dog trader facilities? | 0.7 | Cage individually | Extremely low: U ($1.0x10^{-6}$–0.001) | Interview and observation |
| | | 2 | Are there dogs obtained from other Districts? | 0.3 | Yes, from another Districts with infected status | Height: U (0.7–1.0) | Interview and observation |
| 3 | Probability of unvaccinated dog before transported | 1 | Is every dog vaccinated before transported? | 0.8 | Yes, some dogs are vaccinated and the time is less than 14 days or more than 1 year before departure | Moderate: U (0.3–0.7) | Interview |
| | | 2 | Does every dog be marked or identified after vaccination? | 0.2 | No | Height: U (0.7–1.0) | Interview |
| 4 | Probability of rabies-infected dog is not detected while the process of issuing VCs | 1 | Does every dog be examined for clinical signs? | 0.2 | Yes, all dogs | Low: U (0.05–0.3) | Interview |
| | | 2 | Does every vaccinated dog include a vaccination book legalized by the veterinarian? | 0.1 | Yes, with the legalization of veterinarian | Very low: U (0.001–0.05) | Interview |
| | | 3 | Does every dog serologically tested before VC issued? | 0.5 | No | Height: U (0.7–1.0) | Interview |
| | | 4 | Does every dog required be kept from birth or at least 6 months in the origin area? | 0.2 | No | Height: U (0.7–1.0) | Interview |
| 5 | Probability of rabies-infected dog is not detected in the exit point of **AQS** | 1 | Does document validity checked? | 0.1 | Yes | Very low: U (0.001–0.05) | Interview, questionnaire, and observation |
| | | 2 | Does every dog be examined for clinical signs? | 0.1 | Yes, all dogs | Low: U (0.05–0.3) | Interview, questionnaire, and observation |
| | | 3 | What action is taken if the dog not included documentation of serological test for rabies antibodies? | 0.3 | Given a Health Certificate | Height: U (0.7–1.0) | (BKP Cilegon, 2016) (BKP Cilegon, 2017) |
| | | 4 | What action is taken if a vaccination history is not included? | 0.3 | Not permitted to get through | Low: U (0.05–0.3) | Interview and observation |
| | | 5 | What action is taken if the time vaccinated less than 30 days or more than one year? | 0.1 | Not permitted to get through | Low: U (0.05–0.3) | Interview, questionnaire, and observation |
| | | 6 | What action is taken if the dog with pregnancy or breastfeeding? | 0.1 | Not permitted to get through | Low: U (0.05–0.3) | Interview, questionnaire, and observation |

U = Uniform distribution.

influences the required vaccination level. High proportion of stray or free-roaming dogs indicated unrealistically high vaccination levels [25]. The research conducted by Kadowaki et al. [26] shows that the areas with higher coverage vaccination have a smaller epidemic size. Mandatory vaccination can reduce the incidence of rabies attacks; outbreaks will be larger if it is discontinued.

Monitoring and surveillance were conducted by the District Livestock Services of Garut, Provincial Livestock and Animal Health Services of West Java, and Disease Investigation Center of Subang every year to evaluate antibody titers against rabies. The result of enzyme-linked immunoassay test (ELISA) monitoring in 2017, the immune protective antibody level [>0.5 International Unit/milliliter (IU/ml)] was 75% of 225 blood samples. Therefore, the probability of dog infected in the Garut District related to the result of antibody titers surveillance assessment (P3) was considered as "extremely low" between $1.0 \times 10^{-6}$ and 0.001 (Tabel 1). Nokireki et al. [27] stated that a minimum of 0.5 (IU) antibody titers could prevent rabies incursions.

