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Research Article

The Impact of Snail Control on Intestinal Schistosomiasis Endemic Areas in Indonesia

Junus Widjaja[1,2], Anis Nur Widawati[1,2], Afi Nursafingi[1,2], Ade Kurniawan[2], Helena Ullyartha Pangaribuan[1,3]

[1]National Research and Innovation Agency, Indonesia.
[2]Donggala Unit for Health Research and Development, National Institute of Health Research and Development, Ministry of Health Indonesia, Central Sulawesi.
[3]National Institute of Health Research and Development, Ministry of Health Indonesia, Jakarta.
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I N F O

Corresponding Author:
Junus Widjaja, National Research and Innovation Agency, Indonesia.
E-mail Id:
widjajajunus@gmail.com
Orcid Id:
https://orcid.org/0000-0002-1799-7762
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A B S T R A C T

Introduction: Schistosomiasis is a disease transmitted by a snail-borne trematode in humans, and domestic and wild animals. In Indonesia, schistosomiasis is caused by *Schistosoma japonicum* with an intermediate host, *Oncomelania hupensis lindoensis*. This disease is endemic only in two districts in the Central Sulawesi Province.

Methods: A malacology survey was conducted to assess the effectiveness of snail control activities in the districts of Sigi and Poso. this study was conducted during two distinct periods: February to November 2017 and July to November 2021.

Results: The findings showed that there was a decrease in as well as a variation throughout habitat numbers, snail density, and snail infection rates between the 2017 and 2021 surveys.

Conclusion: Snail control, water-based intervention, conversion of foci areas to productive land, irrigation systems, and molluscicide were the primary causes of this reduction and variation. Therefore, integrated snail control in endemic areas may improve infection control success.

Keywords: Central Sulawesi, *Oncomelania Hupensis Lindoensis*, Schistosomiasis, Snail Control

Introduction

Schistosomiasis is a neglected tropical disease caused by blood trematodes of the genus *Schistosoma*. It remains a major public health issue globally.[1] It is estimated that the disease affects 240 million people in 78 countries, with another 800 million at risk of infection.[2] *Schistosoma japonicum* is endemic in parts of China, the Philippines, and Indonesia.[3] Schistosomiasis is only found in Central Sulawesi Province, specifically the Napu and Bada highlands in Poso District, and the Lindu highlands in Sigi district.[4] The only intermediate snail for *Schistosomiasis japonicum* is *Oncomelania hupensis lindoensis*.[5] Schistosomiasis can cause anaemia, stunting, poor learning abilities in children, severe hepatosplenism, periportal fibrosis with inflammation, and urogenital scarring.[1]

Schistosoma has a complex life cycle that usually involves freshwater snails as intermediate hosts and mammals as definitive hosts.[6] Schistosomiasis differs from other water-borne diseases in that it is not transmitted through the consumption of contaminated water; rather, a person becomes infected when their skin comes in direct contact with freshwater bodies containing the parasite, particularly while doing laundry, bathing, or swimming.[7]

The geographic distribution of schistosomiasis is attributed to the presence of this intermediate host,[8,9] as well as climatic factors.[8,10] The adult *S. japonicum* is capable of infecting humans as well as other mammals such as cattle, buffalo, dogs, pigs, and others, which serve as a reservoir of transmission. Other species that infect animals and humans include *S. haematobium, S. mansoni, S. japonicum, S. intercalatum,* and *S. mekongi. Oncomelania hupensis lindoensis infected* with *S. Japonicum* are common.[11]

Researchers determined 301 snail habitats in schistosomiasis endemic areas in 2016 and 2017.[12] The survey data served as the foundation for developing a road map for eliminating schistosomiasis in Indonesia between 2018 and 2025, with a focus on snail habitat control.[13] The malacological investigation done in the year 2021 has unveiled the persistent existence of snails and their corresponding habitats.[9,14] To assist in schistosomiasis elimination, it is essential to determine the impact of snail control on intestinal schistosomiasis endemic areas in Indonesia between 2017 and 2021.

We used Sentinel-2 composite 248 imagery (publicly available at https://earthexplorer.usgs.gov/) to visualise the surface of the study area. The satellite imagery (Figure 1) was captured on June 3, 2021, when the field survey was conducted.

