Oncomelania lorelindoensis: the intermediate host of Sulawesi's *Schistosoma japonicum*

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Article

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Abstract

Purpose: In this study, I report a study of the genus *Oncomelania* focused on *Schistosoma japonicum* and *Oncomelania lorelindoensis* as the intermediate hosts of Sulawesi schistosomiasis japonica, their distributions in Sulawesi, and the control of *O. lorelindoensis*.

Principal results: Proto-*Oncomelania* originated in eastern Indonesia, Sulawesi. It spread to the Philippines, Japan and then gave rise to *Oncomelania.* It is the intermediate host of *Schistosoma japonicum*. The genus *Oncomelania* comprises five species: *Oncomelania hupensis, O. lorelindoensis* (formerly *O. hupensis lindoensis*)*, O. minima, O. robertsoni,* and *O. quadrasi. Oncomelania lorelindoensis* is the intermediate host of Sulawesi *S. japonicum*. It occurs in and around Lore Lindu National Park: the Bada Valley, the Lindu Valley, and the Napu Valley, Central Sulawesi. This organism may have prevailed in the Kulawi Valley and the Palu Valley of Central Sulawesi Province. Control of *O. lorelindoensis* can use mechanic techniques, molluscicides, and genetic manipulation techniques.

Conclusions: *Oncomelania lorelindoensis*occurs in Central Sulawesi, Indonesia: the Bada Valley, the Lindu Valley, and the Napu Valley. It may also have expanded to other areas around Lore Lindu National Park. This organism is the intermediate host of Sulawesi *S. japonicum.*

Introduction

Oncomelania lorelindoensis (formerly *O. hupensis lindoensis*) is the intermediate host of Sulawesi *Schistosoma japonicum*. *Schistosoma japonicum* has at least 46 species of mammal-definite hosts.[1] These can comprise buffalos, humans, mice, and pigs. Definite hosts of this parasite can also include nonmammals.[2] In Indonesia, endemic areas of *S. japonicum* include the Bada Valley, Lindu Valley, and Napu Valley in Central Sulawesi.[3] In 1974, Sudomo and Carney reported several cases of Sulawesi schistosomiasis japonica in the Kulawi Valley and the Palu Valley.[4]

The west-to-east hypothesis suggests that the distribution of *Oncomelania* and proto-*Oncomelania* into China and Southeast Asia occurred approximately 18 million years ago. Another hypothesis is the east-to-west hypothesis. It states that proto-*Oncomelania* extends from North Australia, namely, eastern Indonesia,[5] including Sulawesi, the islands of Borneo-Philippines,[6] to Japan. After reaching Japan, proto-*Oncomelania* gave rise to *Oncomelania hupensis* in mainland China 15 to 18 million years ago. Then, they returned to colonize Japan, Sulawesi, and the Philippines.[5] However, Liu et al. (2014) suggested that the genus *Oncomelania* could also originate in the "southern continental" region,[6] suggesting that the spread of *O. hupensis* from China did not reach Southeast Asia: Indonesia and the Philippines.

The genus *Oncomelania* has five species: *Oncomelania hupensis, O. lorelindoensis, O. minima, O. robertsoni,* and *O. quadrasi.* Only *O. hupensis* has subspecies: *Oncomelania hupensis tangi, O. hupensis formosana, O. hupensis chiui,* and *O. hupensis nosophora.* Other species have no subspecies.[7]

Oncomelania minima is aquatic.[8] Other *Oncomelania*, for example, *O. lorelindoensis* and *O. robertsoni,* are amphibians.

Three methods are available for controlling Sulawesi schistosomiasis japonica in *O. lorelindoensis*: mechanical, molluscicides through botanical and chemical, and genetic manipulations. *Allium sativum* and *Buddleja lindleyana* are beneficial for botanical control. In Sulawesi, mechanical and chemical methods are used for controlling *O. lorelindoensis.* Mechanical methods can include clearing focus areas and constructing drainage. The chemical method uses niclosamide. Finally, genetic manipulations can occur through anti-schistosomes inoculated into female *O. lorelindoensis.* However, the use of genetic manipulations needs to consider ethical issues.[7] In the future, these techniques will be beneficial for controlling *O. lorelindoensis* and schistosomiasis in Sulawesi.