Based on the data from Disease Investigation Center of Subang, there were no positive samples of rabies from the monitoring results in 2016–2017 using the Fluorescent Antibody Test (FAT) and Polymerase Chain Reaction (PCR). Therefore, the probability of dog infected in the Garut District related to the rabies positive case reports (P4) assessment was considered as "very low" between 0.001 and 0.05 (Table 1). The above probability was assumed to be very low considering that a country or region with no case of digenously acquired rabies virus infection has been confirmed during the past 2 years is one of the points of rabies free status [28]. The FAT method as the gold standard has a high level of sensitivity and specificity for detecting rabies virus [29]. The FAT is correlated well with the real time-PCR, both are useful methods for diagnosis of rabies virus [30]. The sensitivity of this method depends on the degree of tissue autolysis and how to take brain samples [31].

The dog population in Garut District consisted of 13,064 heads owned dogs and 5,789 heads stray dogs. Based on the interviews, dogs were kept by tieding in the yard, inside a cage, and free-roaming, but most are free roaming. The probability of dog infected in the Garut District related to the dog keeping system assessment (P5) was considered as "high" between 0.7 and 1.0 (Table 1). High population density and many stray dogs can increase the transmission of rabies [32]. Unvaccinated free roaming dogs that are both owned and no owned have a high risk for transmission rabies [33]. The incidence of rabies with semi-ranging was high compared with the home dog group. The high incidence rate may due to the high level of contact among dog in semi-ranging group as compared with the home dogs. Beside those efforts to do vaccination by injection to this group of dog is not easy, and as such the rabies transmission cycle continues in this population [34]. Contact with other dogs is one factor that is associated with the incidence of rabies [35].

### *Probability of dog infected with rabies in traders facilities (PN2)*

Probability of dog infected with rabies in dog traders facilities was assessed by evaluating the dog enclosure system (PQ1) and dogs obtained from other District (PQ2). The results are shown in Table 1. Based on the data from the AQS Class II of Cilegon, the number of dogs in the legal movement from Garut to Sumatera Island through Merak Banten Port was 5,050 of 27,223 heads in 2017 and 4,207 of 23,941 heads in 2016. Most of the dogs came from the District of Garut, Sumedang, Sukabumi, and other Districts in the province of West Java. Hunting dogs were kept with an individually cage system at trader facilities. Probability of infected dog in traders facilities related to the dog enclosure system assessment (P1) was considered as "extremely low" between $1.0 \times 10^{-6}$ and 0.001 (Table 1). Probability of dog in the individually cage was extremely low because the transmission rates of confined dogs are assumed to be much lower [25,33].

Based on the results of dog traders interviews, there are some dogs obtained from other District. These dogs come from the free or endemic areas in West Java Province. Therefore, the probability of infected dog in traders facilities related to the dog obtained from other District assessment (P2) was considered as "high" between 0.7 and 1.0 (Table 1). The movement of dogs between landbound areas in Indonesia is a serious problem, due to the differences in the status of the area related with rabies. Therefore, limiting the movement of dogs is required to prevent contact of dogs from infected areas. Kurosawa et al. [36] stated that the key of rabies eradication is the combination of mass vaccination and strong regulations of dog movement restriction.

### *Probability of dog was not vaccinated before transported (PN3)*

Probability of unvaccinated dog before transported was assessed by evaluating dog vaccination (PQ1) and mark or identity of vaccination (PQ2). The results are shown in Table 1. The dog was given a vaccination 2 weeks before transporting, but it was possible that some of the dogs were not vaccinated, or the vaccination was done less than 2 weeks. This occurred because of the addition or replacement of the dogs when it was being sent, or the dog was sick while being vaccinated. The 2-week vaccination before being transported was difficult for dog traders to implement because of an increase in maintenance costs. Probability of unvaccinated dogs before transported

related to the dog vaccination assessment (P1) was considered as "moderate" between 0.3 and 0.7 (Table 1). Dogs vaccination before transported is very important, to get a protective antibody titer. Based on the research conducted by Pimburage et al. [37], a single dose of vaccination is not enough to keep antibody titer for a 1 year period. Dog vaccination is very important for preventing rabies outbreaks. The studies conducted by Mahardika et al. [38] concluded that the rabies outbreaks on the Bali Island occurred due to the introduction of rabies in the large populations of unvaccinated dogs.

