Mammalian Contribution to Transmission of *Schistosoma japonicum* Infection in West Lore, Poso, Central Sulawesi, Indonesia

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ABSTRAK

Budiono NG, Satrija F, Ridwan Y, Handharyani E, Murtini S, Mananta O. 2022. Kontribusi mamalia terhadap transmisi infeksi *Schistosoma japonicum* di Lore Barat, Poso, Sulawesi Tengah, Indonesia. JITV 27(3):142-151. DOI:http//dx.doi.org/10.14334/jitv.v27i3.3026.

Kajian tentang peran hewan domestik dalam penularan schistosomiasis japonica di Kecamatan Lore Barat Kabupaten Poso masih terbatas meskipun penyakit ini bersifat zoonosis. Penelitian ini menggunakan desain potong lintang untuk mengetahui prevalensi schistosomiasis pada mamalia domestik dan untuk mengidentifikasi kontribusi relatif penularan schistosomiasis dari masing-masing spesies mamalia di Kecamatan Lore Barat. Sampel feses diambil dari 209 ekor hewan (44 ekor sapi, tujuh ekor kerbau, dua ekor kuda, 86 ekor babi, dan 70 ekor anjing) dan telur *S. japonicum* diidentifikasi serta diukur intensitas infeksinya menggunakan metode Danish Bilharziasis Laboratory. Pemeriksaan 1852 sampel feses manusia dengan metode Kato-Katz dilakukan oleh Laboratorium Schistosomiasis Lengkeka. Pencemaran lingkungan dengan telur *S. japonicum* dan kontribusi relatif masing-masing spesies diukur. Prevalensi tertinggi infeksi *S. japonicum* pada hewan adalah pada kuda (100%; 2/2), sapi (54,55%; 24/44), dan babi (51,16%; 44/86). Prevalensi pada kerbau dan anjing masing-masing adalah 28,57% (2/7) dan 32,86% (23/70). Penyumbang utama pencemaran telur *S. japonicum* ke lingkungan adalah sapi (69,74%), diikuti babi (21,95%), dan kerbau (4,71%). Penelitian ini melaporkan tingginya prevalensi infeksi *S. japonicum* pada hewan (45,46%), sedangkan prevalensi schistosomiasis pada manusia rendah (0,59%).

Kata Kunci: Hewan, Koprologi, Manusia, *Schistosoma japonicum,* Zoonosis

ABSTRACT

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Studies on the role of domestic animals in the transmission of schistosomiasis japonica in the West Lore Sub-district, Poso District, are still limited despite its importance as zoonosis. This study used a cross-sectional design to determine schistosomiasis prevalence in domestic mammals and identify the relative contribution of each mammalian species' schistosomiasis transmission in the West Lore Sub-District. Fecal samples were obtained from 209 animals (seven buffaloes, 70 dogs, 44 cattle, 86 pigs, and two horses). The Danish Bilharziasis Laboratory technique was used to detect the occurrence of *S. japonicum* egg in feces and the intensity of schistosomiasis infection. The examination of 1852 human fecal samples using the Kato-Katz method was carried out by the Laboratory of Schistosomiasis Lengkeka. The measurement of environmental pollution with *S. japonicum* eggs and the relative contribution of each species in the transmission was performed. The highest prevalence of *S. japonicum* infection in animals was in horses (100%; 2/2), cattle (54.55%; 24/44), and pigs (51.16%; 44/86). The prevalence in buffaloes and dogs was 28.57% (2/7) and 32.86% (23/70). Cattle (69.74%) were the main contributors to *S. japonicum* eggs contamination in the environment, followed by pigs (21.95%) and buffaloes (4.71%). This study reported a high prevalence of schistosomiasis in animals (45.46%) while low human schistosomiasis prevalence (0.59%).

Key Words: Animals, Coprology, Humans, *Schistosoma japonicum*, zoonosis

INTRODUCTION

Schistosomiasis is known as a neglected disease due to schistosome infections. The species infect humans are *Schistosoma japonicum, S. mansoni, S. haematobium, S. mekongi,* and *S. intercalatum* (Inobaya et al. 2014). The disease spreads in 78 tropical and subtropical countries worldwide, and the etiologic agents in East and Southeast Asia are *S. japonicum* and *S. mekongi*. Species of animals that can serve as reservoir hosts for *S. japonicum* are cattle, cats, dogs, horses, pigs, and rodents (Saelens & Gabriël 2020).