In this study, I report a study of the genus *Oncomelania* focused on *S. japonicum* and *O. lorelindoensis* as the intermediate host of Sulawesi schistosomiasis japonica, their distributions in Sulawesi, and the control of *O. lorelindoensis* snails.

Methods and results

In this study, I used BiomedCentral, Google, ScienceDirect, and the PubMed Database in the National Center for Biotechnology Information (NCBI) Database for searching articles on *S. japonicum* Sulawesi and the genus *Oncomelania.* Articles were published between 2011 and 2023. However, other relevant publications published before 2011 were also included.

In this study, I also used the nucleotide NCBI BLAST to assess similar identity and a tree-view rectangle cladogram (NCBI), slanted cladogram (NCBI), and rectangle cladogram from ETE3 and PhyML. I used nucleotide BLAST for two or more alignments to have accession numbers, a similar percentage identity, and a query cover percentage for *Oncomelania*, for example, *O. lorelindoensis* and *O. robertsoni*. For query cover, if the BLAST (megablast) showed that it was not significant, I would do BLAST for somewhat similar sequences.

The generation of a tree-view slanted cladogran was performed from the nucleotide NCBI BLAST results of GenBank. For ETE3 and PhyML sequence alignment, I used FASTA from NCBI BLAST results. Data comprise *Oncomelania hupensis* GU367391.1, *O. minima* AB611791.1, *O. robertsoni* KR002675.1, and *O. quadrasi* DQ112287.1.

Sulawesi *Schistosoma japonicum*

The genetic structure of the population of *S. japonicum* distributed over the Far East is still unclear.[9] *Schistosoma japonicum* radiated eastward and established distinct groups in central and eastern China.[10] However, Yin et al. (2015) suggested that *S. japonicum* originated in the middle and lower reaches of the Yangtze River and spread to Japan, the mountainous areas of China, and to Indonesia and the Philippines.[9] My sequence analysis showed that Sulawesi *S. japonicum* originated on Laozhou

Island, Tongling County, Anhui Province, China. Anhui *S. japonicum* KU196317.1 shares 99.80% identity similarity with Sulawesi *S. japonicum* KU196348.1 (Table 1). It is the highest percentage among other Chinese *S. japonicum* worms.

Five species of the *Schistosoma japonicum* complex can infect animals or humans. These include *S. ovuncatum, S. sinensium, S. japonicum, S. malayensis,* and *S. mekongi.*[11-13] *Schistosoma japonicum, S. malayensis,* and *S. mekongi* cause human schistosomiasis.[14] *Schistosoma japonicum* is the parasite that can infect humans in Sulawesi.[7]

Adult male Sulawesi *S. japonicum* worms are approximately five to 12 millimeters long, and the females are approximately 10 to 14 millimeters long. The worms are usually in pairs. Female worms are on the canalis gynacophorus of male worms. The body and tail of cercariae are thorny and thin. End of tail branched. The body is 125 micrometers long, and the tail is 180 to 230 micrometers long. There are intraspecies variations in Sulawesi *S. japonicum*. Adult male worms from Lindu showed consistent similarities to those from Napu worms. Adult female worms displayed distinct variations. The morphology of worms and cercariae in Lindu and Napu is the same as that in other countries,[15] such as China and the Philippines.

The infection rate of *S. japonicum* in Sulawesi fluctuates every year. For example, the prevalence of the parasite in humans in the Bada Valley was 0.5% in 2008 and 5.9% in 2010. In 2015, the prevalence was 1.75% in the Bada Valley, 1.30% in the Lindu Valley, and 1.90% in the Napu. In 2018, the prevalence was 0.43% in the Bada Valley, 0.19% in the Lindu Valley, and 0.35% in the Napu Valley.[16]

Budiono et al. (2019) suggested that the prevalence of animals with *S. japonicum* in the Lindu Valley was cattle (61.5%), buffalo (42.3%), pigs (35.6%), horses (25%), and dogs (12.5%).[2] No reports are available for the Bada Valley or the Napu Valley. In 2011, the prevalence of mice with Sulawesi *S. japonicum* infection was 6.8% in the Napu Valley. No reports are available for the Bada Valley or the Lindu Valley. In 2015, the prevalence of mice with *S. japonicum* infection was 12.50% in the Bada Valley, 8.16% in the Lindu Valley, and 7.69% in the Napu Valley. In 2017, the prevalence of mice with *S. japonicum* infection was 50% in the Bada Valley, 14.29% in the Lindu Valley, and 7.69% in the Napu Valley.[16] These findings show that the infection rate in animals is high.