Dogs that have been vaccinated were not given a mark or identity, only recorded in a vaccination book. Probability of unvaccinated dogs before transported related to the assessment of marking or identity of the dog (P2) was considered as "high" between 0.7 and 1.0 (Table 1). The permanent identity of dog is needed for certainty of medical history or other information such as the area of origin, but it is still difficult to implement because of the awareness and high cost required. Many choices of dog identity are permanent (tattooing, microchip, ear-tip/notch, and freeze brand), semi-permanent (ID collar and ear tagging), and temporary (Paint/Dye and RFID). Microchip is a choice with reliability, longevity, accuracy, uniqueness, and database required which are very high but has a large cost too. The dog face recognition method can be used to recognize dogs efficiently, so that they can be used as an alternative method for dog identity [39].

### *Probability of rabies-infected dog was not detected while the issuing process of VC (PN4)*

Probability of undetected rabies-infected dog was assessed by evaluating of the examined for clinical sign (PQ1), vaccination book (PQ2), serologically test (PQ3), and kept from birth or at least 6 months in the area of origin (PQ4). The results are shown in Table 1. Dogs that will be transported must have VCs issued by Disnakkan Garut. Before being certified, each dog was examined for clinical symptoms. Probability of undetected rabies-infected dogs related to the examined for clinical sign assessment (P1) was considered as "low" between 0.05 and 0.3 (Table 1).

Dogs that have been vaccinated were recorded in a vaccination book. Probability of undetected rabies-infected dogs related to the vaccination book legalized by veterinarian assessment (P2) was considered as "very low" between 0.001 and 0.05 (Table 1). Serologically test in Disnakkan Garut had not been applied due to the limitations of the test equipment. The study conducted by Kwan et al. [17] concluded that the serological test of rabies must be applied to maintain the risk level from the activities of importing dogs and cats. Dogs vaccination before transported is very important to get a protective antibody titer. As founded in the Bali Province, dogs showed a positive test against rabies even though they have a history of vaccination [40]. Probability of undetected rabies-infected dog related to the serologically test assessment (P3) was considered as "high" between 0.7 and 1.0 (Table 1).

The Animal Health Division of Garut implements a quota system for issuing VC and only issues for native dogs from Garut; nevertheless, it is difficult to guarantee the origin of dogs. Probability of undetected rabies-infected dog related to the being kept from birth or staying at least 6 months assessment (P4) was considered as "high" between 0.7 and 1.0 (Table 1). Showed no clinical sign of rabies the day prior to or on the day of shipment, and were kept since birth or at least 6 months prior to shipment are OIE recommendations for importation [28].

### *Probability of rabies-infected dog was not detected in exit point of the AQS (PN5)*

Probability of undetected rabies-infected dog was assessed by evaluating the verification of the document (PQ1), clinical sign (PQ2), serological test result (PQ3), history of vaccination (PQ4), time of vaccination (PQ5), and dog pregnancy or breastfeeding (PQ6). The results are shown in Table 1. Inspection documents assess to the probability that document incomplete or invalid. There is a probability that document forgery related to vaccination history or serologically test result. Inspection of documents were applied for each dog movement and recorded on the "IQFAST" One Stop Service system. Probability of undetected rabies-infected dog related to the verification of the document assessment (P1) was considered as "very low" between 0.001 and 0.05 (Table 1). Clinical sign examination was carried out for all dogs. Probability of undetected rabies-infected dog related to the clinical sign examination assessment (P2) was considered as "low" between 0.05 and 0.3 (Table 1).

