Gastropod fauna in key habitats surrounding Lake Mainit, Philippines with notes on snail-associated diseases

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Abstract. Lake Mainit is the deepest lake in the Philippines. Nonetheless, cases of schistosomiasis were also reported in several communities surrounding the lake adding to concern to the tourism in the area. This gastropod survey was conducted in ten barangays surrounding Lake Mainit to provide an inventory of gastropods and their possible preference to habitats surrounding the lake. Collection of samples was done monthly from February to November 2014. A total of fifteen gastropod species from nine families were identified, with four species endemic to the country. Of these species, only one, *Vivipara angularis*, was utilized for food, and is collected abundantly in the lake. Other species were either considered agricultural pests (*Ampullaria luzonica, Pomacea luzonica*) while others were known vectors of zoonotic diseases such as *Oncomelania hupensis quadrasi, Melanoides tuberculata,* and *Radix rubiginosa*. Notably, known vectors of schistosomiasis were found in rice fields and creeks but not in the lakeshore study stations. This study is the first documentation of gastropods in five habitats surrounding Lake Mainit and will be helpful as baseline data for researches on snail-associated zoonotic diseases in this area.

Key Words: schistosomiasis, zoonosis, diversity, Caraga region.

Introduction. Lake Mainit is the fourth largest lake in the Philippines, and the deepest in the country (LMDA 2005). Twenty-eight river tributaries contribute to the lake and flows into Butuan Bay (De Guzman et al 2008). The lake is divided almost equally shared between the provinces of Agusan del Norte and Surigao del Norte in Northeastern Mindanao. The lake is known in the region for its rich fish resources. About 31 barangays in the four-lakeshore municipalities are dependent on the lake for food and livelihood (LMDA 2005). There are various points around the lake with potential tourist attractions. Nonetheless, persistent reports of schistosomiasis cases of some residents near the lake communities have hampered the lake tourism and economy in general (LMDA 2010). *Schistosoma japonicum* was reported to be endemic in Lake Mainit as early as 1947 (Pesigan 1947). Over the years, studies has continuously confirmed transmission of the disease in areas surrounding the lake at different prevalence rates (Cassion et al 2013; DOH 2004a,b).

Early studies on the ecology of the lake reported a high diversity of aquatic fauna, most especially on the aspect of fisheries (Galicia & Lopez 2000). De Guzman et al (2008) described biodiversity and fisheries in the lake and has identified declining fish catch, declining quality of lake water and resource use conflicts as major concerns of lakeshore communities. A preliminary list of aquatic invertebrates from the lake was reported; however, nearby habitats surrounding the lake was not explored.

This study aimed to conduct a gastropod survey in 10 lakeshore barangays of Lake Mainit with noted prevalence of schistosomiasis. Identification of the snails was performed up to the lowest possible taxon. Information from this study would be vital for updates on the resource utilization of gastropods in the different habitats surrounding the lake as well as provide information on the possible diseases associated with these gastropods.

Material and Method

Establishment of study stations. The study was conducted in 10 lakeshore barangays surrounding Lake Mainit (Figure 1) particularly Barangay Poblacion and Barangay Cuyago (Jabonga, Agusan del Norte); Brgy Poblacion (Kitcharao, Agusan del Norte), Barangay Poblacion, Barangay Alipao, Barangay Gamuton (Alegria, Surigao del Norte) and Barangay San Isidro, Barangay Magpayang, Barangay San Francisco, Barangay Matin-ao (Mainit, Surigao del Norte). These lakeshore barangays were chosen based on reported cases of schistosomiasis from stool data from municipal rural health units. Study stations for each lakeshore barangay were selected on the basis of preliminary field observations for water contact points for bathing, washing clothes, swimming and play (for young children) or work (fishing). The sites were also chosen based on pre-identified sites with snails, accessibility, and reported positive cases of schistosomiasis. Sampling sites for each lakeshore barangay utilized representative common habitats of snails: (1) Rice fields nearest lakeshore; (2) Moist/damp areas nearest lakeshore; (3) Riverbanks/ creeks nearest lakeshore; (4) Residential areas/houses nearest lakeshore.

