

ARTICLE

## The Habitat Ecology Species of (*Pteropus vampyrus*) and (*Pteropus lylei*) Natural Exploitation as Food Sources in Tra Vinh, Vietnam

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### ABSTRACT

Bat population appears is maintained as the last habitat of these species in the La Ca Pagoda (old) area of the Khmer ethnic people in Tra Vinh. Methods are interview, count individuals in the habitat, species, population, determine the type of plants, the height of the living bats; results of the current status of species, quantity, distribution, residence and reproduction of species; impacts on 2 species of horse bats related to the conservation of horse bats; compared to previous by the Ehb function, with the parameters Hchb (Horseback bat community) the existence of the community compared to the previous time, at least 1 breeding season; Hhbb (Horse bat habitat) on living conditions; Hfhhb (Horse bat food) on food sources for the community to live; Hphb (Horse bat protection) on conditions to protect the community; evaluated by score (0–1); the results the species *Pteropus vampyrus* decreased by 79.51%, the species *Pteropus lylei* increased by 6.8 times. The total number is 1239 individuals, including 1072 THB and 168 LHB. Both of these species have been recorded in previous surveys. The number of individuals counted was larger than the previous survey (1239 individuals compared to 957 individuals); the number of LHB in this survey was much smaller than the previous count (168 individuals compared to 820 individuals); the number of THB was 1072 individuals compared to 137 individuals). Using a function-based

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assessment method with ecologically relevant parameters can objectively assess the distribution and status of threatened populations to effectively protect their survival.

**Keywords:** Ecological Habitat; *Pteropus vampyrus*; *Pteropus lylei*; Ca La Pagoda; Tra Vinh; Mekong Delta

## 1. Introduction

The order Chiroptera is the second largest order in the class Mammalia, with about 1,116 species, distributed globally, except for the Arctic and Antarctic<sup>[1]</sup>. These species, 65 species, are similar to *Pteropus*, but only 22 species are distributed in Southeast Asia. In Vietnam, only 3 species of this genus have been recorded: the Larger Horse Bat (LHB) (*Pteropus vampyrus*), the Little horse bat (LHB) (*Pteropus hypomelanus*), and the Thai horse bat (THB) (*Pteropus lylei*)<sup>[2]</sup>. Currently, all 3 species are at high risk of extinction<sup>[3]</sup>. The Red List<sup>[4,5]</sup>, the GHB (*P. vampyrus*) and the LHB (*P. hypomelanus*) are classified as NT (near threatened), the THB (*P. lylei*) is classified as VU (near endangered). Decree 84/2021/ND-CP<sup>[6]</sup> amending and supplementing Decree 06/2019/ND-CP<sup>[7]</sup> on the management of endangered, precious and rare wild plants and animals and the implementation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, all three species are listed in Appendix IIB — a group of wild animals that are not yet threatened with extinction but are at risk of being threatened if not strictly managed<sup>[8,9]</sup>, restricted from exploitation and use for commercial purposes, and species listed in Appendix II CITES with natural distribution in Vietnam

The GHB was discovered on the island of Java in Indonesia and described<sup>[10]</sup> with the original name *Vespertilio vampyrus*, Dobson and Andersen<sup>[11]</sup> changed to (*Pteropus vampyrus*), which is the largest species of the three species above. The THB (*Pteropus lylei*) is the second largest bat species after the GHB (*P. vampyrus*) in Vietnam. The LHB (*Pteropus hypomelanus*) has a similar external morphology to the TBH but is smaller in size.

Usually, horse bats choose places that are safe from predators, have abundant food sources, and are less affected by human impact on their habitat<sup>[12]</sup>. The study<sup>[13]</sup> found that horse bats often perch on trees belonging to the families Combretaceae, Annonaceae, Rutaceae, Caesalpiniaceae, Sapotaceae, Myrtaceae, Anacardiaceae, Meliaceae, Fabaceae, Verbenaceae, Bombacaceae, Bignoniaceae, and

Moraceae.

In the world, the GHB is surveyed. Southeast Asia is a critical area for biodiversity conservation, but rapid land-use changes endanger Bats, which are a critical component of this diversity<sup>[14]</sup>. In Vietnam, this species has been recorded in the provinces: Thua Thien–Hue, Ba Ria–Vung Tau, Soc Trang, Kien Giang, and Ca Mau<sup>[15–24]</sup>.

Because these species get food from nectar and fruits, they often look for food sources in the orchards of the community, so they are easily caught and killed; on the other hand, these are species with large size and weight, so they are hunted by the community to provide food as a food source from wild animals. This is the reason why these species are at risk of extinction in the near future, so it is very necessary and urgent to research and discuss necessary solutions to take action to protect these species.

In the Mekong Delta, two species of horse bats, the large horse bat and the Thai horse bat, are found. They live in populations of two species and intermingle in communities on tall forest trees in strictly protected areas such as pagodas of the Khom Me ethnic group. The question is (1) if there is no protected habitat, (2) if there is no food source for the species, (3) if there is hunting and extermination, what is the survival potential, (4) the community of these two species? The survival of the above two species is a function of four variables set out in the research objective of these two endangered species.

In this paper the conservation of two species of Horse Bat (*Flying fox*) is (HB), (*Pteropus lylei*) is Great Horse Bat (GHB), (*Pteropus vampyrus*) is Thai Horse Bat (THB); evaluates the conservation at a given time compared to a previous time by a function Ehb that parameters Hchb (Community of horse bat) existence of the community at a given time compared to a previous time, at least 1 breeding season; Hhhb (Habitat of horse bat) for living conditions; Hfhb (Food of horse bat) food sources for the community to live; Hphb (Protection of horse bat) conditions for protecting the community; it is evaluated by score (0–1).