The disease is zoonotic as the etiological worm species infect humans and more than 40 species of mammals (Li et al. 2014). The cycle of schistosomiasis transmission involves humans (and other mammals) through contact with *S. japonicum* cercariae-infested area where the parasite and intermediate snail host inhabit (McManus et al. 2020). Infected non-human mammals can be the source of *S. japonicum* egg contamination into the environment during animal defecation (Lin 2019). Animals, including non-human mammals, are expelling their feces through open defecation around residential areas (Mohd Zain et al. 2015). Non-human mammals infected with *S. japonicum* contaminate the environment with *S. japonicum* eggs while defecating, and they become schistosomiasis spreaders to the intermediate host snails (Satrija et al. 2015). Lastly, due to this reason, the disease's life cycle is sustainable and can threaten public health as human disease and/or re-infection with *S. japonicum* can occur. Animals infected with *S. japonicum* may show decreased appetite, diarrhea, and weight loss. Animal deaths can occur in severe cases (Lin 2019). Information on the role of mammalian species, especially domestic animals that live close to humans in endemic areas of Indonesia, is still lacking.

Domestic animals are China's primary players in transmitting schistosomiasis (Li et al. 2014). Buffaloes have a role in transmitting the disease for more than 80% in an area of the country (Gordon et al. 2019). A previous study in China reported that the displacement of buffaloes from endemic regions could reduce parasite reproduction rates to below one ($R_0<1$). That study successfully inhibited schistosomiasis transmission from humans and bovines to the intermediate hosts (*Oncomelania hupensis* snails) (Borlase et al. 2021). Although 46 mammalian species are susceptible to *S. japonicum,* 13 of which live in Indonesia, only a few are important in transmission to humans (Satrija et al. 2015).

Schistosomiasis in Indonesia spreads over twenty-eight villages in two districts of Central Sulawesi Province. Six of these villages are in the Sub-district of West Lore, located in the Bada Valley. The sub-district was firstly reported as an endemic area of schistosomiasis in 2008 (Gunawan et al. 2012). Non-human mammal cases of schistosomiasis in West Lore have never been reported (Gunawan et al. 2012), except for a point survey in 2015 (Nurwidayati et al. 2015) that found three mice infected with *S. japonicum.* Therefore, non-human mammal surveillance and measuring each species' relative involvement in the environmental contamination with *S. japonicum* eggs are needed. This study is designed to determine both human and domestic mammal schistosomiasis prevalence, measure the index of *S. japonicum* contamination by mammals, and calculate the relative contribution of mammals in the transmission of schistosomiasis japonica. These efforts aim to prevent *S. japonicum* eggs from infecting definitive hosts in the environment. Endemic residents at high risk of *S. japonicum* infection must be well-versed in the dangers of the disease.

MATERIALS AND METHODS

Study design and location

A cross-sectional study was performed in the West Lore Sub-district, Poso District, Central Sulawesi Province, in the second semester of 2018. The sub-district is situated 750 m above sea level. The total population of the West Lore community in 2017 was 3300 people (BPS 2018). Most of the residents of West Lore are farmers. Six villages of the West Lore Sub-district are Tomehipi, Tuare, Kageroa, Lengkeka, Lelio, and Kolori. All villages were chosen to be the location of this study. The sampling coordinates were taken using a Global Positioning System (GPS) Garmin to map the spread of schistosomiasis in animals. This study also used secondary data of focal point *O. h. lindoensis* snail reported by Vector-Borne Diseases Research Unit of Donggala, National Institute of Health Research and Development. This study uses secondary data from 1852 samples of the West Lore Sub-district residents obtained from the Lengkeka Schistosomiasis Laboratory to determine human schistosomiasis prevalence. This study also made a distribution map of schistosomiasis using the QGIS application.

Ethical clearance

The study obtained ethical approval from the Institute for Research and Community Service of IPB University with no. 67/2017. Animal owners permitted the researchers to collect fecal samples from their animals with informed consent.