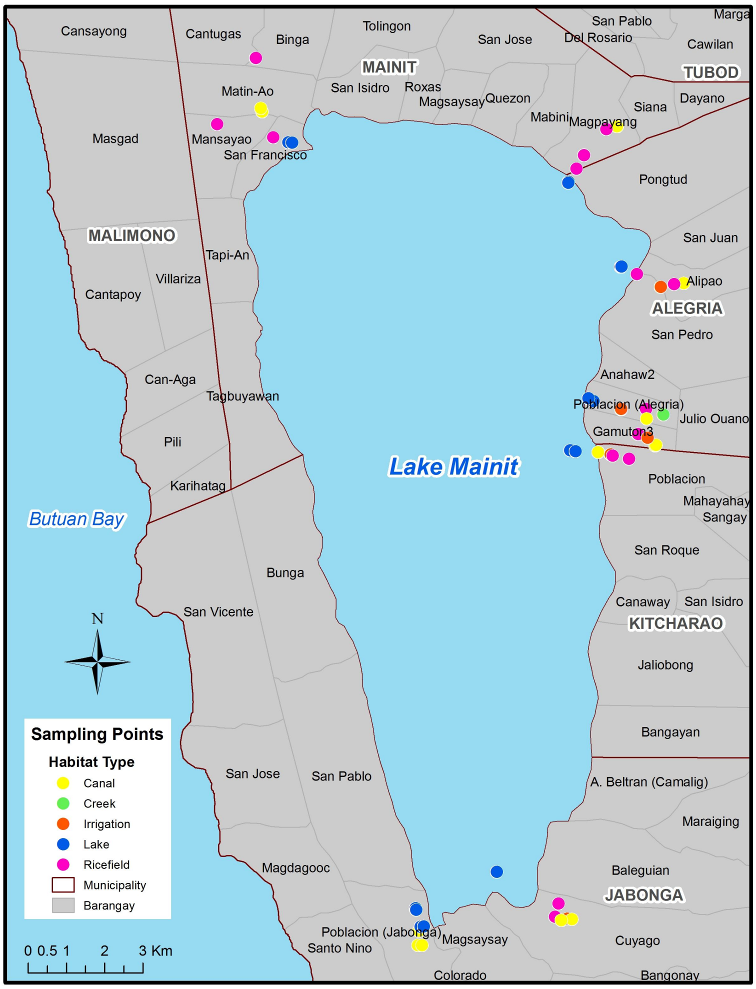

Figure 1. Map of Lake Mainit with identified stations for the study (original).

Within each site, a belt transect was established. The main transect was 50 m in length with a 1 m line perpendicular on both sides of the main transect. The total area covered by the belt transect was 100 m^2. Sampling stations were not repeatedly utilized for the monthly snail collection to avoid bias in determining for abundance/density. The geographical locations of all sampling sites were taken with the geographical position satellite, model GARMIN GPS 72.

Collection of snails. Collection of snails was done for 10 months (February 2014-November 2014). Snail sampling was carried out using standard snail scoops or occasionally, by hand collection throughout the entire sampling period. Sampling time was fixed at 30 minutes per location and was performed between 6:00 am to 10:30 am. All snails collected were placed in individual vials before transporting to the laboratory.

Biodiversity attributes. Indices of biodiversity such as Species Richness, Abundance, Dominance, Evenness and Shannon's Diversity were computed using PAST® software.

Statistical analysis. Data on abundance were checked for normality if applicable, log transformation was performed. Univariate statistical techniques were used to analyze spatial and temporal variations in snail abundance. One-way Analysis of Variance was used to compare differences between sites and seasons. P-values <0.05 was considered statistically significant. The multivariate statistical procedure was employed to explore the data. Data on abundance were fourth-root transformed to reduce the influence of dominant species. Morisita index of similarity was utilized. The resulting matrices were used to conduct cluster analysis and non-metric multidimensional scaling (nMDS). The data on biodiversity indices were overlaid in the resulting ordination of the transformed values. Software such as GraphPad Prism for univariate statistics and PRIMER6 for biodiversity indices and multivariate analysis were used.

Results and Discussion

Snail species, composition, and characteristics. A total of 344,476 freshwater snail individuals represented by 15 species were collected from 42 sampling sites within the ten key lakeshore barangays surrounding Lake Mainit (Table 1). Among these snail species, four were endemic in the Philippines (*Pomacea luzonica, Ampullaria luzonica, Jagora dactylus* and *Vivipara angularis*, while the rest of the 11 species considered as introduced and non-native to the Philippines. From these species, *A. luzonica* was the most abundant (n=89, 429) followed by *P. luzonica* (n=74, 729) and *Tarebia granifera* (n=31, 669). Some of these snail species were economically important (Table 2). *V. angularis* locally known as "igi" is widely used as food and highly sold on the market, while *P. luzonica*, and *A. luzonica* were considered as agricultural pests (Burela & Martin 2011; Anderson 1993). Other species like *T. granifera, Melanoides maculata, Melanoides tuberculata, Gyraulus* sp., *Bithynia* sp., *Bullastra cumingiana*, *Thiara scabra, Radix rubiginosa, Radix auricularia, Biomphalaria* sp., and *Oncomelania hupensis quadrasi* were known vectors for zoonotic diseases that naturally infect animals and humans and cause health complications and illnesses (Chaniotis et al 1980; Fernandez et al 2014; Dung et al 2013; Appleton et al 2009; Cassion et al 2013). De Guzman et al (2008) provided a preliminary list of aquatic invertebrates from the lake which included 6 univalves, however, no studies have been conducted to determine actual parasites associated with these snails from Lake Mainit. This study has reported 15 gastropod species, 9 species more than previously reported (De Guzman et al 2008) perhaps because of the bigger scope of habitat coverage.