Distribution of Sulawesi *Schistosoma japonicum*

According to nucleotide sequences, people with *S. japonicum* from China, Japan, and Taiwan brought this parasite to Sulawesi, Indonesia.[7] Muller and Tech found *S. japonicum* parasites in the feces of patients in Palu in 1937. Faust and Bonne reported adult worms in dogs, humans, and other wild-type animals in 1948.[15] Carney et al. (1973) found the intermediate host of Sulawesi *S. japonicum* in 1971,[4] and then Davis and Carney named this intermediate host *O. hupensis lindoensis* in 1973.[17] Moreover, Nelwan (2022) named this intermediate host *O. lorelindoensis* along with *O. robertsoni* and *O. quadrasi* based on sequences using NCBI BLAST.[7,18]

Humans and birds can transmit Sulawesi schistosomiasis japonica from endemic areas. For example, in rare cases, birds may transport ingested snails long distances and secrete them alive in a new area.[19] Carney et al. reported that a few cases of the disease occur in the Kulawi Valley and the Palu Valley, with individuals in these cases spending considerable time visiting or working in the Lindu Valley.[4] Therefore, it could also have expanded to other new areas. These areas can include the Kulawi Valley, the Lariang River, the Palu Valley, and the Salo Karangan River. The Lariang River also flows in West Sulawesi Province. In addition, the Salo Karangan River also flows in South Sulawesi Province. This means that Sulawesi schistosomiasis japonica may have prevailed in South Sulawesi, and West Sulawesi.

Proto-*Oncomelania lorelindoensis*

Proto-*Oncomelania lorelindoensis* plays an important role in developing the genus *Oncomelania.* The distribution of this precursor form of *Oncomelania* species should be informed as much as possible. It will explain how this genus occurred.

Pomatiopsinae transmit the parasitic *Schistosoma japonicum* blood-fluke in China, Indonesia, and the Philippines. Pomatiopsinae are amphibious to terrestrial and have a wide distribution.[8] The east-to-west hypothesis suggests that Proto-Pomatiopsinae diverges in Australia. Proto-*Oncomelania* colonizes northward of Australia. It was in Borneo and eastern Indonesia[6] including Sulawesi and Maluku. This means that proto-*Oncomelania* in Sulawesi is proto-*Oncomelania lorelindoensis.* It is reasonable to state that all species in the genus *Oncomelania* originated from proto-*Oncomelania lorelindoensis*, with subsequent dispersal to the southern Philippines. It occurred during the Mio-Pliocene. Then, it colonizes the Far East.

Proto-*Oncomelania lorelindoensis* first colonized the Philippines as proto-*Oncomelania quadrasi,* Japan as proto-*Oncomelania minima,* and China as proto-*Oncomelania hupensis* and proto-*Oncomelania robertsoni* (Table 2 and Figure 1). Each proto-*Oncomelania* formed each species in the genus *Oncomelania.* All are five species.

The genus *Oncomelania*

The colonization of Japan would have occurred in the mid-Miocene, followed by an invasion of the Yangtze Plain of China from its east coast. At that time, the change from proto-*Oncomelania* gave rise to Japanese Pomatiopsinae and *O. hupensis. Oncomelania hupensis* colonizes China, and back-tracking recolonizes the Philippines and Sulawesi. Allozyme and DNA-sequence-based phylogenies for *Oncomelania* showed that the “southern continental” pomatiopsines and Japanese *O. minima* were similar to all other *Oncomelania*.[6]

Oncomelania snails in China may be the same species or subspecies of *O. hupensis.* In other Far East countries, *Oncomelania* snails have been considered either subspecies or independent species of *O. hupensis*.[20] Attwood et al. (2015) introduced the idea that *Oncomelania* snails originated in *O. hupensis*,[5] except for *O. lorelindoensis, O. minima, O. robertsoni,* and *O. quadrasi*.[7] This supports that the genus

Oncomelania has five species: *Oncomelania hupensis, O. lorelindoensis, O. minima, O. robertsoni,* and *O. quadrasi,* as suggested by Nelwan[7]