Fecal collection

Stool samples were taken from 209 animals (70 dogs, 86 pigs, two horses, seven buffaloes, and 44 cattle). With the help of local leaders, the researchers informed animal owners the day before sampling. The researchers asked animal owners not to release their animals for morning fecal collection by rectal palpation, the minimum weight of fecal samples from individual studied animals was 20 g. Fresh stool samples that fall around the animal or in the cage were collected for animals that cannot be palpated rectally. Interviews were conducted to obtain supporting data in the form of characteristics of the animal owner, data on the sex of

the animal, the age of the animal, the purpose of rearing the animal (for consumption animals, for sale, or working animals) collected from the animal owner, along with the time of taking stool samples. The feces were stored in plastic clips in an icebox at 2-8°C. The samples were held in the refrigerator until further examination in the laboratory. A positive diagnosis of infection by *S. japonicum* was carried out with the Danish Bilharziasis Laboratory procedure (Carabin et al. 2015; Budiono et al. 2019).

Danish Bilharziasis Laboratory (DBL) technique

The DBL technique is a combination technique that involves filtration and sedimentation. Briefly, 5 g of feces were weighed, dissolved in 50 mL of 0.9% NaCl, agitated, and sieved using graded mesh sieves (filter mesh sizes were 400 µm, 100 µm, and 40 µm). The mixture of samples retained in a 40 µm sieve was transferred into a Baermann glass that already contained 0.9% NaCl. The mixture was then kept for 10 minutes in the darkroom. The sedimented materials in Baermann glass were transferred to a test tube for centrifugation and made into a 2.25 mL mixture by transferred sedimented materials mixed with 0.9% NaCl. For the calculation of *S. japonicum* eggs, the mixture of 150 µL (of the 2.25 mL previous mixture) was transferred into the counting chamber and was added with 850 µL of 0.9% NaCl (to make 1 mL of total volume). The researchers counted *S. japonicum* eggs in three counting chambers to determine the number of eggs per gram of feces. The criteria for *S. japonicum* egg are based on morphological observation of eggs in fecal samples. The morphology of *S. japonicum* eggs is round, with a length and width of 70-100 µm x 50-70 µm. The eggs of *S. japonicum* are non-operculate, have a transparent shell, and have a minute- or rudimentary-lateral spine or knob that may be unnoticeable and difficult to see. If the number of counted eggs differed by >10% with the triple-slide calculation, the egg counting was reexamined (Carabin et al. 2015; Budiono et al. 2019).

Kato-Katz method

The laboratory officers examined human *S. japonicum* infection with the Kato-Katz technique, the technique recommended by the World Health Organization. Briefly, a nylon filter and standard volume plastic mold representing ±41.7 mg of feces were used (He et al. 2018). The nylon filter was used to sieve the feces. The sieved feces were placed in the plastic mold to get the feces weight of ±41.7 mg. Three slides were prepared from each regimented fecal sample, and each slide was examined under the microscope by a trained examiner. A total of 1852 fecal

samples from the West Lore Sub-district residents were collected. The prevalence of human schistosomiasis was calculated by dividing the number of infected individuals by the number of examined individuals. In addition, the intensity of infection of each infected individual was calculated.

Total daily egg output

Total daily egg output (TDEE) for each animal species was measured with the following formula (Cao et al. 2016).

$$TDEE = \left(\frac{\text{total positive}}{\text{examined}}\right) \times TA \times P \times E \times F(g)$$

where TA is total animals, P is prevalence, E is egg per gram of infected animal feces, and F is fecal weight in gram (g).

The total daily egg output from a host a day (EPD), which represents the potential for contamination by each species, with a slightly different formula as follows (Cao et al. 2016):

$$EPD = N \times P \times EPG \text{ of infected animals } \times \left(\frac{F (g) \text{ per day}}{100}\right)$$

where N is the number of animals of a particular species, P is prevalence, and F is the fecal weight per day in gram (g).

Contamination index

The contamination index (CI) for each species was calculated using previously published formulas (Gordon et al. 2012; Gordon et al. 2015). The data needed are the arithmetic mean of eggs per gram of feces (EPG) from infected animals, number of infected animals, and weight of feces (g) with the following formula:

$$CI = A \times \sum\text{infected animals} \times F (g)$$

where A is the arithmetic means of EPG of infected animals and F is fecal weight in gram (g).

The daily weight of feces excreted by each cattle and buffalo is 25 000 g (Gordon et al. 2015), horse 15 000 g (Lawrence et al. 2003), dog 150 g (Brambillasca et al. 2010), pig 500 g (Huaynate et al. 2006), and human 250 g (Rose et al. 2015).