V. angularis is popularly known as "igi" in Lake Mainit and is sold in large quantities in the markets as a delicacy of locals, or as feed for fishponds (De Guzman et al 2008). However, *V. angularis* was known also as a natural vector for the trematode *Euparyphium paramunirum* (Velasquez 1964). *Biomphalaria* and *Oncomelania* are known in the Philippines to harbour cercariae of *Schistosoma* trematodes. However, literature review would show that several of the collected gastropods (i.e. *T. granifera, M. maculata, M. tuberculata, R. auricularia*) in the present study were already reported to harbour schistosomes in other countries.

Table 1

Inventory of gastropods in Lake Mainit, Philippines and their economical and medicinal importance

Scientific name	*Rice fields*	*Creeks*	*Lakes*	*Canals near houses*	*Irrigation sources*	*Economic and medicinal importance*
Ampullariidae						
Ampullaria luzonica, Reeeve	+	+	+	+	+	Agricultural pest
Pomacea luzonica, Reeve	+	+	+	-	+	Agricultural pest
Bithyniidae						
Bithynia sp.	+	+	+	+	+	vector for zoonotic diseases*
Lymnaeidae						
Bullastra cumingiana, Pfeiffer	-	+	-	+	+	vector for zoonotic diseases*
Radix rubiginosa, Michelin 1831	+	+	+	+	+	Vector for schistosomiasis
Radix auricularia, Linnæus 1758	+	+	+	+	+	Vector for schistosomiasis
Pachychilidae						
Jagora dactylus Lea & Lea, 1850	+	+	+	+	+	vector for zoonotic diseases
Planorbidae						
Biomphalaria sp.	+	+	+	+	+	Vector for schistosomiasis
Pomatiopsidae						
Oncomelania sp. *hupensis-quadrasi* Möllendorff, 1895	+	+	-	+	+	Vector for schistosomiasis
Planorbidae						
Gyraulus sp.	+	+	-	+	+	Vector for zoonotic diseases*
Thiaridae						
Melanoides maculata Born, 1780	+	+	+	+	+	Vector for zoonotic diseases*
Melanoides tuberculata Müller, 1774	+	+	+	+	+	Vector for zoonotic diseases*
Tarebia granifera Lamarck, 1816	+	+	+	+	+	Vector for zoonotic diseases*
Thiara scabra Müller, 1774	+	+	+	+	+	Vector for zoonotic diseases*
Viviparidae						
Vivipara angularis, Muller	+	+	+	-	+	Used as food; Known vector for zoonotic diseases*

*including schistosomiasis.

Table 2

Total number of snails in 5 habitats surrounding Lake Mainit, Philippines

Species	Present study (2014)						De Guzman et al 2008
	Rice fields	Creeks	Lakes	Canals-Res	Irrigation sources	Total	
Ampularia luzonica	9747	10951	9419	53892	5420	89429[1]	+
Vivipara angularis	32	58	1094	0	27	1211	+
Biomphalaria sp.	118	1436	193	375	11	2133	-
Bithynia sp.	1017	736	18	35	838	2644	-
Bullastra cumingiana	0	187	0	282	333	802	-
Gyraulus sp.	1367	842	0	1542	2878	6629	-
Jagora dactylus	5040	5451	3754	6722	2596	23563	-
Melanoides maculata	7385	7621	4097	6903	4861	30867	+
Melanoides tuberculata	2111	1009	6334	2650	1377	13481	-
Oncomelania hupensis quadrasi	1043	41	0	1214	318	2616	-
Pomacea luzonica	9822	10320	6052	44797	3738	74729[2]	+
Radix auricularia	3058	5593	5860	4170	3582	22263	--
Radix rubiginosa	10627	4181	3298	6075	6807	30988	-
Tarebia granifera	7634	7398	5156	9395	2086	31669[3]	-
Thiara scabra	977	2115	1469	4386	1882	10829	-

Species accumulation plot. The species accumulation plot graphs the cumulative counts of species abundance against the number of samples conducted. The plot shows that the total number of samples in the different sampling areas are adequate (Figure 2).