Both *O. quadrasi* and *O. minima* are in different groups than *O. hupensis* and *O. robertsoni*. However, *O. quadrasi* is closer to *O. robertsoni* and *O. hupensis* than *O. minima* to *O. robertsoni* and *O. hupensis* (Table 3, Figure 2). *Oncomelania lorelindoensis* shares 86.21% identity similarity with *O. hupensis hupensis* KR002674.1.[21] *Oncomelania quadrasi* DQ112287.1 shares 84.40% identity similarity with *O. hupensis hupensis* KR002674.1.[7] In addition, *O. lorelindoensis* and *O. quadrasi* have a 6.2 value-pairwise difference in the percentage of the 12S rRNA gene. Both have 6.4 value-pairwise differences from Yunnan *O. hupensis hupensis*.[22] This shows that *O. lorelindoensis* should be in the same branch as *O. quadrasi* in a slanted cladogram (Figure 3), for example. However, both of them have distant family relationships.

Oncomelania lorelindoensis

The intermediate hosts of Sulawesi *S. japonicum* occur in Lindu and its surroundings. These include the Lindu sub-district, North Lore sub-district, and Lore Peore sub-district. These subdistricts are within Lore Lindu National Park or close to the park. Previous literature stated that intermediate hosts of Sulawesi *S. japonicum* originated in Chinese *Oncomelania hupensis.* Therefore, those authors named this intermediate host *Oncomelania hupensis lindoensis*.[17] It is still within the *Oncomelania hupensis* group. My sequences show that Sulawesi *Oncomelania* snails are beyond the *O. hupensis* group because they have distant relationships. Based on that, I named the intermediate host of Sulawesi *S. japonicum* with the name *Oncomelania lorelindoensis* to replace *O. hupensis lindoensis.*

Oncomelania lorelindoensis has a conical shell that is yellowish-brown and clear. Snails have a size of approximately 6.5 to 7.5 millimeters of circle and a length of approximately 1 to 5 millimeters for adult snails[15] with an open umbilicus. Sulawesi *Oncomelania* snails have lips that protrude from the base of their shell. The operculums in these snails contain a horny substance and are rather hard. The glands around the eyes of *O. lorelindoensis* are light yellow to bright yellow.[21,23]

In 2011, the prevalence of *O. lorelindoensis* with Sulawesi schistosomiasis japonica was 3.56% in the Lindu Valley and 0.98% in the Napu Valley. No reports are available for the Bada. In 2016, the prevalence was 5.84% in the Bada Valley and 4.96% in the Lindu Valley. No reports were available for the Napu Valley. In 2017, the prevalence was 0.81% in the Bada Valley, 3.43% in the Lindu Valley, and 7.63% in the Napu Valley.[16] This shows that the infection rate in snails is high.

Habitats of *Oncomelania lorelindoensis*

The epidemiology of Sulawesi *S. japonicum* depends on the existence of its intermediate host. This is due to the development of the larval stages of *S. japonicum* worms that occur in the body of the *O. lorelindoensis* snail. The life of snails depends on the existence of suitable habitats that keep them alive.[3]

Habitats of *O. lorelindoensis* occur in two habitat areas: natural and disturbed. Natural habitats can include forests and rivers. Disturbed habitats can include rice fields and former agricultural pastures.[24] Snails of this species live in muddy water, in moist places, and in watery places.[25]

The intermediate host of Sulawesi *S. japonicum* occurs in the highland of Central Sulawesi *S. japonicum* endemic areas. The natural habitat of the snail is in the forest borders and in the forest or lakeside. Its habitat is shrubs under large trees that are always wet.[26] In addition, habitats can comprise rivers, swamps, and water seepage.[24] Disturbed habitats can comprise abandoned rice fields, former farm meadows, and the edges of irrigation canals. Overall, *O. lorelindoensis*'s habitats in Lore Lindu National Park comprise forest (7.64%), grassland (18.06%), plantations (29.86%), and rice fields (44.44%).[26] Generally, these habitats include rice fields, irrigation with stagnant water, and grass or leaf fall. This intermediate host lives in moist, watery places, but snails die when submerged in water[26] for quite a long time.[23]

Oncomelania lorelindoensis habitat may also have occurred in the Lariang River, the Palu River, and the Salo Karangan River. The headwaters of these rivers are in Lore Lindu National Park, where Sulawesi schistosomiasis japonica endemic areas occur.[7] Floods could carry snails[27] from the headwaters to the lower land of the rivers, especially the Lariang River and Palu River. Snails can spread along these rivers. Potential habitats, for example, forests and rice fields along these rivers, can become new habitats for *O. lorelindoensis* snails. For example, birds can carry accidentally infected snails to these three rivers. Consequently, new endemic areas can occur.