Relative transmission index

The relative transmission index (RTI) was calculated using data on the total number of individuals of each species, the prevalence of each species, the number of feces released by individuals of each species, in addition to the number of eggs per gram of feces of each species (EPG) are required (Cao et al. 2016). The formula of RTI is as follows:

$$RTI = \frac{N \times P \times FE \times EPG}{\sum(N \times P \times FE \times EPG)}$$

where N is the number of individuals of particular species, P is prevalence, FE is the number of feces excreted per day (g), and EPG is the total egg per gram of feces.

Data analysis

An infected animal is an animal wherein the researchers found at least one of *S. japonicum* eggs on observation by the Danish Bilharziasis Laboratory method. The total number of eggs was counted using this method. Total egg count in the form of the arithmetic mean of eggs per gram of feces (AMEPG) was changed to the geometric mean of eggs per gram of feces (GMEPG) to indicate the intensity of infection (van Dorssen et al. 2017).

RESULTS AND DISCUSSION

The population of domestic animals and humans in the West Lore Sub-district was 1 623 and 2 520, respectively. The number of samples taken from animals was 209, and humans were 1852, while the overall prevalence of schistosomiasis in animals was 45.46% (95/209). The highest prevalence of *S. japonicum* infection in animals was in horses (100%; 2/2), cattle (54.55%; 24/44), and pigs (51.16%; 44/86). The prevalence in buffaloes and dogs was 28.57% (2/7) and 32.86% (23/70), respectively. Pigs had the highest arithmetic mean of eggs per gram of animal feces (17.02), and buffaloes had the lowest (1.0) (Table 1).

The prevalence of schistosomiasis in humans in West Lore is 0.59%. Schistosomiasis prevalence in humans in each village was 3.11% (6/193) in Tomehipi Village, 1.56% (4/276) in Kageroa Village, and 0.29% (1/347) in Tuare Village. No *S. japonicum* infection was found in the examined persons in the other three villages (Lengkeka, Lelio, and Kolori) (Table 1). The highest degree of *S. japonicum* infection in humans occurred in Kageroa Village (146 eggs per gram of

feces or EPG), followed by Tuare Village (96 EPG) and Tomehipi Village (42.67 EPG). The cattle sampled came from all villages except Lengkeka Village. Sampled buffaloes came from Kageroa Village and Kolori Villages. There was one buffalo infected with *S. japonicum* in the two villages. The sampled horses came from Tuare Village, and all are positive for schistosomiasis. The samples of humans, pigs, and dogs were from all the study villages. The study found *S. japonicum*-infected animals from all villages surveyed, while human infection by *S. japonicum* from three villages, namely, Tomehipi, Tuare, and Kageroa (Table 2).

Based on the relative transmission index, this study estimated that the total number of *S. japonicum* eggs released from infected individuals (animals and humans) was 19 580 703 eggs. Cattle are the primary contributor species of schistosomiasis transmission in the West Lore Sub-district (69.74 %). Other species, pigs and buffaloes, contributed 21.95 % and 4.71 % of *S. japonicum* egg contamination. The contribution of the horse, dog, and human species is less than 2% (Table 1). The calculation of the contamination index showed that overall, infected cattle contributed the most (3 576 000) in contaminating *S. japonicum* eggs into the environment every day. The cow contamination index at the individual level was also the highest, with 149 000 *S. japonicum* eggs per day (Table 3).

Figure 1 shows the location of animals infected by *S. japonicum* and the intermediate host snail foci. Schistosomiasis remains a public health concern in Indonesia. Several decades of disease control programs have not succeeded in achieving disease eradication. The World Health Organization sets the elimination of schistosomiasis by 2025 (Deol et al. 2019). Continuous surveillance of schistosomiasis in humans, animals, and snails is the effort to achieve this target. A region targeting the elimination must ensure no new cases of schistosomiasis in humans, animals, and snails for five consecutive years (Fornillos et al. 2019).

Table 1 Relative Transmission Index of *S. japonicum* infection in humans and animals in West Lore Sub-district

Species	Cattle	Buffaloes	Horses	Pigs	Dogs	Humans
Total of the population at risk	168	129	4	987	335	2520
Total of examined individuals	44	7	2	86	70	1852
Total of positive individuals	24	2	2	44	23	11
Prevalence	54.55%	28.57%	100.00%	51.16%	32.86%	0.59%
The arithmetic means of eggs per gram of feces	5.96	1.0	5.5	17.02	3.69	85.1
Fecal weight (g)	25000	25000	15000	500	150	250
Total daily egg excretion	13654956	921382.5	330000	4297117.7	60929.8	316316.7
Relative transmission index	69.74%	4.71%	1.69%	21.95%	0.31%	1.62%