Materials and Methods

Site Study

This study was conducted during two distinct periods: February to November of the year 2017 and July to November 2021. The study focused on regions known to be affected by schistosomiasis, namely Napu Highlands and Bada Highlands in the Poso district, as well as Lindu Highlands in the Sigi district. Sigi district has five villages, namely Puroo, Langko, Anca, Tomado, and Olu. Lake Lindu serves as a vital resource for livelihood, leisure activities or recreational use, and irrigation purposes. Poso district has 24 villages: Sedoa, Watumaeta, Wuasa, Banyusari, Kaduwa, Dodolo, Alitupu, Winowanga, Maholo, Mekarsari, Tinimbo, Tamadue, Kalimago, Wanga, Siliwanga, Watutau, Betue, Torire, Tomehipi, Lengkeka, Kageroa, Tuare, Lelio, and Kolori (Figure 1). We conducted a malacology survey to collect information on snail infection. In addition, the impact of snail control was determined by comparing the malacology survey data from 2017 and 2021.

Snail Survey and Collection

The man-per-minute or random quadrant method was used for snail sampling. Each snail taker took the snails for 5 minutes at a time, and this process was repeated several times until all plot areas were covered. A point displacement of at least 1 square meter was required. Using tweezers, a snail was picked up, placed in the provided snail container, and counted at each point. The snails gathered from the site arewere subsequently transferred into a designated snail container. They were examined in the laboratory by crushing/ breaking the shell. Three snails were placed on a clean slide and then carefully crushed with medium tweezers. After adding 1-2 drops of water to each snail, they were examined under a dissecting microscope. Using a pair of needles or small tweezers, the cercariae were carefully examined.[14] The results were documented by categorizsing them based on gender and the developmental stages of the parasites, including sporocysts, cercariae, and other types of parasites (Figure 2). The geographical coordinates of the snail sites were recorded using a hand-held GPS (Geographical Positioning System).

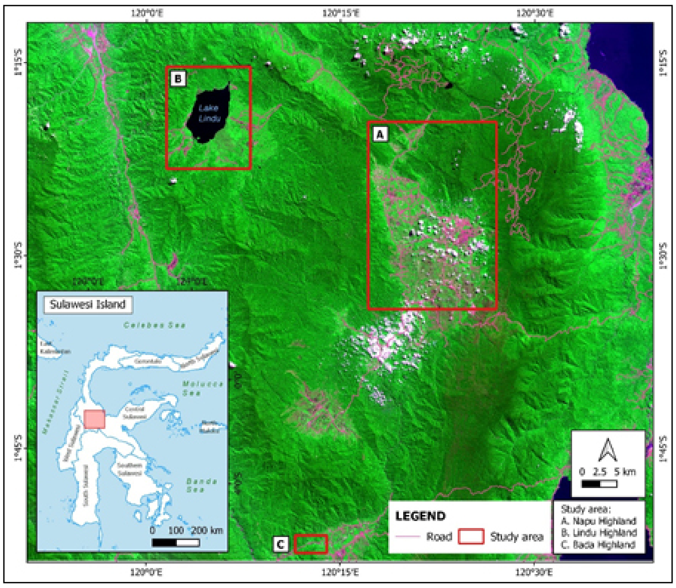

Figure 1.A Map Showing the Locations of Malacological Surveys in the Lindu, Napu, and Bada Highlands

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Figure 2.Method and Procedure of Malacology Survey

Table 1.Number of Schistosomiasis-infected Snails in Different Years in Poso and Sigi Districts

Year/ Place of Collection	No. of Villages	No. of Foci	Number of Snails Collected (n)	Number of Infected Snails * (n (%))	Others Snails ♦	Type of Foci	Area (m^2)
Total number	29	301	43,247	2,732 (6.3)	20	20	1,649,405
2017							
Napu	18	243	40,194	2,481 (6.0)	-	1,2,3	1,082,185
Lindu	5	32	2,576	200 (7.0)		1,2,4	552,759
Bada	6	26	477	51 (10.0)	20	1,2,4,5	14,461
Total number	19	198	30,060	1,461 (4.8)	50	50	663,672
2021							
Napu	18	183	25,972	1,043 (4.0)	50	1,2,3	636,284
Lindu	2	25	2,485	400 (16.0)	-	1,2,4	26,988
Bada	1	4	1,603	18 (1.0)		4,5	400

1: rice field; 2: plantation; 3: swampy field, 4: water seepage; 5: pond
**Oncomelania hupensis lindoensis* ♦*Sulawesidrobia* spp.