The dog displaying clinical signs will not be permitted by AQS to moved; however, animals incubating the disease but not showing clinical signs may be permitted. Therefore, the results of serological tests are very necessary for prevention of this. Dogs from the origin area do not have serological test results. The serological test was carried out by the AQS Class II of Cilegon for 10% of the samples. Based on the results of serological test with the ELISA method in 2016, only 26 of the 491 samples showed protective antibody against rabies, whereas in 2017, there were 58 out of 427 samples showing protective antibody against rabies. The ideal timing for blood collection is between 8 and 30 days after the primary vaccination. The formation of antibody titers against rabies reaches a peak 14 days after vaccination [41]. Non-protective antibody titers are possible due to vaccination time intervals with blood sampling less than 2 weeks, or not vaccinated. In addition to these factors, the type and number of vaccinations, age,

reproductive status, sex, value, and dog breed affected the antibody response [27]. Serological test results were not included in Health Certificate because serological test process requires minimum of 2 days, while the cage capacity is insufficient to accommodate all dogs that are transported. Probability of undetected rabies-infected dog related to the serological test result assessment (P3) was considered as "high" between 0.7 and 1.0 (Table 1).

Therefore, regulatory and budget support is required so that the testing of titers can be done in the area of origin. Rapid and sensitive examination of rabies antibody titers required to be developed in the Animal Health Service area of origin and at the exit points and entry point of AQS. Currently, the detection of rabies antibody with biosensors based has been developed with accurate results and short test times. The limit of detection of this test is 0.5 μg/ml [42]. The results of the examination in the "IQFAST" system if there is no vaccine book or vaccinated for less than 2 weeks was rejected to transport or not permitted to get through. Probability of undetected rabies-infected dog related to the history vaccination assessment (P4) was considered as "low" between 0.05 and 0.3 (Table 1). Probability of undetected rabies-infected dog related to the time of the vaccination assessment (P5) was considered as "low" between 0.05 and 0.3 (Table 1).

Most hunting dogs were males, so pregnancy examination was not applied. Probability of undetected rabies-infected dog related to the dog with pregnant or breastfeed assessment (P6) was considered as "low" between 0.05 and 0.3 (Table 1). AQSs have a role as border control for the introduction of rabies, but the condition of dogs in the area of origin also determines. The study was conducted by Weng et al. [43] indicate that the quarantine inspection period depends on other factors such as increasing vaccination coverage and the number of legally imported dogs.

## Results of the risk estimation

The nodes probability is shown in Table 2. The probability of dog infected with rabies in dog trader facilities (NP2) was considered as the lowest, with "low" category and 0.26 (90%; 0.21–0.30) of probability value. In addition to these nodes, another notes have moderate categorical values but different in their probability values. The probability of undetected rabies-infected dog during VC issuance (NP4) was considered as the highest, with "moderate" likelihood and 0.63 (90%; 0.51–0.75) of probability value. The second highest node probability was probability of unvaccinated dogs before transported (NP3). The probability number of this node was considered "moderate" with probability of 0.57 (90%; 0.39–0.75). Two other probabilities were probability of dog infected in Garut District (PN1) and probability of dog not detected in BKP Cilegon (PN5) were considered as "moderate" with probability 0.54 (90%; 0.41–0.67) and 0.36 (90%; 0.27–0.46).

The result of risk estimation from assessing on rabies entry to Sumatera through hunting dog movement from Garut District was considered as "very low" with a probability of 0.02 (90%; 0.01–0.03) (Table 2). There were 2 of 100 dogs from Garut District entered to Sumatera possibly infected by rabies. The number of dog movement to Sumatera reached 27,000 heads per year which 5,050 heads of them come from Garut District. Although the probabilities are "very low," the impact of a rabies incursion into this island are potentially large associated with the volume of dogs movement per year. There are about 100 dogs from Garut District possibly infected by rabies per year entering the Sumatera Island. This risk value must be a concern for policy makers, especially if it is associated with the volume and frequency of movements. Risk management measures are required to prevent the entry of rabies from Garut District to Sumatera Island.