Table 2. Distribution of *S. japonicum*-infected hosts by village using the Danish Bilharziasis Laboratory (for animals) and Kato-Katz (for humans) techniques

Species	Cattle		Buffaloes		Horses		Pigs		Animals		Humans	
Village	+/N	%	+/N	%	+/N	%	+/N	%	+/N	%	+/N	%
Tomehipi	0/1	0	Na	Na	Na	Na	5/16	31.25	5/28	17.86	6/193	3.11
Tuare	13/22	59.09	Na	Na	2/2	100	12/19	63.16	7/16	43.75	1/347	0.29
Kageroa	9/17	52.94	1/3	33.33	Na	Na	8/10	80.00	8/13	61.54	4/256	1.56
Lengkeka	Na	Na	Na	Na	Na	Na	1/5	20.00	3/7	42.86	0/380	0
Kolori	0/2	0	¼	25	Na	Na	12/22	54.55	0/2	0	0/385	0
Lelio	2/2	100	Na	Na	Na	Na	6/14	42.86	0/4	0	0/291	0
Total	24/44	54.54	2/7	28.57	2/2	100	44/86	51.16	23/70	32.86	11/1852	0.59

+/N = Numbers of positive individuals/numbers of examined individuals

Table 3. Prevalence, the intensity of infection (arithmetic and geometric mean of eggs per gram of feces), and contamination index of *S. japonicum* in animals (DBL) and humans (Kato-Katz) in West Lore Sub-district

Species	Positive number	The arithmetic means of eggs per gram of feces	The geometric means of eggs per gram of feces	Overall contamination index	Individual contamination index
Cattle	24	5.96	5.11	3 576 000	149 000
Buffaloes	2	1.0	1.0	50 000	25 000
Horses	2	5.5	3.74	165 000	82 500
Pigs	44	17.02	8.11	374 440	8 510
Dogs	23	3.69	3.23	12 730.5	553.5
Humans	11	85.1	67.5	234 025	21 275

The peculiarity of *S. japonicum* infection from other *Schistosoma* infections is the wide range of definitive hosts, namely humans and other mammals. Domestic animals and wildlife can act as zoonotic reservoirs (Cao et al. 2016). Species' variety of final hosts makes disease control more difficult. Understanding the transmission dynamics of schistosomiasis in each species is critical for developing disease control programs (Satrija et al. 2015). Domestic animals infected with schistosomiasis, particularly cattle, horses, and buffaloes, can be the primary transmission source in another Indonesian endemic sub-district (Lindu) (Budiono et al. 2019). This study firstly reports that domestic mammals contribute to schistosomiasis transmission in the West Lore Sub-district.

Based on the roadmap for eradicating schistosomiasis and the Indonesian government's coordination with other stakeholders, control efforts are carried out to achieve the cessation of local disease transmission by 2020 with an effective surveillance system. The discontinuation of local schistosomiasis

transmission means no *S. japonicum* infection in humans, animals, and snails for five consecutive years (2021-2025) (Kemenkes & Bappenas 2018).

