

Research Article

DIVERSITY AND RELATIONSHIP BETWEEN WATER BUGS (HEMIPTERA) AND WATER BEETLES (COLEOPTERA) IN DIFFERENT HABITATS AT SOME NATIONAL PARKS IN NORTH VIETNAM

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ABSTRACT

The research on water insect biodiversity (Hemiptera, Coleoptera) in Vietnam was very limited and mainly focused on taxonomy. In this study, the diversity index and relationships between the number of individuals of water bugs (Hemiptera) and water beetles (Coleoptera) in primary forest habitats, secondary forest habitats, agricultural crop habitats and shrub habitats in Ba Be National Park, Bac Kan Province, Vu Quang National Park, Ha Tinh Province, Hoang Lien National Park, Lao Cai, Lai Chau Provinces were studied and evaluated. From 75 sampling sites in four habitats in three National Park were collected 1892 individuals of the water bugs (Hemiptera) and water beetles (Coleoptera) representing 73 species of 48 genera of 14 families. Among them, 42 species of water bugs (Hemiptera) with 27 genera of 10 families, 31 species of water beetles (Coleoptera) with 21 genera of 4 families. The number of species in the family Nepidae, Gerridae (Hemiptera), Dytiscidae, Hydrophilidae (Coleoptera) were highest in secondary forest habitats, shrub habitats and lowest in agricultural crop habitats, shrub habitats. The diversity index (Dominance_D, Simpson_1-D, Shannon_H, Evenness_e^H/S, Brillouin, Menhinick, Margalef, Equitability_J, Fisher_alpha, Berger-Parker, Chao-1) in different habitats did differ between water bugs (Hemiptera) and water beetles (Coleoptera). The Simpson_1-D, Shannon_H, Margalef indexes of water bugs (Hemiptera) have value in primary forest habitat > secondary forest habitat > agricultural crop habitats > shrub habitats. Meanwhile, water beetles (Coleoptera) have value in agricultural crop habitats > shrub habitats > secondary forest habitats > primary forest habitats. The relationship between the number of individuals of water bugs (Hemiptera) and water beetles (Coleoptera) in different habitats in three National Parks was weak and different. In primary forest habitats, this relationship showed a positive, weak correlation. The analysis model species packing in the primary forest habitat was a parabolic curve with a downward concavity, showing the co-increase and co-decrease of water bugs and water beetles. In secondary forest habitats, this relationship showed a positive, very weak correlation. The analysis model species packing in the secondary forest habitats was a curve, showing the co-increase of water bugs and water beetles. In agricultural crop habitats and shrub habitats, the relationship showed a negative, very weak correlation. The analysis model species packing in the agricultural crop habitats and shrub habitats is a straight line and did not show the contrasting increase and decrease of water beetles and water beetles.

Keywords: water bugs, water beetles, Hemiptera, Coleoptera, diversity index, forest, agricultural crop, shrub, habitats.

INTRODUCTION

The water insects of the order Hemiptera, Coleoptera are an integral part of food chains and nutrient cycling in freshwater ecosystems, and they are essential components of the diets of fish, amphibians, and many birds and mammals (Morse, 2017) and their abundance and response to changes in environment make water insects of the order Hemiptera, Coleoptera a key indicator for monitoring the impact of human activities on water quality (Adu & Oyeniya, 2019) and they are widely used for monitoring freshwater ecosystems (Souto *et al.*, 2019). Ecological variation combined with repeated, parallel transitions (adult, larval, or both) has placed water insects as a leading research group for questions related to evolution. Dispersal, ecological species formation, and diversification rate. The water insects are an integral part of any aquatic or wetland ecosystem, serving as indicators of ecological diversity and habitat characteristics (Kaghani *et al.*, 2022).

There are about 18,000 water beetles species of Coleoptera on Earth today, and at least 50% of species of 30 families are considered to be

entirely aquatic. Of these, the Oriental (2,200 described species/3,580 estimated) and the Australian/Pacific Realm (1,340/2,100), the Nearctic (1,420/1,550) are by far the poorest region in terms of water beetle diversity (Jäch & Balke, 2008). The water bugs species of order Hemiptera were started by the studies of Damgaard (2008), Chen *et al.*, (2008) which comprised 23 families and more than 5000 species of 350 genera, making it the most diverse group of hemimetabolous insects (Henry, 2009). The survey was conducted in 6 different habitats in the Lonjsko Polje Nature Park and found that in total 341 Coleoptera specimens belonging to 29 species (Hydradephaga) were collected. The highest species richness was recorded in Habitats 3, with 15 species (Joanna *et al.*, 2016). A study of the influence of ponds on the water bug community in Saxony, Germany, recorded 40 water bug species found in most ponds. Species of the Corixidae and Notonectidae (Hemiptera) families act as pioneer species in new and old ponds. Canonical correspondence analysis (CCA) showed that among the main factors influencing the structure of water bugs of the families Corixidae and Notonectidae were soil, vegetation, pesticides and age of the ponds. The distribution of adjacent ponds in areas with different land uses positively influences the diversity and abundance of Hemiptera water bug populations (Armin *et al.*, 2010).