Ethical Approval

This study protocol was reviewed and approved by the Ethics Committee of the Faculty of Medicine, Tadulako University, Central Sulawesi Province (No. 1627/UN 28.1.30/KL/2021).

Results

Snails with morphological features, classified as *Oncomelania hupensis lindoensis,* were discovered all over the highlands. In 2017, cercariae were found in 200 (7%) snails in Lindu, 51 (10%) in Bada, and 2.481 (6%) in Napu. The number of snail communities in these three highlands reached 43,247 after four years. The prevalences of schistosomiasis in snails were 6%, 7%, and 10% in Napu, Lindu, and Bada, respectively. In 2021, cercariae were found in 400 (16%) snails in Lindu, 1,40043 ,(4%) in Napu, and 18 (1%) in Bada.

The snail habitats showed a decrease of approximately 30% in both 2021 and 2017, resulting in a total decline of 11%.of *O.hupensis lindoensis* was found to prefer paddy fields and plantation habitats throughout the three survey areas. However, while water seepage was discovered in both Lindu and Bada, ponds were found only in Bada (Table 1). However, it was discovered that the number of snail habitats increased in several villages, including Maholo

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and Tamadue (Table 2). The potential habitat for snails in the Napu Valley is much larger than that available in Lindu and Bada. The infection rate in Lindu was 7% in 2017 but rose to 16% by 2021.

Snails prefer uncultivated former rice fields that are close to active rice fields. They can also be found in waterways on cocoa, coffee, or mixed plantations. The water channel is covered in fallen dry leaves, also known as "litter". Plantation habitats are frequently found near community settlements. Snail infections have also been discovered in seepage water habitats, particularly in Lindu, Bada, and Napu.

Plantation habitats can be found in the villages of Alitupu, Dodolo, Winowanga, Maholo, and Watumaeta. While rice fields have been discovered in the villages of Maholo, Tamadue, and Tomado, the remaining habitat types are ponds and water seepage. Snail habitats include seepage water, which serves as a source of water for the community's daily needs, such as bathing and washing.

Snail habitats have declined due to a variety of factors, including conversion to rice fields or plantations, being carried away by floodwaters, being buried by soil due to landslides, and molluscicide spraying. According to the observations, the swamp area has been converted to rice fields (Figure 3).

Table 2.Snail Habitat Numbers in Schistosomiasis Endemic Villages in 2017 and 2021

No.	Highland	Villages	Number of Habitats		Type of Foci	No.	Highland	Villages	Number of Habitats		Type of Foci
			2017	2021					2017	2021	
1.	Napu	Sedoa	33	13	1,2,3	-	-	Wanga	5	3	1,2
-	-	Watumaeta	19	14	1,2	-	-	Watutau	2	2	1
-	-	Wuasa	4	3	1,2	-	-	Betue	0	0	0
-	-	Banyusari	1	1	1	-	-	Torire	0	0	0
-	-	Kaduwa	11	7	1,2,3	2.	Lindu	Anca	12	11	1,2,4
-	-	Dodolo	34	26	1,2,4	-	-	Tomado	16	14	1,2
-	-	Alitupu	23	22	1,2,4	-	-	Langko	1	0	1
-	-	Winowanga	39	20	1,2	-	-	Puroo	3	0	1
-	-	Maholo	24	29	1,2	-	-	Olu	0	0	0
-	-	Mekarsari	16	13	1,2	3.	Bada	Lengkeka	5	4	4,5
-	-	Tamadue	7	17	1,2	-	-	Kageroa	4	0	1,2,5
-	-	Kalimago	14	13	1,2	-	-	Tomihipi	8	0	1
-	-	Tinimbo	9	0	1,2	-	-	Tuare	8	0	1,2,5
-	-	Siliwanga	2	0	1	-	-	Kolori	1	0	1