This study reported the overall prevalence of schistosomiasis in animals using the Danish Bilharziasis Laboratory technique of 45.46% of the 209 animals examined. The animals examined include horses, cattle, pigs, buffaloes, and dogs. Animal schistosomiasis prevalence varies between 28.57%-100%. The results of the current study support previous studies that *S. japonicum* is zoonotic and can infect mammals other than humans (Li et al. 2019). In addition, the high infection rate in animals in this study (2018) can be the basis for the Indonesian government to develop a strategy for controlling animal schistosomiasis. A previous study (Zhang et al. 2019) highlighted that schistosomiasis control that does not involve animal control is not efficient. This study found animals infected by *S. japonicum* in all study villages: cattle, buffaloes, horses, dogs, and pigs. These *S. japonicum*-infected animals may be the source of desease
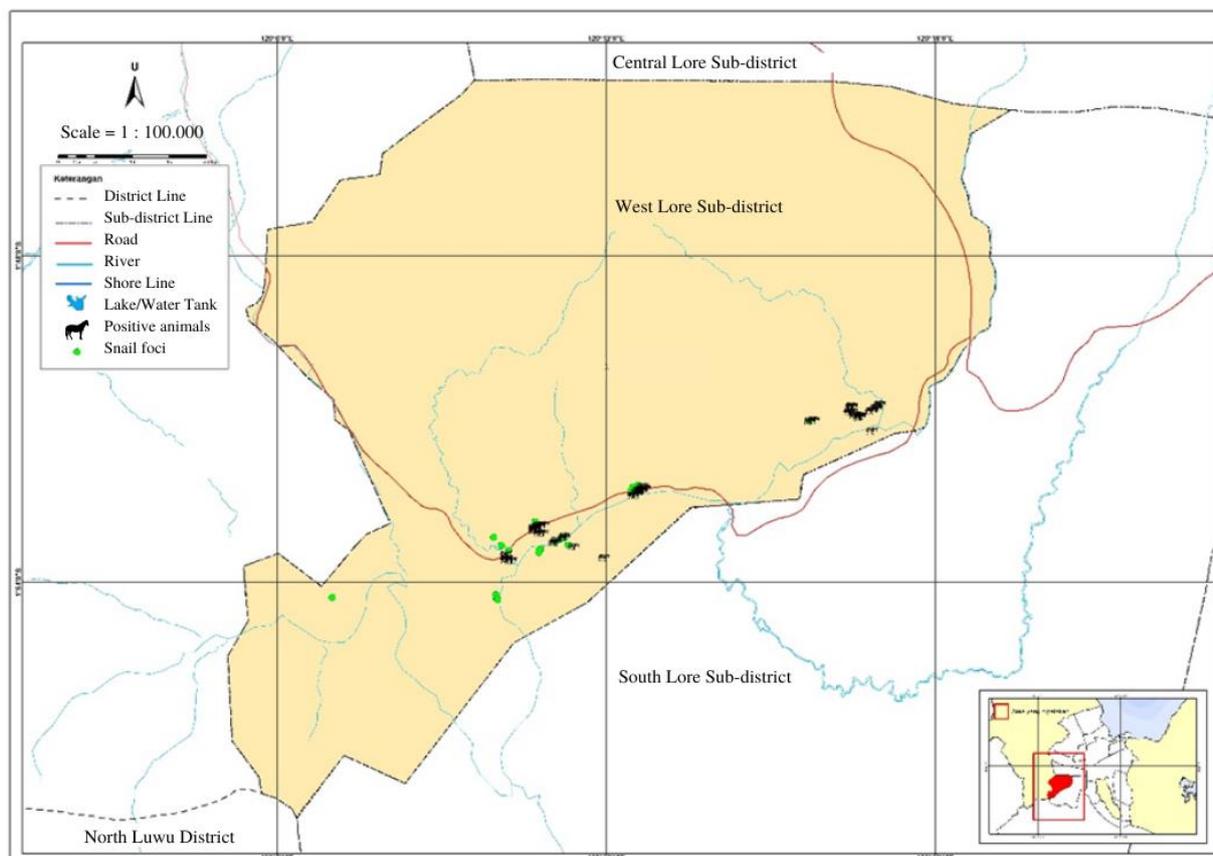
Figure 1. Distribution map of schistosomiasis in animals and intermediate host snails in West Lore Sub-district.

transmission in the West Lore Sub-district. This outcome is dissimilar from a previous study (2010) which failed to find *S. japonicum* infection in 90 animals examined (19 dogs, 55 pigs, one horse, three buffaloes, and 12 cattle) (Rosmini et al. 2014). Another survey did not find *S. japonicum* infection in animals in Lengkeka, Kageroa, Tuare, and Tomehipi villages, with samples of 17, 14, 30, and 31, respectively (Anastasia et al. 2019). The result variations may be due to the different number of samples in collection time and examination methods. Rosmini et al. (2014) found no *S. japonicum* worms in 14 successfully trapped and necropsied rats. No previous studies have demonstrated the presence of *S. japonicum* infection in non-human mammals in West Lore, except for a point survey by Nurwidayati et al. (2015) that reported *S. japonicum* infection in 3 mice. Such studies are still limited to rodents. In addition, the number of animals examined in the study is very limited (Nurwidayati et al. 2015). Previous studies by Rosmini *et al.* (2014) and Anastasia et al. (2019) used the formalin-ether centrifugation method to examine animal feces, while this study used the Danish Bilharziasis Laboratory technique. Detecting *S. japonicum* eggs in feces is still the gold standard in diagnosing schistosomiasis in human and animal species. Due to limited resources, this study used the DBL method, a coprology diagnostic test, to detect *S. japonicum* eggs in animal feces. Even though it has limitations, such as less than 80% sensitivity and 92% specificity for a single-day sample collection (Carabin et al. 2005), the technique has several advantages. The DBL technique's benefits are that it is (1) easy to perform; (2) a quantitative examination tool; and (3) not toxic; (4) it can differentiate between viable and unviable *S. japonicum* eggs; (5) be reexamined for quality control; and (6) be applied to diagnose other trematode infections (Carabin et al. 2005; Anh et al. 2008; Budiono et al. 2018; Lumain & Balala 2018).