A study conducted in the Ganges River recorded 29 aquatic insect species, including three Coleoptera species belonging to two families,

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four Hemiptera species belonging to four families, and 22 Odonata species belonging to three families at 14 sampling sites. Shannon diversity index, Pielou evenness index (J'), and Berger-Parker dominance index were recorded. Gerridae dominated at >92% of sampling sites and Notonectidae at >28% of sampling sites (De *et al.*, 2021). Renato *et al.*, (2019) evaluated the relationship between Hemiptera and Coleoptera diversity and habitat type, altitude, and forest extent in the Los Tuxtlas rainforest and found that Hemiptera and Coleoptera species richness and abundance were significantly higher in forests than in grasslands. A study of the diversity, distribution and habitat relationships of water beetles in Kampong Speu Province, Cambodia showed that with 152 individuals representing 22 species, 10 genera and 9 families, the Scirtidae family was the most abundant in the 10 sampling sites. Analysis of individual proportions showed that some families differed in their relationship of individual proportions to their habitat. The Scirtidae family were positively associated with primary forest habitat and shrub habitats, but negatively associated with agricultural crop habitats. The Limnichidae family were positively associated with elevation and erosion, while the Dytiscidae family were positively associated with streambeds characterized by small stones, but negatively associated with water depth and streambeds characterized by large stones (Doeurk *et al.*, 2022). The diversity and abundance of water beetles at five different sites in the Kolkas region of India were studied. The diversity index showed that site forest habitats were the richest (11 species), followed by agricultural crop habitats and shrub habitats (10 species each), secondary forests (9 species). The richness ranking showed that site shrub habitats had fewer rare species and more common species than the other sites (Vaibhao *et al.*, 2011).

In Vietnam, research on the diversity of water insects (Hemiptera, Coleoptera) is still scarce and limited. The studies on the water insects in tropical ecosystems have mainly focused on taxonomy (Truong *et al.*, 2023). Sato (1972) listed the species composition and recorded 6 species of the Noteridae family (Coleoptera) in the provinces of Lao Cai, Bac Kan, Tuyen Quang, Nghe An, Quang Ngai, Kon Tum, Hoa Binh, Quang Tri, Ninh Thuan, Dak Lak, Gia Lai, Lam Dong. The water beetle fauna in Hanoi is a typical lowland fauna in mainland Southeast Asia, including many species with a wide distribution range (Tran Anh Duc *et al.*, 2010). In some streams in Ha Giang Province, a total of 44 species of Hemiptera were recorded, belonging to 32 genera of 16 families (Tran Anh Duc *et al.*, 2016). Research on water insects conducted at Cuc Phuong National Park, Ninh Binh Province, Ba Be National Park, Nam Xuan Lac Species and Habitat Conservation Area, Bac Kan Province, Vu Quang, Ha Tinh Province showed that at the research sites, 19 species belonging to 11 genera in 3 families of water beetles were recorded in both undisturbed and disturbed ecosystems. The protected undisturbed ecosystem had relatively high Margalef (d) and Shannon - Weiner (H') diversity coefficients, $d = 2.23-3.87$ (good diversity) and $H' = 2.15-3.85$ (medium diversity), respectively. Six indicator species of undisturbed aquatic ecosystems were recorded at the study sites. 30 species of water bugs of Hemiptera with 25 genera in 10 families were recorded, the Margalef index (d) in Ninh Binh, Bac Kan has a rich diversity, Gia Lai has normal diversity. Shannon - Weiner index (H') in Ninh Binh has average diversity. Bac Kan has average diversity and Gia Lai has low diversity. Some species of water bugs and water beetles are biological indicators for ponds, lakes, and swamps containing dirty water, and some other species are indicators for wetland ecosystems and natural streams containing clean (Lam *et al.*, 2022; Tran *et al.*, 2022; Truong *et al.*, 2023). Recently, Nguyen *et al.*, (2024) studied the genus *Cybister* Curtis, 1827 in Vietnam. All five species were diagnosed with illustrated morphology, legs and male genitalia. Additional measurement data and updated identification

keys for all species have been provided. Two species *Cybister convexus* Sharp, 1882 and *Cybister danxiaensis* Zhuo-Yin Jiang, 2023 were recorded for the first time in Vietnam. Vu Quang National Park is an Asian Heritage Park located in the area of 3 districts Vu Quang, Huong Khe and Huong Son with a total area assigned for management of over 56,646.9 hectares, of which 52,000 hectares are primary forest, the rest are protection forests, secondary forest, agricultural crop and shrub. Ba Be National Park is an Asean Heritage park that stretches over 10,048 ha and has many different ecosystems within its borders. The ground and surrounding mountains are made up mainly of limestone karst which is characteristic of the north of Vietnam, and the forests consist of mostly primary forests, the rest are protection forests, secondary forests with bamboo growing closer to banks of the lake and agricultural crops. In the heart of the Ba Be Asean Heritage Park is Ba Be Lake which is the largest and highest natural freshwater lake in Vietnam. The Hoang Lien National Park is an Asean Heritage park that stretches within an area of 28,509 hectares and comprises three zones primary forest, secondary forest and agricultural crop. It still retains a quite good amount of immense primaevial forest with diverse flora with 2,147 species and fauna with more than 1,500 species. That's why, in this study, diversity indices and relationships in the number of individuals of species between the water bugs (Hemiptera) and water beetles (Coleoptera) in different habitats including primary forest habitat, secondary forest habitat, Agricultural crop habitats and Shrub habitats (grasses, herbaceous plants and local plants...) in 3 ASEAN Heritage Park were studied and evaluated.