The behavior of using river or ditch water in the Napu Valley has a 2.31 times higher risk of infection with the parasite compared to the behavior that does not use river or ditch water.[24] This suggests that other rivers in Sulawesi can be habitats for *S. japonicum* worms and their intermediate hosts. This means that the Lariang River, the Palu River, and the Salo Karangan River may be potential habitats for *O. lorelindoensis* and Sulawesi *S. japonicum*. An intermediate host of Sulawesi *S. japonicum* may have occurred in South Sulawesi and West Sulawesi provinces. The transmission of schistosomiasis in Corsica, France, supports that schistosomiasis can occur from one river to another. In the case of Corsica, it is from the Cavu River to the Solenzara River. These two rivers do not intermingle.[28]

Environmental characteristics of *Oncomelania lorelindoensis*

Environmental factors that affect the breeding of *O. lorelindoensis* can include air temperature, humidity, pH, and sunlight.[29] Humidity, sunlight, and temperature are the limiting factors for a snail's life. The optimal temperature is between 16 °C and 28 °C, with a pH value between six and eight. The sun is an important factor in the existence of cercariae of the genus *Schistosoma.* In addition, it is important to release cercariae at water temperatures between 10 °C and 30 °C, even higher[30] and between 22 °C and 25.5 °C.[25]

Three classes of phytoplankton are in the habitats of *O. lorelindoensis.* These include *Chlorophycea, Cyanophycea,* and *Diatomae.* All are feeding of *O. lorelindoensis. Chlorophycea* is more dominant than those of other classes. However, Hadidjaja and Sudomo (1976) stated that *Diatomae* are the main feeding of *O. lorelindoensis*.[30]

It seems that food, humidity, pH, sunlight, and temperature are important factors for the life of Sulawesi *S. japonicum* and its intermediate host. Places that are suitable for both can become new areas for these two organisms.

Control of *Oncomelania lorelindoensis*

Indonesia uses two approaches for controlling *O. lorelindoensis*: mechanic and chemical. Mechanic control is achieved by clearing focus areas, constructing drainage, backfilling, or draining focus areas. Chemically, it is through spraying niclosamide (bayluscide) molluscicide. This country has used this molluscicide since the 1980s.[29] However, chemical molluscicides can damage the environment. Therefore, botanical molluscicides may be more useful for controlling *O. lorelindoensis*. It will not damage the environment. Botanical molluskicide sources are available for controlling Sulawesi *Oncomelania.* These can include *Allium sativum* and *Buddleja lindleyana*.[31,32]

Genetic manipulation techniques may also be useful. However, ethical issues must be fully considered before using these approaches in the field. These methods will not kill or damage the snail of *O. lorelindoensis*[7] and will not damage the environment.

Conclusions

Oncomelania lorelindoensis is an intermediate host of Sulawesi *Schistosoma japonicum*. Sulawesi *S. japonicum* originated in Anhui Province, China. It occurs within and around Lore Lindu National Park, Central Sulawesi, Indonesia, and may also prevail in South Sulawesi Province and West Sulawesi Province. *Oncomelania lorelindoensis* is close to the Philippines' *O. quadrasi*. Precursor forms of the genus *Oncomelania* originated in proto-*Omcomelania lorelindoensis.* These include proto-*Oncomelania hupensis,* proto-*Oncomelania lorelindoensis,* proto-*Oncomelania minima,* proto-*Oncomelania robertsoni,* and proto-*Oncomelania quadrasi.* Each formed each species in the genus *Oncomelania: Oncomelania hupensis, O. lorelindoensis, O. minima, O. robertsoni,* and *O. quadrasi.* Control of *O. lorelindoensis* can be achieved through mechanical techniques, molluscicides with botanical and chemical techniques, and, in the future, genetic manipulation techniques.

Declarations

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Conflicts of interest

I declare that no conflicts of interest exist.

Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

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Tables

Table 1. Percentage of identity similarity of *Schistosoma japonicum*

Species		***S. japonicum***	**Location**
	accession	KU196317.1	Laozhou Island, Anhui, China
S. japonicum	KU196348.1	99.80%	Central Sulawesi Indonesia
S. japonicum	KU196379.1	99.79%	The Philippines
S. japonicum	KU196389.1	99.79%	Sichuan, China
S. japonicum	KU196408.1	99.75%	Yunnan, China
S. japonicum	KU196369.1	99.69%	Anhui, China
S. japonicum	KU196328.1	99.68%	Hunan, China
S. japonicum	KU196318.1	99.66%	Hubei, China
S. japonicum	KU196359.1	99.38%	Japan
S. japonicum	KU196299.1	99.34%	Anhui, China
S. japonicum	KU196338.1	99.29%	Hunan, China
S. japonicum	KU196398.1	98.01%	Taiwan

S.: Schistosoma

Table 2. Proto-*Oncomelania* and *Oncomelania* spp

Proto-*Oncomelania*	*Oncomelania* spp	Countries
Proto-*Oncomelania hupensis*	*Oncomelania hupensis*	China
Proto-*Oncomelania lorelindoensis*	*Oncomelania lorelindoensis*	Indonesia
Proto-*Oncomelania minima*	*Oncomelania minima*	Japan
Proto-*Oncomelania robertsoni*	*Oncomelania robertsoni*	China
Proto-*Oncomelania quadrasi*	*Oncomelania quadrasi*	Philippines

Table 3. Percentage identity of genus *Oncomelania*

Species		*O. quadrasi*
	accession	**DQ112287.1**
O. robertsoni	KR002675.1	87.25%
O. hupensis	GU367391.1	84.48%
O. minima	AB611791.1	82.13%
Species		***O. minima***
	accession	**AB611791.1**
O. robertsoni	KR002675.1	84.60%
O. hupensis	GU367391.1	82.44%
Species		***O. hupensis***
	accession	**GU367391.1**
O. robertsoni	KR002675.1	88.29%