Many animals live close to human settlements in West Lore, such as cattle, buffaloes, horses, dogs, and pigs. Most of these animals were raised by releasing them into the wild. Several possible explanations for the difference in results from previous studies are that the study used a different examination technique than the previous one, and the animal species examined differed between this study and prior studies. Theoretically, cross-infection between definitive host species can occur. Cross-infection frequency depends on the access of each animal species to *O. h. lindoensis* snail foci as the transmission site of the final host infection. Schistosomiasis transmission in an area is dynamic and complex due to each location's cultural and biological factors. Variation in yield differences occurs because of animal species' sensitivity to

infection. It can also cause infection variations in different areas (Cao et al. 2016). Previous studies found cattle and goats were more susceptible to *S. japonicum* infection than buffaloes (Liu et al. 2012; Cao et al. 2016).

Human schistosomiasis prevalence in 2018 was 0.59%. The prevalence decreased by 90% compared to the 2010 survey (5.9%; 88/1484) (Rosmini & Risti 2015) and when it was first discovered (2008) (0.8 %; 9/1067) (Satrija et al. 2015). There were variations of prevalence in different study villages in 2018. This study reports a variation in prevalence by village, from 0% in 3 villages (Lengkeka, Kolori, and Lelio) to 3.11% in Tomehipi. The coverage of the schistosomiasis survey in humans in 2018 was 73.49% (1852/2520), higher than the survey coverage in 2008 (38.2%; 1067/2793) and 2010 (61.1%; 1484/2427) (Satrija et al. 2015; Rosmini & Risti 2015). Reports of schistosomiasis cases in the West Lore Sub-district are continuing because of the continuous transmission in the area around the location of the water bodies. Sugiarto et al. (2011) found a significant relationship between human activities in endemic sites in water contaminated with *S. japonicum* cercariae. Most West Lore inhabitants carry out activities such as farming, allowing *S. japonicum* to infect them. Also, *S. japonicum* can infect various definitive host species, including humans, but its transmission is highly dependent on the availability and abundance of sensitive definitive hosts (Webster et al. 2016). In addition, there is a relation between re-infection with the presence of intermediate hosts (snails), which can be a source of transmission to humans (Mujiyanto & Jastal 2014; Pawakkangi et al. 2018).

This study firstly reports the contribution of domestic mammals to the transmission of schistosomiasis in West Lore. In total, infected animals and humans lay as many as 19 580 703 *S. japonicum* eggs per day based on the calculation of the relative transmission index. Infected cattle were the main contributor to the contamination of *S. japonicum* eggs to the environment (69.74%), while infected pigs and buffaloes contributed 21.95% and 4.71% of *S. japonicum* egg contamination. The succinct contribution of horses, dogs, and humans in disease transmission (<2%) was reported. This finding differs from the previous one in those buffaloes was the main contributor (62.3%) to schistosomiasis transmission in the Lindu Sub-district. Cattle and horses in the Lindu Sub-district contributed 24.03% and 11.18% to schistosomiasis transmission, respectively (Budiono et al. 2019). Differences in species contributing to disease at the two study sites may be due to location differences and variations in host availability in endemic locations.

In addition, the difference in disease transmission is closely related to the distribution of intermediate hosts (*O. hupensis* snails) (Xu et al. 2020). The different roles of definitive host species as reservoirs and their contribution to disease transmission can be the basis for disease control at the local level, which can vary from one area to another. Buffaloes and cattle are the main reservoir animals for *S. japonicum* infection in swamp and lake areas in China (Shao et al. 2013; Sun et al. 2017) and the Philippines (Gordon et al. 2015; Tenorio & Molina 2020). This study evaluates disease in domestic animals living in schistosomiasis endemic areas to determine their role in transmitting *S. japonicum* infection to humans. The overall prevalence of *S. japonicum* infection in animals in this study (42.11%) was lower than reported in Coronado (58.2%) (Tenorio & Molina 2020) and North Samar (62.1%) (Gordon et al. 2015) of the Philippines. Differences in results may occur due to sampling locations and examination techniques. The study in the Philippines used the formalin–ethyl acetate sedimentation-digestion (FEA-SD) method, which removed 70% of debris from cattle or buffalo fecal samples (Xu et al. 2012).