MATERIALS AND METHODS

Water insect surveys

The study was conducted at 75 sampling points in Ba Be National Park, Bac Kan Province (22°25' N; 105°37'E-22,417°N; 105,617°E), Vu Quang National Park (18°15'46.4" N; 105°27'47.7" E -18°33'06.5" N; 105°54'73.4" E), Ha Tinh Province, Hoang Lien National Park (22°07' N; 103°00' E -22°23' N; 104°00' E), Lao Cai, Lai Chau Provinces (Fig. 1). The sites were primary forest habitats (tropical rain forestor high mountain forest), secondary forest habitats, agricultural crop habitats (rice fields, low shrubs and weeds, or fructiculture fields...) and shrub habitats (grasses, herbs, and geophytes...). The middle elevations are between 91 m and 1850 m.

The water insects were sampled in May, June, and November 2021, January, and September 2022, January, August, and September 2023 and June 2024. During this period, each sampling point was sampled 10 samples. Sampling was carried out between 10 am and 6 pm, using a pond net with an area of net = 0.5 m² (180 cm long extension rod, mesh size 0.5 mm). For each sampling point, the pond net was swept about 10 times/1 sampling through the water, so that different vegetational units, substrates, the banks of ponds, streams, and water areas were covered. Sampling is carried out in both flowing water, still water, near the shore, around aquatic plants and on different types of bottom substrate. Use the net to sweep into places with substrates such as aquatic plants, tree branches, tree roots, leaves, etc.

All samples of Hemiptera and Coleoptera were preserved in 70% ethanol and brought to the laboratory for further analysis. They were later identified at the species level using a stereo-zoom microscope a Nikon SMZ 800N Digital Stereo Microscope, using Helicon Focus 7 software. The identification of water beetles according to Delève (1968), Brancucci (1983), Mazzoldi (1995), Jäch (1998, 2008), Jäch & Balke (2003), Komarek (2003), Grey & Kelly (2016); of water bugs according to Andersen *et al.*, (2002), Jansson (1986), Bal & Basu

(1994), Schuh & Slater (1995), Berend *et al.*, (2013), Lanna *et al.*, (2001), Zettel *et al.*, (2012), Zettel & Lane (2011), Lansbury (1968), Lansbury (1972), Polhemus & Polhemus (1998).

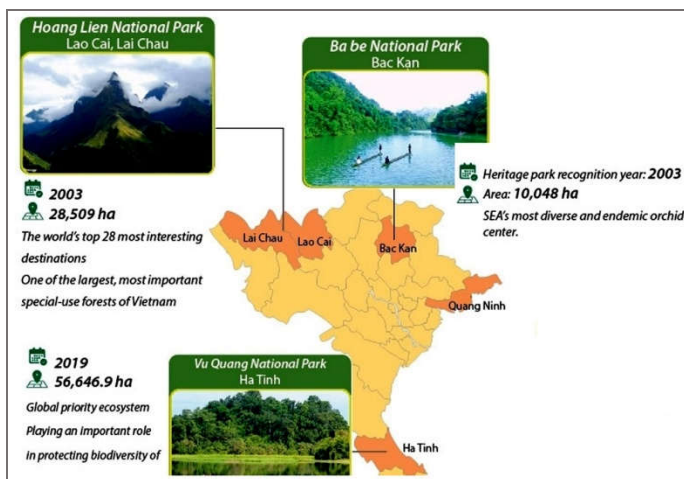


Figure 1. The National Parks in North Vietnam to study water bugs and water beetles

Data analysis

Biodiversity indexes including Dominance_D, Simpson_1-D, Shannon_H, Evenness_e^H/S, Brillouin, Menhinick, Margalef, Equitability_J, Fisher_alpha, Berger-Parker, Chao-1, mean of individuals, diversity index alpha, species richness, correlation number individual between bugs and water beetles were calculated using the software Fast 4.03.

RESULTS

The diversity of water insects (Hemiptera, Coleoptera) in different habitats

With 1892 individuals the water bugs (Hemiptera) and water beetles (Coleoptera) representing 73 species of 48 genera of 14 families (Appendix 1) were recorded. Among them, 42 species of water bugs (Hemiptera) with 27 genera of 10 families; 31 species of water beetles (Coleoptera) with 21 genera of 4 families. The most diverse Hemipteran families were family Gerridae with 8 species (19.04% of the total species water bugs with 40 individuals), family Nepidae with 8 species (19.04% of the total species water bugs with 35 individuals), family Naucoridae with 6 species (14.28% of the total species water bugs with 41 individuals), family Notonectidae with 5 species (11.90% of the total species water bugs with 21 individuals). The most diverse Coleopteran families were family Dytiscidae with 15 species (48.38% of the total species water beetles with 76 individuals), Hydrophilidae with 10 species (32.25% of the total species water beetles with 59 individuals), followed by Gyrinidae with 4 species (12.90% of the total species water beetles with 23 individuals).