O. : Oncomelania

Figures

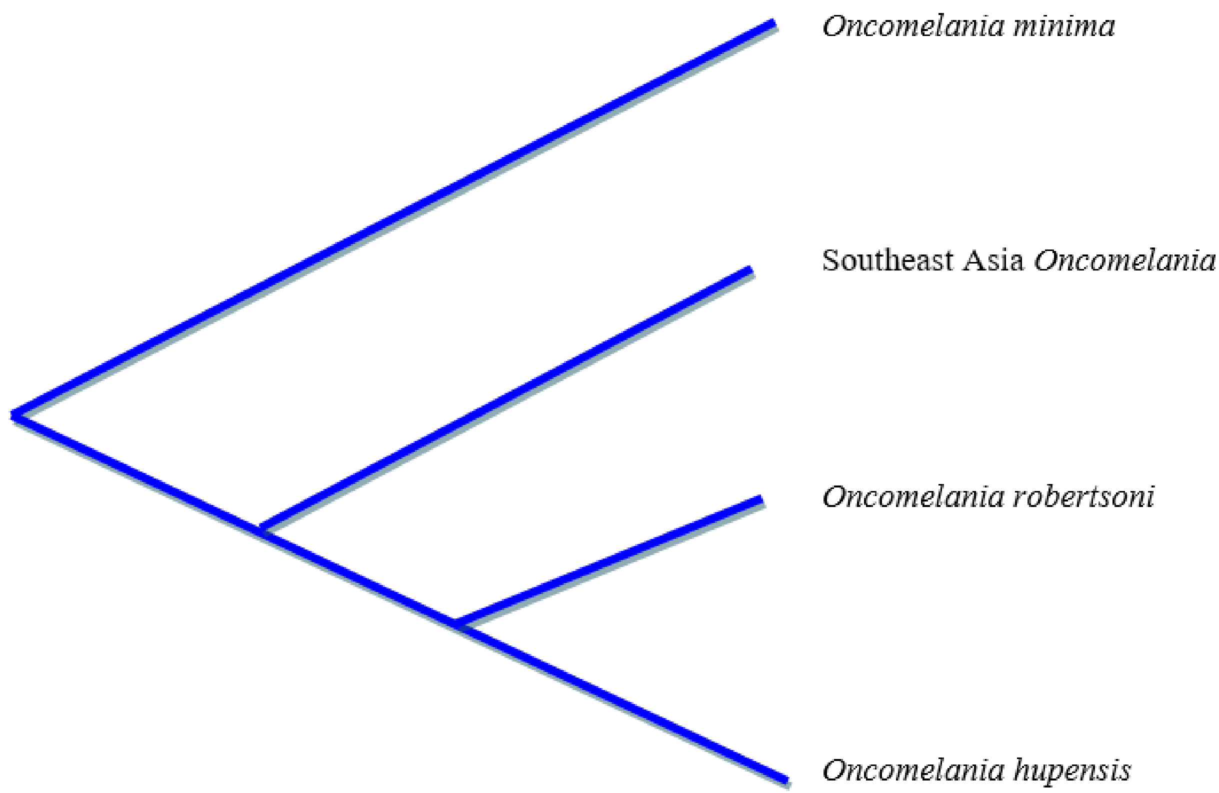

Figure 1

Genus *Oncomelania* in the Far East. It seems that *Oncomelania hupensis* and *Oncomelania robertsoni* close to Southeast Asia *Onconelania* i.e. *Oncomelania lorelindoensis* and *Oncomelania quadrasi.* All are amphibious, except *Oncomelania minima,* which is aquatic.