### *Sensitivity analysis*

The greatest influence on the overall probability of entry assessment was the probability of unvaccinated dogs before transported related to the dog vaccination (0.66), followed by probability of dogs were infected in traders facilities related to the dog obtained from other District (0.41). Vaccination program in the origin area of the dog (0.32) as well as the probability of undetected rabies-infected dogs while the process of issuing VC related to the serologically test (0.27) were also shown to be influential parameters. The fifth most determinant parameter was

**Table 2.** Result of risk assessment (*output @ risk).

| No | Node (*N*) | Node probability | Likelihood |
|---|---|---|---|
| 1 | Probability of dog was infected in the origin area | 0.54 (0.40–0.67)* | Moderate |
| 2 | Probability of dog was infected in facilities of dog trader | 0.26 (0.21–0.30)* | Low |
| 3 | Probability of unvaccinated dog before transported | 0.57 (0.39–0.75)* | Moderate |
| 4 | Probability of rabies-infected dog was not detected while the process of issuing VCs | 0.63 (0.51–0.75)* | Moderate |
| 5 | Probability of rabies-infected dog was not detected in the of exit point **AQS** | 0.36 (0.27, 0.46)* | Moderate |
| | Risk estimation | 0.02 (0.01–0.03)* | Very low |

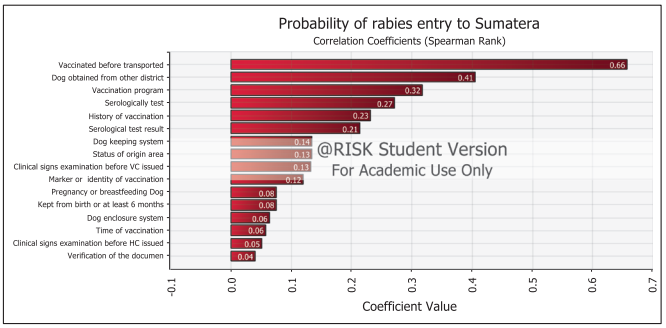


**Figure 2.** Tornado graph illustrating the results of sensitivity analysis by Spearman's correlation coefficient.

the probability of document of vaccination history that is not included (0.23). The graph of the correlation sensitivity analysis of the entry assessment of rabies is shown in Figure 2.

Sensitivity analysis identifies the parameter inputs that could be referenced for further data collection to improve model outputs or surveillance and control to mitigate rabies incursion risk [44]. The parameters of the vaccination program in the origin area and the rabies antibody test are the parameters for which data is available. The parameter of unvaccinated dog before transported has a limited available data, which are sum of vaccinated dog and time of vaccination applied. Parameter of dogs obtained from other District has limited available data, which are accuracy of the District of origin and the amount. Therefore, in the advanced risk assessment, completeness and accuracy of data are required for these parameters.

Risk management to mitigate rabies incursion risk can be focused on the most influence risk parameter. The risk mitigation suggested in this study are vaccinations applied to each dog before being transported, restrictions on dog traffic between Districts, mass vaccination in the origin area, serologically test for every dog, and dog without history vaccination not permitted to move. Sensitivity analysis makes it easy for policy makers to direct resources to reduce uncertainty related to data collection. Reduced uncertainty can provide better estimates of risk, so prevention can be more targeted [45].

The semi-quantitative approach provides a more consistent assessment, reduces ambiguity, and can compare risks with risk management strategies rather than qualitative approaches [46]. However, all risk assessment approaches require the best collection and evaluation of available data.

## Conclusion

The risk of rabies introduction into Sumatera Island through the movement of hunting dog from Garut District identified in this study is "very low." In this study, dog vaccination before transported, dog obtained from other District, vaccination program, serologically test, and history of vaccination are the top-five most correlated parameters based on the sensitivity analysis. Risk management can be focused on these five parameters. Semi-quantitative likelihood evaluations can consider the volume of dog traffic, which is an important issue in the risk analysis, which is not easy to get with a simpler qualitative approach.

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## Conflict of Interests

The authors declare that they have no conflict of interest.

## Authors' contribution

Amanatin Amanatin: conducted the study, collected the data, field observation, interpreted the data, and drafted the manuscript. Etih Sudarnika, Denny Widaya Lukman, and I. Wayan Teguh Wibawan reviewed and improved the manuscript.

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