The water bugs (Hemiptera) in Vu Quang National Park, the family Nepidae have the number of species in primary forest habitats> secondary forest habitats> agricultural crop habitats>shrub habitats; the family Gerridae has the number of species in primary forest habitats> secondary forest habitats> shrub habitats> agricultural crop habitats. The water beetles (Coleoptera) with the family Dytiscidae have a number of species in primary forest habitats> secondary forest habitats> shrub habitats> agricultural crop habitats; the family Hydrophilidae has a number of species in primary forest habitats> shrub habitats> secondary forest habitats> agricultural crop habitats

(Fig. 2A). In Hoang Lien National Park, the water bugs (Hemiptera) with family Nepidae has the number of species in secondary forest habitats> primary forest habitats> agricultural crop habitats> shrub habitats> primary forest habitats> secondary forest habitats> shrub habitats> agricultural crop habitats. The water beetles (Coleoptera) with the family Dytiscidae have a number of species in primary forest habitats> secondary forest habitats> shrub habitats> agricultural crop habitats; the family Hydrophilidae has a number of species in primary forest habitats> shrub habitats> agricultural crop habitats> secondary forest habitats (Fig. 2B). At Ba Be National Park, the water bugs (Hemiptera) with family Nepidae has the number of species in primary forest habitats> shrub habitats> agricultural crop habitats> secondary forest habitats> primary forest habitats> secondary forest habitats> agricultural crop habitats> shrub habitats. The water beetles (Coleoptera) with the family Dytiscidae have a number of species in agricultural crop habitats> primary forest habitats> secondary forest habitats> shrub habitats> primary forest habitats> secondary forest habitats> shrub habitats > primary forest habitats > agricultural crop habitats (Fig. 2C).

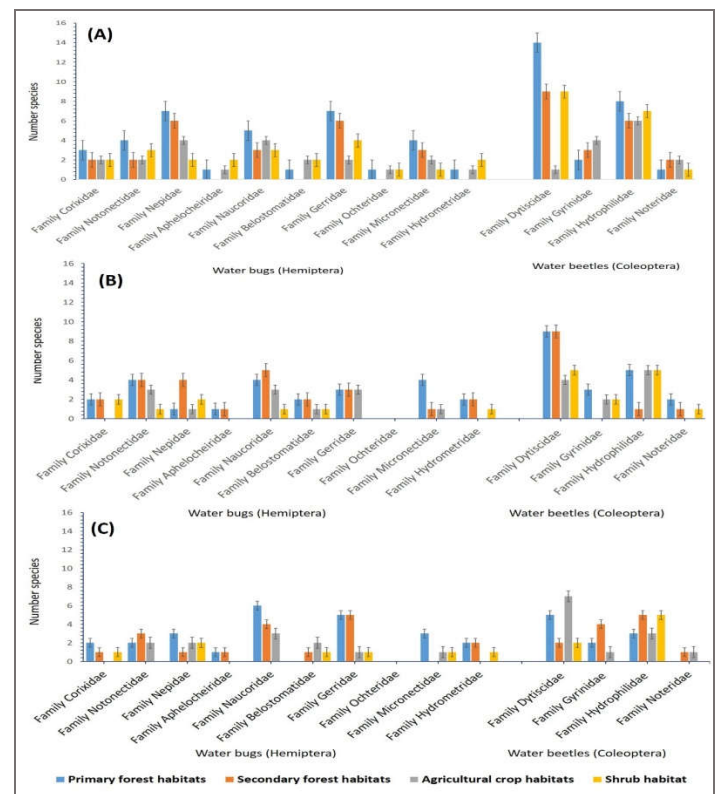


Figure 2. The number of species of water bugs (Hemiptera) and water beetles (Coleoptera) in different habitats at three National Parks in North Vietnam. A-Vu Quang National Park, Ha Tinh Province; B- Hoang Lien National Park, Lao Cai, Lai Chau Province; C- Ba Be National Park, Bac Kan Province

The mean of individuals of water bugs (Hemiptera) in different habitats in the three National Parks had different values (Fig. 3A), the mean of individuals in the primary forest habitats was highest in Vu Quang National Park; in shrub habitats was highest in Hoang Lien and Ba Be National Parks. The mean of individuals of water beetles (Coleoptera) in different habitats in the three National Parks had too different values (Fig. 3B), the mean of individuals in primary forest habitat was highest in Vu Quang and Ba Be National Parks; the mean of individuals in agricultural crop habitats and primary forest habitats was highest in Hoang Lien National Park.