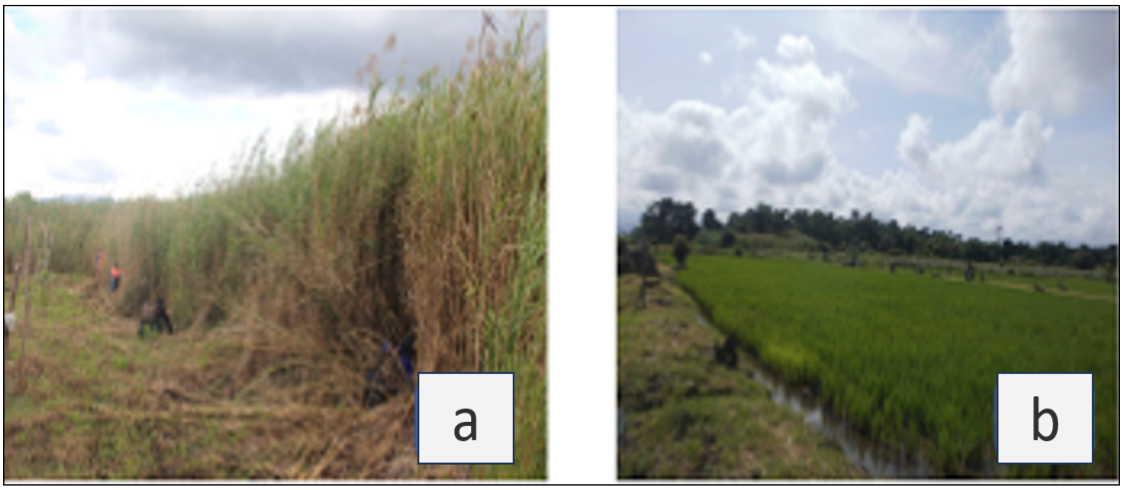

Figure 3.Snail Habitat Conversion (a) Before (Swamp) (b) After (Paddy Field)

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Snails are commonly found in abandoned rice fields. They are found attached to grass stalks or leaves. The snails were collected and identified as *Oncomelania* spp., with a small size and dark brown colour, and an adult size no larger than a grain of rice. Besides *Oncomelania*, other snails found belonged to the Indopyrgus spp. from the Hydrobiidae family and the Sulawesidrobia genus. This snail has a morphology similar to the *O. hupensis lindoensis* snail but is smaller in size. Under the microscope, *S. japonicum* cercariaes resemble tiny flatworms with fishtails. Their body size is approximately 200 by 70 micrometres, and the tiny tail length is 220 micrometres. Other than *Oncomelania* snails, the cercariae were not found in any other snails (Figure 4).

carried out by the community as well as individuals from various sectors (Figure 3).

Since the official launch of the schistosomiasis elimination roadmap in 2018, efforts to control the disease have been quite impactful. The Bada model, which was implemented in the Bada area in 2019, as well as the Poso district health office-initiated community-led movement to eliminate schistosomiasis, have both reinforced community participation.[17] Lindu was one of the areas affected by the 2018 natural disaster, so the government shifted its entire budget to deal with the aftermath. This also had an impact on snail habitat control efforts, which were impeded by the disaster and thus increased the infection rate of snails in Sigi.