The contamination index measures the total *S. japonicum* eggs discarded by infected individuals in the study. The results showed that all infected cattle, pigs, horses, buffaloes, dogs, and humans emitted 3 505 500, 374 440, 165 000, 50 000, 12 730.5, and 234 025 *S. japonicum* eggs/day to the environment, respectively. Each cow lays 149 000 eggs per day, while each buffalo, horse, pig, and dog lays 25 000, 82 500, 8 510, and 553.5 *S. japonicum* eggs per day. Each infected human lays 21 275 *S. japonicum* eggs per day.

The presence of snails as *S. japonicum* intermediate hosts plays a role in infection sustainability and disease control complexity (Satrija et al. 2015). This study attempts to map the distribution of animals infected by *S. japonicum* (Figure 1). It also measures the proximity of infected animals to the location of the *O. h. lindoensis* snails as the study included location data of snail foci sourced from previous research publications (Mujiyanto & Jastal 2014; Pawakkangi et al. 2018). Based on observations during sample collection, the *O. h. lindoensis* snail foci adjacent to the site of the positively infected animals. The location of the snail focus is the home range of animals raised in a wild-free system. The map depiction supports that the infection of animals by *S. japonicum* occurs during activities (such as grazing, wallowing, drinking, and excretion) around the location of the intermediate hosts, *O. h. lindoensis* snails. The snail foci in West Lore Sub-district are close to residential areas and animal husbandry sites. The settlers living in West Lore mostly work as farmers, which allow them to contact the source of schistosomiasis transmission. This condition could be the reason for human infection with *S. japonicum* in endemic villages in West Lore, even though the government has implemented a mass (praziquantel) drug administration program.

The challenge of controlling schistosomiasis in the West Lore Sub-district is community behavior, and people in the area keep domestic animals traditionally. West Lore inhabitants raise animals with four different approaches. First, the animals are fully released. An example of this animal raising is horse and dog species. Second, animals are kept in a cage at night and released during the day. An example of this animal management is cattle and buffaloes. Third, the animals are in pens. Some pig owners are adopting this kind of animal raising. Last, the animals are tied, and the owners move them once or twice a day into (a) different place(s) to let them graze or find food. Some cattle, pig, and buffalo owners raise their animals with this approach.

These animal raising techniques allow domestic mammals to be infected with *S. japonicum* while the animals are doing activities around the water bodies that are also intermediate-host snail foci. Animals' continuous contact with *S. japonicum* cercariae in the snail foci during their activities, such as free grazing/eating, drinking, wallowing in water, defecating, and peeing, can be the possible cause of animal infection by the zoonotic worms. In addition, if the animals have already been infected, they can be the disease spreader. Infected animals defecating around the transmission sites, where the infected snail intermediate hosts (*O. h. lindoensis*) reside, can be the source of other animal and human infections. In addition, these animal rearing methods provide an opportunity for animal infection by *S. japonicum* and persistent disease infection sources. Some sub-district areas consist of land with swamps and puddles of water. The people of West Lore have free access to meadows with running water and grasslands that hold water. Also, domestic mammals in the sub-district have access to water bodies, and some species, such as cattle, buffaloes, and horses, graze in the pasture area. Dogs can roam in such areas as these animals are free-living and have no cages. Residents, free-roaming domestic animals, and rodents doing activities in schistosomiasis active transmission sites (*O. h. lindoensis* snail foci) are receptive to *S. japonicum* infection. Hence, the involvement of rodents and other wild animals in schistosomiasis transmission is still questionable. Further research opportunities are testing praziquantel efficacy in bovines to reduce animal schistosomiasis prevalence in the country.

CONCLUSION

The main contributors to the contamination of *S. japonicum* eggs to the environment were cattle (69.74%), followed by pigs (21.95%), and buffaloes (4.71%). The presence of *S. japonicum* infection in animals using the Danish Bilharziasis Laboratory technique in West Lore is still high, with the highest prevalence in animals (45.46%). On the contrary, the infected humans in the same area are scarce (0.59%). Mass chemotherapy of schistosomiasis in infected humans and animals still needs to be carried out.

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