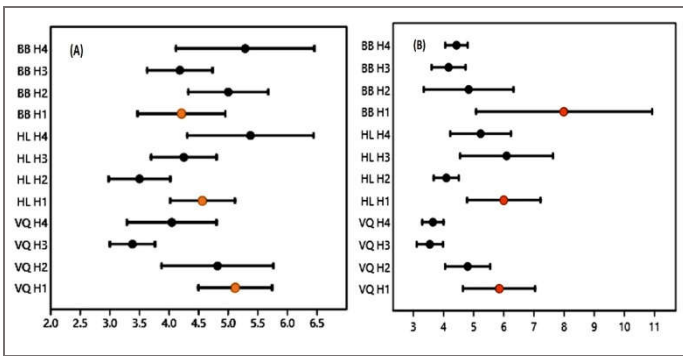


Figure 3. The mean of individuals of (A) water bugs (Hemiptera) and (B) water beetles (Coleoptera) in different habitats in three National Parks of North Vietnam. VQ-Vu Quang National Park, Ha Tinh Province; HL- Hoang Lien National Park, Lao Cai, Lai Chau Province; BB- Ba Be National Park, Bac Kan Province. H1- primary forest habitat; H2-secondary forest habitat; H3-agricultural crop habitats and H4-shrub habitats

The diversity index in different habitats in three National Parks (the Dominance_D, Simpson_1-D, Shannon_H, Evenness_e^H/S, Brillouin, Menhinick, Margalef, Equitability_J, Fisher_alpha, Berger-Parker, Chao-1 index) did differ between water bugs (Hemiptera) and water beetles (Coleoptera) (Appendix 2, Appendix 3). The diversity index of water bugs (Hemiptera) including Simpson_1-D, Shannon_H, Margalef indexes have decreasing value in primary forest habitat > secondary forest habitat > agricultural crop habitats > shrub habitats (Appendix 2). Meanwhile, the diversity index of water beetles (Coleoptera) including Simpson_1-D, Shannon_H indexes has decreasing value in agricultural crop habitats > shrub habitat > secondary forest habitats > primary forest habitats, and the Margalef index has value in agricultural crop habitats > primary forest habitats > shrub habitat > secondary forest habitats (Appendix 3).

The diversity index alpha in different habitats in three National Parks did differ between water bugs (Hemiptera) and water beetles (Coleoptera) (Fig. 4). The diversity index alpha showed clear differences for the water bug group in the four studied habitats. The value of diversity index alpha is shown in primary forest habitat > secondary forest habitat > agricultural crop habitats > shrub habitats (Fig. 4A). However, this diversity index alpha is not clear for the group of water beetles. The value of diversity index alpha is shown in agricultural crop habitats > primary forest habitats > shrub habitat > secondary forest habitats (Fig. 4B)

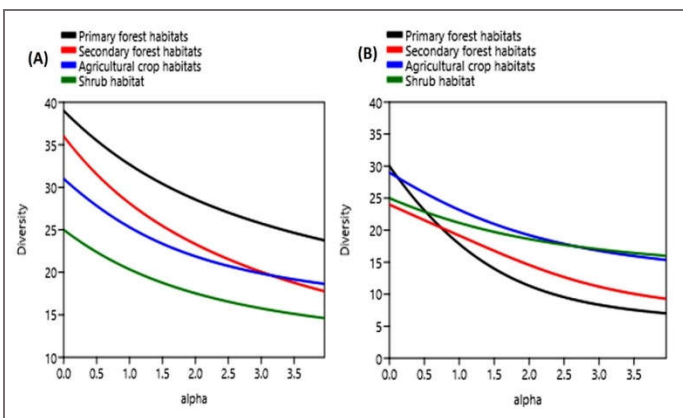


Figure 4. The diversity index alpha of (A) water bugs (Hemiptera) and (B) water beetles (Coleoptera) in different habitats in three National Parks in North Vietnam

The species richness in different habitats in three National Parks did differ between water bugs (Hemiptera) and water beetles (Coleoptera) (Fig. 5). The species richness showed clear differences for the water bug group in the four studied habitats (Fig. 5A). However, this species richness for the water beetles group showed differences in the agricultural crop habitats and primary forest habitats, but was no different in secondary forest habitats and shrub habitat (Fig. 5B).

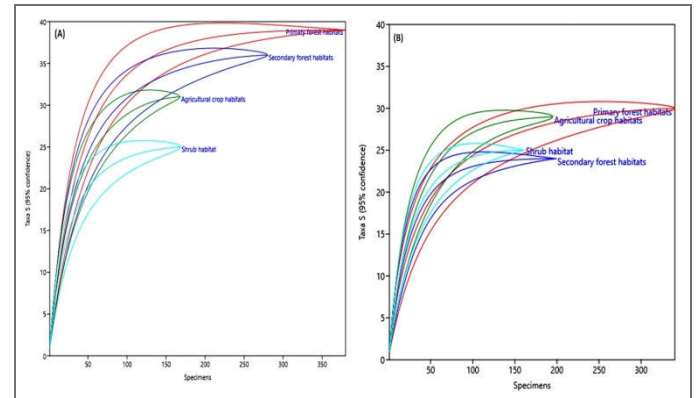


Figure 5. Species richness of (A) water bugs (Hemiptera) and (B) water beetles (Coleoptera) in different habitats in three National Parks of North Vietnam (mean ± 95% confidence intervals).