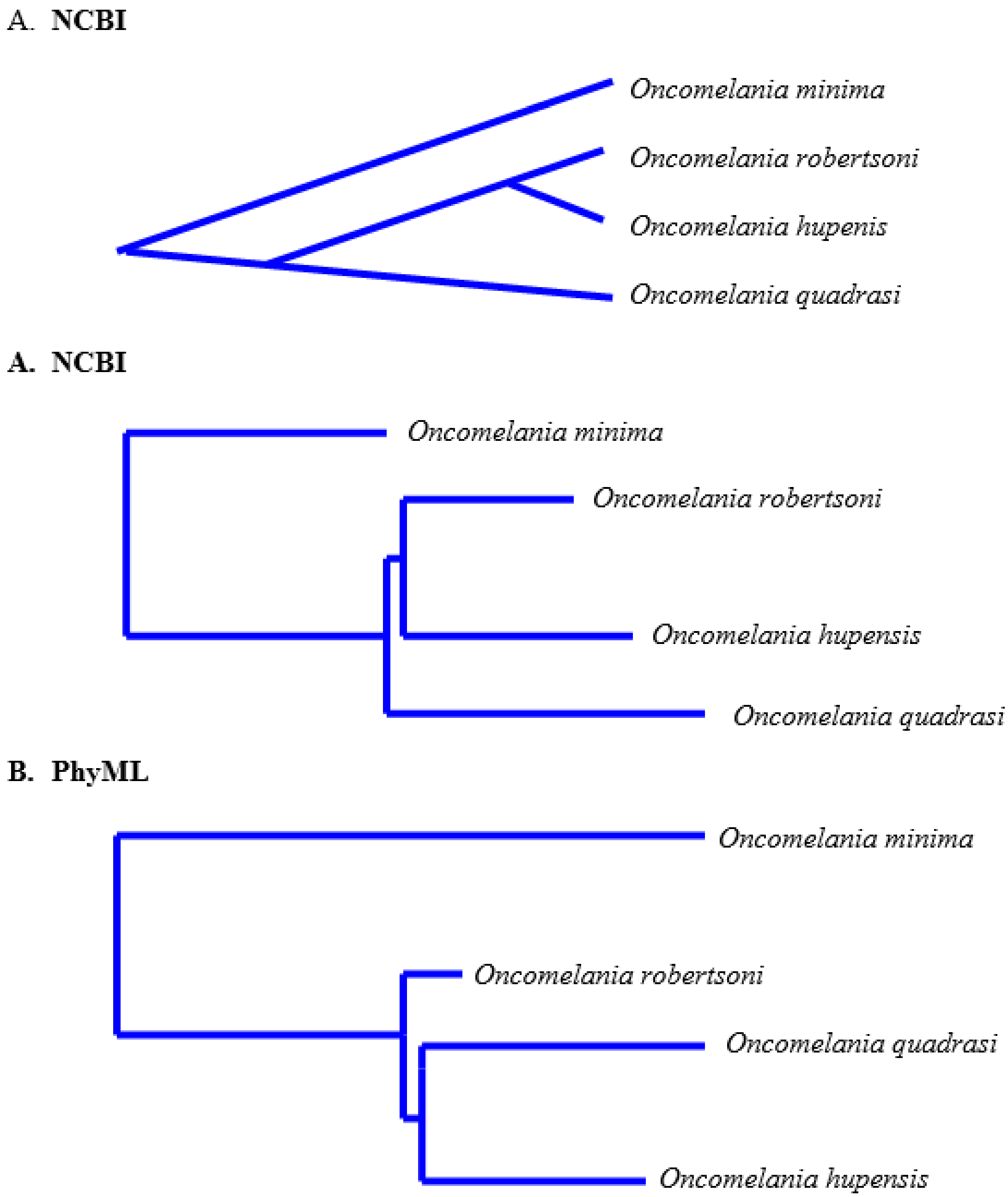

Figure 2

Blast for trees view. A. NCBI slanted cladogram (modified from NCBI alignment.) **B.** NCBI rectangle cladogram (modified from NCBI.) **C.** PhyML rectangle cladogram (modified from ETE3.) All show relatedness of *Oncomelania.* Figure B and Figure C show branch lengths of each species in the genus *Oncomelania.*

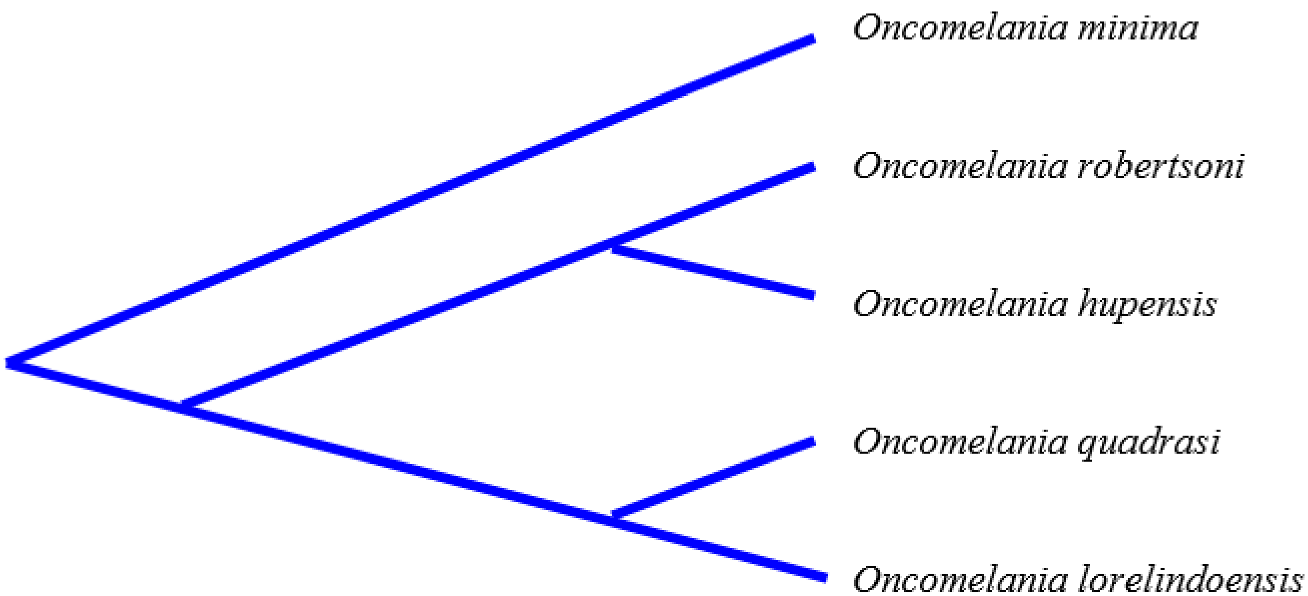

Figure 3

All species in the genus *Oncomelania.* It includes East Asia *Oncomelania* and Southeast Asia *Oncomelania.* East Asia *Oncomelania* includes *Oncomelania hupensis, O. minima,* and *O. robertsoni.* Southeast Asia *Oncomelania* includes *O. lorelindoensis* and *O. quadrasi.*