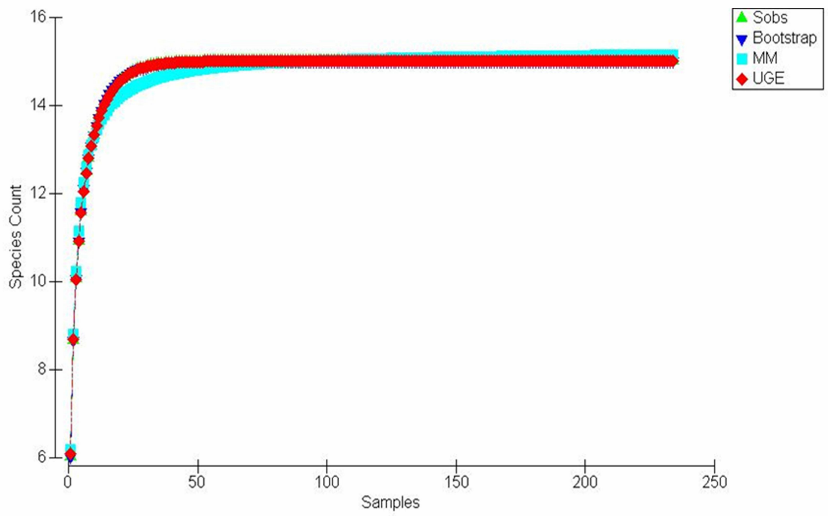

Figure 2. Species accumulation curve of gastropods collected in study stations surrounding Lake Mainit, Philippines. Sobs- Species observed, MM-Michaeles Menten, UGE- Ugland, Gray & Elingsen index.

Snails were most abundant in number in canals near residential houses (Table 3). Snails were least abundant near irrigation sources. Summary on the number of snails per habitat indicate that several species are specifically found in distinct habitats (Figure 3).

Table 3.1.

Diversity indices of gastropods in rice fields nearest Lake Mainit, Philippines

Indices	*San Isidro*	*San Francisco*	*Matin-ao*	*Magpayang*	*Kitcharao*	*Alegria*	*Jabonga*	*Gamuton*	*Cuyago*	*Alipao*
Taxa	6.33	7	6.83	6.83	6.83	9	6	6	6	6
Dominance	0.22	0.26	0.22	0.23	0.21	0.164	0.2592	0.2987	0.2819	0.2392
Simpson	0.77	0.73	0.77	0.76	0.78	0.836	0.7908	0.7013	0.7181	0.7608
Shannon	1.61	1.54	1.63	1.61	1.67	1.909	1.544	1.406	1.521	1.564
Evenness	0.82	0.68	0.77	0.75	0.8	0.7499	0.7861	0.6803	0.7631	0.7961
Individuals	3722	7344	5335	7832	11,779	11, 827	4425	3422	4211	2356

Table 3.2.

Diversity indices of gastropods in creeks nearest Lake Mainit, Philippines

Indices	*San Isidro*	*San Francisco*	*Matin-ao*	*Magpayang*	*Kitcharao*	*Alegria*	*Jabonga*	*Gamuton*	*Cuyago*	*Alipao*
Taxa	4.83	7	8.33	6	8	8	7	4	6	6
Dominance	0.33	0.24	0.22	0.31	0.18	0.1963	0.2083	0.264	0.212	0.202
Simpson	0.66	0.75	0.77	0.68	0.81	0.8037	0.7917	0.736	0.768	0.798
Shannon	1.28	1.59	1.73	1.35	1.82	1.785	1.709	1.357	1.573	1.673
Evenness	0.78	0.71	0.69	0.65	0.81	0.7453	0.7888	0.9709	0.8681	0.8881
Individuals	6366	8055	7303	14395	5010	5017	596	6695	4995	2694

Table 3.3.

Diversity indices of gastropods in canals near residential areas nearest Lake Mainit, Philippines

Indices	*San Isidro*	*San Francisco*	*Matin-ao*	*Magpayang*	*Kitcharao*	*Alegria*	*Jabonga*	*Gamuton*	*Cuyago*	*Alipao*
Taxa	9.16	8.16	6.33	8	7.16	8	7	4	6	6
Dominance	0.17	0.17	0.29	0.1363	0.3	0.1963	0.2083	0.264	0.1867	0.2149
Simpson	0.82	0.82	0.7	0.8027	0.69	0.8037	0.7917	0.736	0.8133	0.7851
Shannon	1.87	1.9	1.5	1.685	1.48	1.785	1.709	1.357	1.73	1.661
Evenness	0.73	0.83	0.74	0.7453	0.64	0.7453	0.7888	0.9709	0.9402	0.8778
Individuals	17713	16204	10,728	5494	8133	5494	5583	1889	2456	1956

Table 3.4.