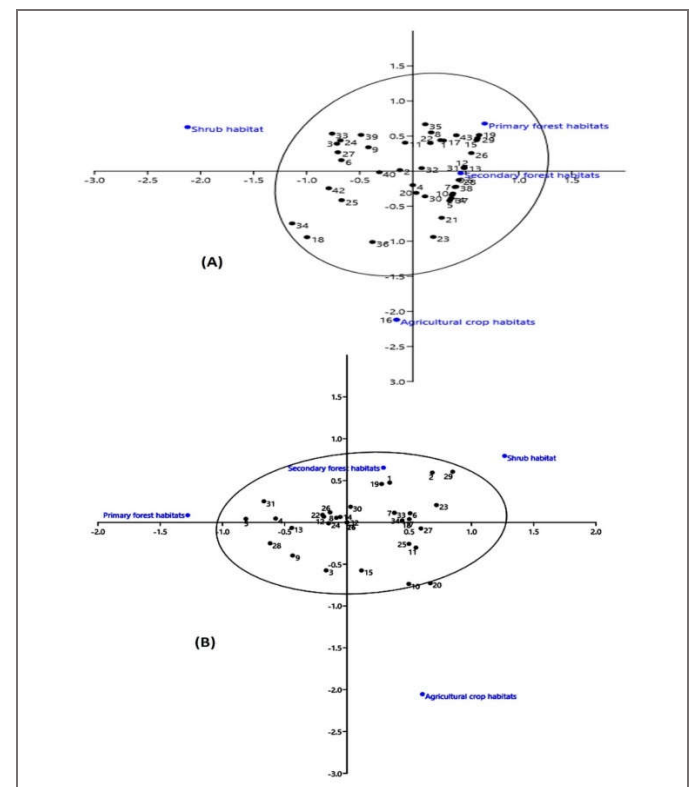


Figure 6. Correspondence analysis of (A) water bugs (Hemiptera) and (B) water beetles (Coleoptera) in different habitats in three National Parks of North Vietnam (mean ± 95% confidence intervals)

The correspondence analysis of water bugs (Hemiptera) with different habitats in three National Parks of North Vietnam shows that the correspondence of water bugs is very similar in primary forest habitat and secondary forest habitat, except in agricultural crop habitats and shrub habitat (Fig. 6A). Meanwhile, the water beetle species (Coleoptera) have correspondence in secondary forest habitats, except for primary forest habitats, agricultural crop habitats and shrub habitats (Fig. 6B)

The relationship of water bugs (Hemiptera) and water beetles (Coleoptera)

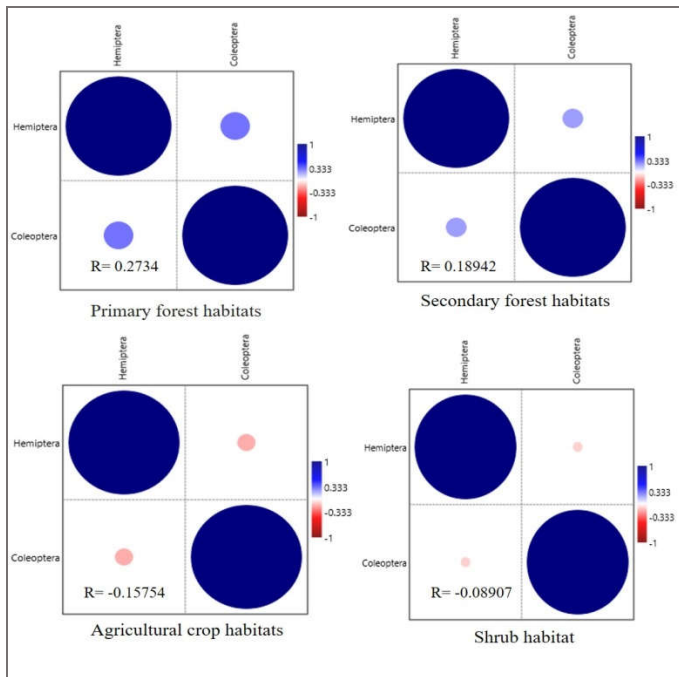


Figure 7. The correlation analysis of individual water bugs (Hemiptera) and water beetles (Coleoptera) in different habitats in three National Parks of North Vietnam (mean ± 95% confidence intervals)