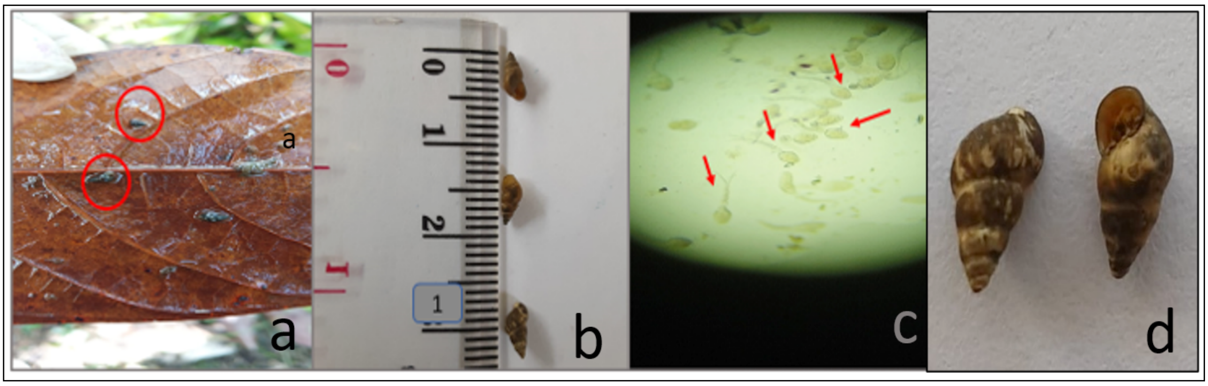

Figure 4(a).*Oncomelania* spp. Snails Attached to Cocoa Leaves (b).*Oncomelania hupensis lindoensis* Snail Identified in the Study (c).A Microscopic View of Oncomelania Snails Revealing the Presence of Snails undergoing a Shedding Process, Particularly Observed in Mammalian Species characterised by Forked Tails (d).*Oncomelania hupensis lindoensis* Snails

Discussion

Another feature that may potentially contribute to the transmission is the presence of snail habitats.[15] The infected snail releases cercariae that resemble tadpoles (Figure 4(c)), with a finely spiky body and tail surface, and a forked tail tip.[16] The organism has a body length measuring 125 picometers, while its tail length ranges between 180 and 230 picometers.

It has an oval-shaped sucker mouth with a pointed outer surface, which bears resemblance to its overall shape. Additionally, these cercariaes have the capacity to invade the organisms (humans or animals), later maturing into adult schistosomes.

From 2017 to 2021, the number of snail habitats also decreased, particularly in the Napu and Bada highlands. According to the district health office, this is due to snail habitat control activities that were actively carried out again in 2018, such as improving and constructing waterways, cleaning waterways, drying focus areas, converting focused land to productive land, and spraying. These activities are

The World Health Organization (WHO) has endorsed and advocated mass drug administration utilising praziquantel (PZQ) for the global control and elimination of schistosomiasis. However, PZQ is not completely curative in killing adult worms, cannot kill migrating schistosomula or the early stages of the disease, and does not prevent reinfection.[18]

The only approach that will result in long-term sustainability and elimination is integrated control that targets the entire life cycle.[19] Controlling intermediate snails is one of the efforts. When it comes to controlling snail populations, it is advised to employ control measures that encompass not only the use of molluscicides but also the implementation of environmental modifications.[20] The local health authorities implement snail control measures through two distinct methods, namely mechanical and chemical approaches. The snail's habitat is sprayed with 0.2 g/m2 of molluscicide (Bayluscide 70% WP) every six months as part of the chemical control. Niclosamide is the only chemical molluscicide approved by the WHO and has been used in other endemic areas for about 30 years, including China.[21] This finding,

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as well as evidence from other studies, indicates that snail control is effective in accelerating transmission in highly endemic areas.[22,23] Furthermore, this is consistent with the findings of a meta-analysis, which found that snail control with molluscicides (niclosamide) is effective in controlling schistosomiasis and reducing transmission.[24]

There is, however, a consistent positive correlation between the increased prevalence of infection in humans and the prevalence of snail infections. This contradicts the low rates of snail infection and high rates of human infection found in field studies in endemic areas.[25,27] Snails may not be ideal to release cercariae around the peak of the rainy season. Also, mixing more water makes human waste less concentrated, which makes it harder for miracidia to find snail hosts in wavy water.[26]

Habitat influences snail control preferences. The intervention method implemented in the regions of Napu and Bada primarily centres on the enhancement of community engagement. Lindu's main priority is the expansion of cross-sectoral responsibilities, which involves the establishment of enduring water channels and ponds, and the prominent initiatives within the agricultural sector that centre around rice field shaping.

We discovered that the risk of schistosomiasis transmission was higher near human water contact sites with more snail habitats, such as Watumaeta dan Tamadue village (Napu highland). Moreover, water seepage habitats have been used as community water sources in Lengkeka and Alitupu villages.

Conclusion

We still find infective snails in the endemic areas of Lindu, Bada, and Napu. The integrated snail control has a significant effect on reducing the number of foci in each endemic village. However, apart from preventive chemotherapy, community and cross-sector participation is vital for snail control success. Furthermore, as part of surveillance, malacological surveys in a larger area are considered essential to anticipate the risk of transmission and optimise elimination.

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