Diversity indices of gastropods in the shoreline of Lake Mainit, Philippines

Indices	*San Isidro*	*San Francisco*	*Matin-ao*	*Magpayang*	*Kitcharao*	*Alegria*	*Jabonga*	*Alipao*	*Cuyago*	*Gamuton*
Taxa	5	7.16	5.66	6.16	6.66	7	5	6	6	5
Dominance	0.24	0.2	0.23	0.31	0.29	0.2356	0.2768	0.1875	0.3	0.3768
Simpson	0.75	0.79	0.76	0.68	0.7	0.7644	0.7232	0.8125	0.72	0.8232
Shannon	1.5	1.71	1.57	1.41	1.5	1.635	1.416	1.724	1.43	1.436
Evenness	0.9	0.78	0.88	0.71	0.7	0.7328	0.8245	0.9341	0.73	0.8445
Individuals	19296	18,332	2220	8017	7869	4030	2113	2440	3321	2413

Table 3.5.

Diversity indices of gastropods in irrigation sources nearest Lake Mainit, Philippines

Indices	*San Isidro*	*San Francisco*	*Matin-ao*	*Magpayang*	*Kitcharao*	*Alegria*	*Jabonga*	*Alipao*	*Gamuton*	*Cuyago*
Taxa	7.5	8.16	6.33	7.3	7.16	8	7	6	8	7
Dominance	0.32	0.17	0.29	0.33	0.3	0.1543	0.2083	0.4331	0.1937	0.1837
Simpson	0.67	0.82	0.7	0.66	0.69	0.8457	0.7917	0.5669	0.8063	0.7063
Shannon	1.46	1.9	1.5	1.48	1.48	1.96	1.709	1.176	1.876	1.776
Evenness	0.61	0.83	0.74	0.62	0.64	0.8872	0.7888	0.5404	0.8157	0.8257
Individuals	8901	5411	3221	6901	442	4802	3321	4901	4111	6880

For example, *V. angularis* can be found abundantly in lakes, it can also be found in rice fields and creeks but in very few numbers. Nonetheless, this species was not observed in canals near residential areas. *B. cumingiana* was consistently not observed in rice fields and lakes. *Gyraulus* sp., and *O. hupensis quadrasi* two reported vector genera of schistosomiasis were not observed in the lakeshore. *Biomphalaria* sp., is an another reported vector was common for all the five habitats of the study but is few in numbers.

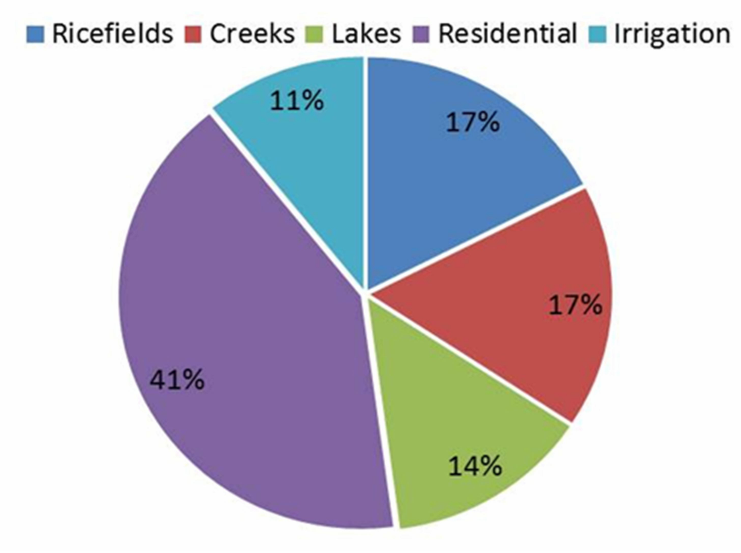

Figure 3. Percent (%) composition of snails from 5 habitats surrounding Lake Mainit.