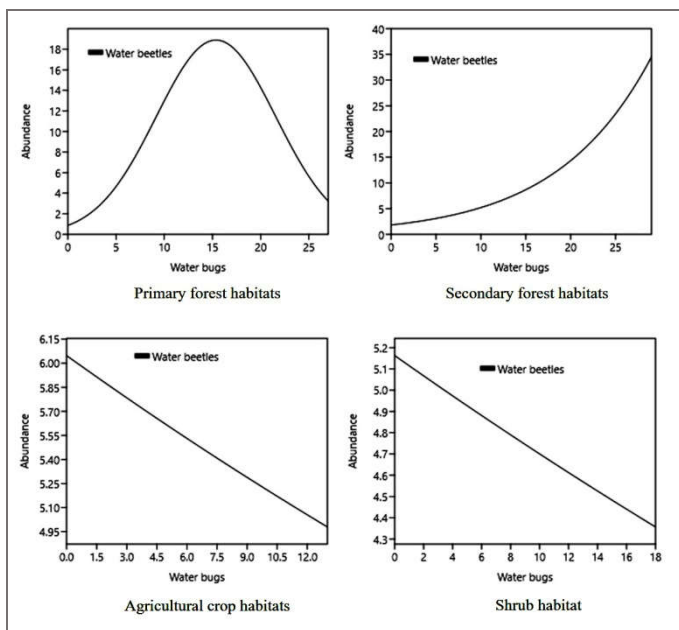


Figure 8. The analysis model species packing of the number of individual water bugs (Hemiptera) and water beetles (Coleoptera) in different habitats in three National Parks of North Vietnam

The investigation showed that there was a relationship between the number of individuals of water bugs (Hemiptera) and water beetles (Coleoptera) in different habitats in three National Parks. However, this relationship is weak and different in each (Figs. 7, 8).

In primary forest habitats, the relationship between the number of individuals of water bugs (Hemiptera) and water beetles (Coleoptera) showed a positive, weak correlation ($R = 0.2734$). Thus, the number of individuals of water bugs and water beetles in primary forest

habitats correspond and grow together (Fig. 7). The analysis model species packing in the primary forest habitat is a parabolic curve with a downward concavity, showing the co-increase and co-decrease of water bugs and water beetles (Fig. 8). In secondary forest habitats, the relationship between the number of individuals of water bugs (Hemiptera) and water beetles (Coleoptera) showed a positive, very weak correlation ($R = 0.18942$). Thus, the number of individuals of water bugs and water beetles in secondary forest habitats is growing together (Fig. 7). The analysis model species packing in the secondary forest habitats is a curve, showing the co-increase of water bugs and water beetles (Fig. 8).

In agricultural crop habitats and shrub habitats, the relationship between the number of individuals of water bugs (Hemiptera) and water beetles (Coleoptera) showed a negative, very weak correlation ($R = -0.15754$ and $R = -0.08907$). Thus, the number of individual water beetles and water beetles in the agricultural crop habitats and shrub habitats is not corresponding, and if the number of individual water bugs increases, the number of individual water beetles will decrease and vice versa (Figs. 7). The analysis model species packing in the agricultural crop habitats and shrub habitats is a straight line, shows the contrasting increase and decrease of water beetles and water beetles (Fig. 8).

DISCUSSION

In Ba Be National Park, Bac Kan Province, Vu Quang National Park, Ha Tinh Province, Hoang Lien National Park, Lao Cai, Lai Chau Provinces North Vietnam with 42 species of water bugs (Hemiptera), 27 genera of 10 families were recorded by this study which is different from the study of Tran Anh Duc *et al.*, (2010, 2016) when research in Ha Noi city and Ha Giang Province (recorded 31 species with 20 genera of 7 families). Furthermore, 42 species of water bugs (Hemiptera) were recorded in Ba Be, Hoang Lien, Vu Quang is higher than recorded in Ninh Binh, Bac Kan and Lao Cai Provinces (30 species) by Lam *et al.*, (2022) and Tran *et al.*, (2022). 31 species of water beetles (Coleoptera) with 21 genera of 4 families in this study which is higher than recorded of Deleve (1968) when study in Nghe An Province with 20 species of families Noteridae and Dytiscidae. Sato (1972) recorded 6 species belonging to the family Noteridae (Coleoptera) in Lao Cai, Bac Kan, Tuyen Quang, Nghe An, Quang Ngai, Kon Tum, Hoa Binh, Quang Tri, Ninh Thuan, Dak Lak, Gia Lai, Lam Dong Provinces which is higher than in this study (records 2 species belonging to the family Noteridae).

In the present study, the diversity index of water bugs (Hemiptera) including Simpson_1-D, Shannon_H, Margalef indexes have decreasing value in primary forest habitat > secondary forest habitat > agricultural crop habitats > shrub habitats. Meanwhile, the diversity index of water beetles (Coleoptera) including Simpson_1-D, Shannon_H indexes has decreasing value in agricultural crop habitats > shrub habitat > secondary forest habitats > primary forest habitats, and the Margalef index has value in agricultural crop habitats > primary forest habitats > shrub habitat > secondary forest habitats. This result is similar to Nichols *et al.* (1998) probably because geomorphological heterogeneity plays a major role in determining species diversity.