Distribution and diversity. Multivariate analyses (Figure 4 and 5) show the similarities in the distribution and population of snail species. *B. cumingiana* was shown to be distinctly clustered from the rest of the snail species due to its small number of specimens collected throughout the study period. This snail also prefers shaded habitats (creeks, canals, irrigation sources) compared to areas that are exposed to direct sunlight with ample, steady supply of water (i.e. lakes and rice fields). *P. luzonica* and *A. luzonica* obtained a high index of similarity due to its overall high density of population. Several species are clustered together closely *R. rubiginosa, T. scabra, R. auricularia, M. maculata, T. granifera* and *J. dactylus* due to its presence in all five habitats in significant populations. *M. tuberculata* and *V. angularis* were clustered together due to its high populations along the lakeshore compared to the other four habitats. Interestingly, reported vector genera of schistosomiasis (*Bithynia* sp., *Gyraulus* sp., *Oncomelania quadrasi*, and *Biomphalaria* sp) were clustered together due to their “low” or “0” densities in the lakeshore compared to the other habitat types.

A number of snail species in the rice fields range from 6 as lowest (Jabonga, Ganuton, Cuyago, Alipao) to 9 as highest (Poblacion Alegria). The population of rice field gastropods was also highest in Alegria and Kitcharao. *R. rubiginosa*, *P. luzonica* and *A. luzonica* were the most abundant snails, while *V. angularis* was the least observed species in the rice fields (Tables 3.1-3.5). A number of species in creeks range from 4-8, with the highest population of snails observed in a creek in Magpayang. The population gastropods near creeks and canals near residential areas were dominated by *A. luzonica* and *P. luzonica*. Gastropods in the lakeshore had the least number of species composition with *B. cumingiana, Gyraulus* sp. and *Oncomelania* sp. conspicuously absent. *V. angularis* was observed in its highest number in the lake compared to the other habitats. However, the lakeshore population was also dominated by *A. luzonica* and *P. luzonica*. Irrigation sources had the least population of gastropods compared to the other habitats. However, the population was dominated by *R. rubiginosa, A. luzonica* and *M. maculata*. *R. rubiginosa* dominated the rice field habitat in all sampling period except in the month of August because the rice field was dry due to the post rice harvest activity. *A. luzonica* and *P. luzonica* dominated the residential habitat in all sampling period.

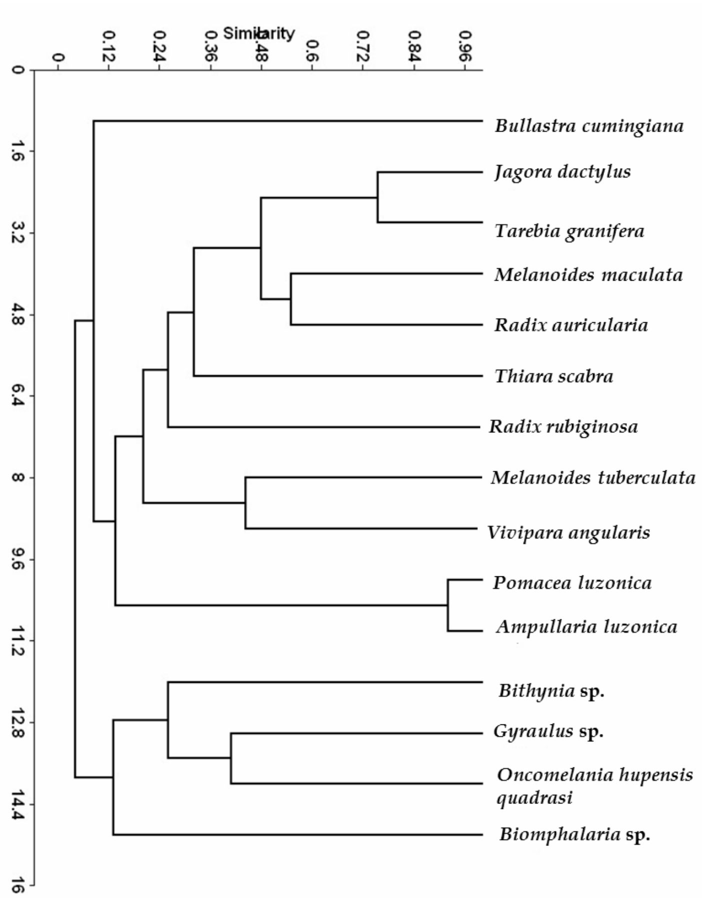

Figure 4. Morisita Index of similarity of gastropods across study stations in Lake Mainit.