Shannon diversity index, Pielou evenness index (J'), and Berger-Parker dominance index were recorded. Gerridae dominated at >92% of sampling sites and Notonectidae at >28% of sampling sites (De *et al.*, 2021). This result is similar in this study to the family Gerridae with 8 species (19.04% of the total species of water bugs with 40 individuals), family Notonectidae with 5 species (11.90% of the total species water bugs with 21 individuals), the water bugs (Hemiptera)

in Vu Quang National Park with the family Gerridae has the number species in primary forest habitat> secondary forest habitat> shrub habitats> agricultural crop habitats, In Hoang Lien National Park, the water bugs (Hemiptera) with the family Gerridae has the number species in primary forest habitat> secondary forest habitat> shrub habitats> agricultural crop habitats and at Ba Be National Park, the water bugs (Hemiptera) with the family Gerridae has the number species in primary forest habitat> secondary forest habitat> agricultural crop habitats> shrub habitats

In sampling sites of agricultural lands and forests, the heteropteran families with the high number of species (number of individuals) were Gerridae, Notonectidae consistent with the study of De *et al.*, (2021) in river Ganga from Brijghat to Narora in Uttar Pradesh. Renato *et al.*, (2019) evaluated the relationship between Hemiptera and Coleoptera diversity and habitat type, altitude, and forest extent in the Los Tuxtlas rainforest and found that Hemiptera and Coleoptera species richness and abundance were significantly higher in forests than in grasslands. This result is similar in this study as in primary forest habitats, the relationship between the number of individuals of water bugs (Hemiptera) and water beetles (Coleoptera) showed a positive, weak correlation. The analysis model species packing in the primary forest habitat is a parabolic curve with a downward concavity, showing the co-increase and co-decrease of water bugs and water beetles. In Vu Quang National Park, Hoang Lien National Park, Ba Be National Park the family Dytiscidae has the number of species in primary forest habitat> secondary forest habitat> shrub habitats> agricultural crop habitats, the family Hydrophilidae has the number of species in primary forest habitat> shrub habitats> agricultural crop habitats> secondary forest habitat. The mean of individuals of water bugs (Hemiptera) in different habitats in the three National Parks had different values as was highest in the primary forest habitat in Vu Quang National Park; was highest in the shrub habitats in Hoang Lien and Bac Kan National Parks.

The mean of individuals of water beetles (Coleoptera) in different habitats in the three National Parks had too different values, the mean of individuals in primary forest habitat was highest in Vu Quang and Ba Be National Parks; in agricultural crop habitats and primary forest habitat was highest in Hoang Lien National Park. This result is similar to the study of Doeurk *et al.*, (2022) as analysis of individual proportions showed that some families differed in their relationship of individual proportions to their habitat. The family Scirtidae were positively associated with primary forest habitat and shrub habitats, but negatively associated with agricultural crop habitats. The family Limnichidae were positively associated with elevation and erosion, while the family Dytiscidae were positively associated with streambeds characterized by small stones, but negatively associated with water depth and streambeds characterized by large stones. Vaibhao *et al.*, (2011) as the diversity and abundance of water beetles at five different sites in the Kolkas region of India. The diversity index showed that site forest habitat was the richest (11 species), followed by agricultural crop habitats and shrub habitats (10 species each), secondary forest (9 species), the richness ranking showed that site shrub habitats had fewer rare species and more common species than the other sites.

CONCLUSION

In four different habitats in Ba Be National Park, Bac Kan Province, Vu Quang National Park, Ha Tinh Province, Hoang Lien National Park, Lao Cai, Lai Chau Provinces in North Vietnam were collected 1892 individuals the water bugs (Hemiptera) and water beetles (Coleoptera) representing 73 species of 48 genera of 14 families. Among them, 42 species of water bugs (Hemiptera) with 27

genera of 10 families, 31 species of water beetles (Coleoptera) with 21 genera of 4 families. The number of species of the family Nepidae, Gerridae, Dytiscidae, Hydrophilidae were highest in secondary forest habitats, shrub habitats and lowest in agricultural crop habitats, shrub habitats. The mean of individuals of water bugs (Hemiptera) was highest at the primary forest habitat in Vu Quang National Park; was highest at shrub habitats in Hoang Lien and Ba Be National Parks. The mean of individuals of water beetles (Coleoptera) in primary forest habitat was highest in Vu Quang and Ba Be National Parks; was highest at agricultural crop habitats and primary forest habitats in Hoang Lien National Park.

The diversity index in different habitats in three National Parks did differ between water bugs (Hemiptera) and water beetles (Coleoptera). The Simpson_1-D, Shannon_H indexes of water bugs (Hemiptera) have decreasing value in primary forest habitat> secondary forest habitat> agricultural crop habitats> shrub habitats. Meanwhile, water beetles (Coleoptera) have decreasing value in agricultural crop habitats> shrub habitats> secondary forest habitats> primary forest habitats.

The relationship between the number of individuals of water bugs (Hemiptera) and water beetles (Coleoptera) in different habitats in three National Parks is weak and different. In primary forest habitats, this relationship showed a positive, weak. The analysis model species packing in the primary forest habitat was a parabolic curve with a downward concavity, showing the co-increase and co-decrease of water bugs and water beetles. In secondary forest habitats, this relationship showed a positive, very weak. The analysis model species packing in the secondary forest habitats was a curve, showing the co-increase of water bugs and water beetles. In agricultural crop habitats and shrub habitats, the relationship showed a negative, very weak correlation. The analysis model species packing in the agricultural crop habitats and shrub habitats is a straight line, did not show the contrasting increase and decrease of water beetles and water beetles.

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