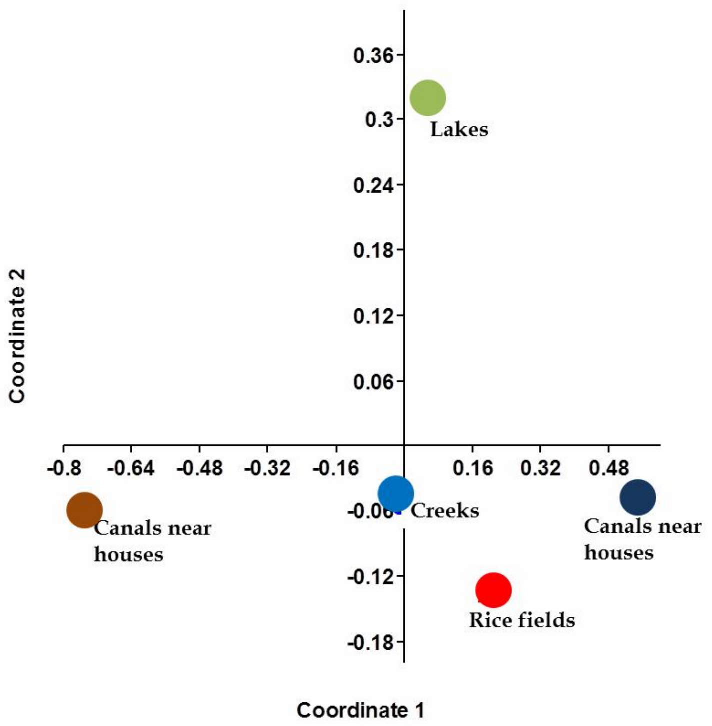

Figure 5. PCA of gastropods in Lake Mainit in different habitats.

Generally, *A. luzonica* are commonly found in creeks and rice fields, where they are considered pests, but some also prey on them (Moorman et al 2008). *Bithynia* species prefer in slow moving muddy rivers, artificial and natural ponds, lakes, irrigation canals and swamps (Petney et al 2011). *Radix* species air-breathing are pulmonates and prefer to live in creeks, rice fields, moist and damp places. Distribution of *J. dactylus* was initially reported to be restricted in Bohol, Cebu and Guimaras Island (Köhler & Glaubrecht 2003). *Biomphalaria* species can live under water and cannot survive elsewhere. *Oncomelania* species can live both in and out of water in humid areas such as canals of irrigation systems, swamps as vegetation is important in maintaining a suitable temperature and humidity. *Oncomelania* feed on plant surfaces above water other than the usual food sources of typical aquatic snails (WHO 1995). It should be noted however that despite prevalence of schistosomiasis in many areas surrounding the lake, only very little number of *Oncomelania* and *Biomphalaria* were collected during the 10-month collection period.

No clear pattern of similarity or trend was observed in the density of population of snail species across months of the study and in the barangays (Figure 6 a,b). However, the population of snails was seen decreased during the months of May and June 2014 in the rice fields, probably due to the relatively drier soil in the rice fields during the harvest season. San Isidro and San Francisco canals and lakeshore study stations had the highest snail density compared to other stations. From observation of these notable habitats, there is ample slow-flowing or stagnant water source, and the vegetation is enough. Food and shade were also available and conducive to the growth and reproduction of snails. Snails collected from Cuyago, Alipao, Gamuton, Jabonga, and Alegria were dispersed probably due to its lower number of individuals among the habitats studied. It should be noted, however, that insurgencies in the months of July, September and November 2014 in many areas covered by our study resulted in gaps in the period of collection. Collection of samples during January and December 2014 was not feasible and safe with constant rain in Lake Mainit. The majority of the study stations in the lakeshore, rice fields, and irrigation sources were also flooded and inaccessible during these months. A pattern of similarity of snail population, however, less, can be observed in the 5 habitats of the study (Figure 6c) due to consistent domination of certain snail species and conspicuous absence of certain species in certain habitats.

This study is the first comprehensive report on the gastropod fauna in Lake Mainit, Philippines. The inventory of gastropods in this study would serve as a benchmark reference for gastropod research in this area especially on habitat preferences of some snail species. Laboratory studies regarding parasites associated with the gastropods in the area could shed light on the host-parasite relationships and the potential risk of exposure to certain habitats for trematode diseases particularly schistosomiasis.

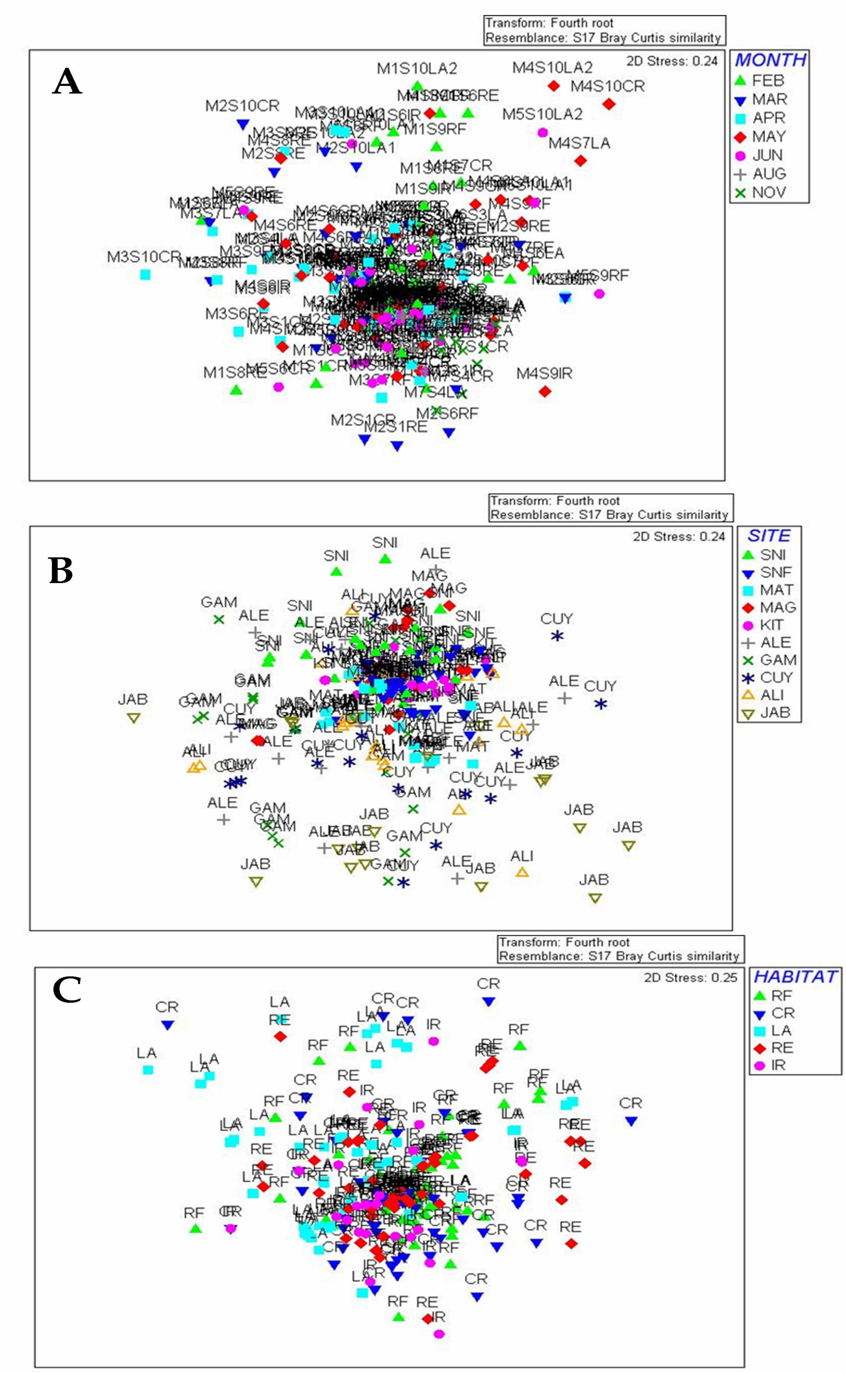

Figure 6. Non-metric multidimensional scaling of gastropods (A) across months, (B) barangays and (C) habitats. (SNI - San Isidro; SNF - San Francisco; MAT - Matin-ao; MAG - Magpayang; KIT - Kitcharao; ALE - Alegria; GAM - Gamuton; CUY - Cuyago; ALI - Alipao; JAB - Jabonga; RF - Rice fields; CR - creeks, LA - Lakes; RE - residential areas/canals; IR - irrigation).

Conclusions. The results of the study provided an in-depth account of gastropods from five lakeshore habitats surrounding Lake Mainit where a total of 15 gastropod species from 9 families were identified. This study is the first documentation of gastropods in five habitats surrounding Lake Mainit and will be helpful as baseline data for researches on snail-associated zoonotic diseases in Lake Mainit. From these species, several were known vectors of zoonotic diseases such as *O. hupensis-quadrasi, M. tuberculata*, and *R. rubiginosa*. Nonetheless, known snail vectors of schistosomiasis were found in rice fields and creeks but not in the lakeshore study stations. It is recommended that future studies should explore the determination of actual trematode parasites inhabiting snails, especially in ricefields and creeks, as well as trematodes from bovines (carabao and cattle) to better understand the pathway of zoonosis in these habitats.

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