## 2. Materials and Methods

### 2.1. Method of Scoring

Rationale: We consider the bat community as a function of  $y$  (Horse Bat Conservation) and the influencing parameters are  $x$ , where  $x_1$  (Horse Bat Community is survival of bat),  $x_2$  (Horse Bat Habitat is place to live),  $x_3$  (Horse Bat Food resources is the range of food source),  $x_4$  (Horse Bat Protection level is the combined threat from external natural enemies).

With:  $y = x_1 + x_2 + x_3 + x_4$

$y$ : Horse Bat Conservation

$x_1$ : Horse Bat Community

$x_2$ : Horse Bat Habitat

$x_3$ : Horse Bat Food sources

$x_4$ : Horse Bat Protection Levels

The  $x$  parameters have equal roles in contributing to existence and development. These parameters are evaluated on a scale from 0 to 1. If the score is 0, it is extinct. If the score is 1, the species is being protected and developed. To evaluate them, the population can be surveyed twice in a row. If the species rate is found to be decreasing, it is considered

endangered. The function of  $y$  is the average sum of the 4 parameters  $x_1, x_2, x_3, x_4$  (each parameter has a score from 0–1).

$Y = 0$  extinct

$Y = <0-0.25$  extinction risk

$Y = 0.25-0.5$  severe threat

$Y = 0.50-0.75$  moderate threat

$y = 0.75 \rightarrow 1$  low threat

$y = 1$  no threat

### 2.2. Method of Counting the Number of Individuals at the Roost

The number of horse bats at the roost was counted once using the counting method<sup>[25]</sup> of K. E. Barlow, K. (2014) (Figure 1, Table 1). Accordingly, the average number of bats perched on a tree was calculated, and the number of trees with bats roosting was counted. The total number of bats was calculated by the product of the number of trees with bats roosting and the average number of bats per tree. The number of bats per tree was calculated by the average of 2 consecutive counts with the help of binoculars.



Figure 1. Interview with the temple abbot about the history of the habitation of the horse bat.

Table 1. Location of interviewed households.

No.	Interviewee	Sex	Profpection	Living Time	Coordinates
1	Interview 1 (In. 1)	Female	Garden	40	10.046367, 106.262727
2	In. 2	Male	Garden	60	10.046367, 106.262727
3	In. 3	Male	Garden	40	9.9582317, 106.2972012
4	In. 4	Male	Garden	60	10.003670, 106.226209
5	In.5	Male	Garden	40	10.0400522, 106.2844735
6	In. 6	Male	Farming	70	10.0538515, 106.2663169
7	In.7	Male	Farming	35	10.043896, 106.261308
8	In.8	Male	Garden	40	10.0209592, 106.2584503
9	In.9	Male	Livestock	40	9.9570424, 106.252278
10	In. 10	Male	Livestock	63	10.003007, 106.232285
11	In. 11	Female	Farming	40	10002446, 106.237574
12	Din.12	Male	Farming	73	10.003250, 106.236403
13	In.13	Male	Garden	64	10.058986, 106.261617
14	In. 14	Male	Farming	70	10.0545025, 106.2553953

Table 1. Cont.

No.	Interviewee	Sex	Profession	Living Time	Coordinates
15	In. 15	Male	Woodworker	40	10.064787, 106.249947
16	In. 16	Female	Housewife	40	10.046132, 106.262038
17	In. 17	Female	Housewife	70	9.973090, 106.249890
18	In.18	Male	Garden	70	9959913, 106.241855
19	In. 19	Male	Handicraft	70	10.064020, 106.257107
20	In. 20	Female	Garden	65	9.731502, 106.362018
21	In.21	Male	Garden	30	9.731502, 106.362018
22	In. 22	Male	Garden	72	9.731502, 106.362018
23	In. 23	Female	Monk	80	9.809132, 106.489652
24	In. 24	Male	Livestock	66	9.831011, 106.489622
25	In.25	Male	Livestock	45	9.828131, 106.479793
26	In. 26	Male	Bicycle Repair	55	9.827502, 106.478554
27	In.27	Male	Retire	75	9.996465, 106.290048
28	In. 28	Male	Garden	60	10.015535, 106.275474
29	In. 29	Female	Housewife	45	9.924050, 106.3039
30	In. 30	Female	Housewife	69	9.9730819, 106.2499031
31	In. 31	Male	Trade	70	10.006108, 106.281856
32	In. 32	Male	Garden	64	9.990429, 106.293223
33	In.33	Male	Trade	35	9.996009, 106.271895
34	In. 34	Female	Coffee shop	35	9.9448231, 106.2730781
35	In. 35	Male	Livestock	62	9.753535, 106.139235
36	In. 36	Male	Farming	72	9.698230, 106.226259

Note: Duration of residence is the time the household head has lived at the residence until the time of the interview survey.

### 2.3. Interview Method

The interviews were based on prepared interview questions (Figure 2). The purpose of the interviews is to learn about the areas where horse bats used to live, the demand for horse bat meat, the business demand, and people’s awareness of the conservation of horse bat species. The interview areas were scattered throughout Tra Vinh province to collect information about the areas where horse bats forage. The interview process, investigation of illegal trade, and illegal hunting were carried out in the districts of Cang Long, Cau

Ngang, Tieu Can, Tra Cu, Chau Thanh, and Cau Ke.

The interview method is used to find out the number of interviewees who understand the government’s policies on forestry law and biodiversity protection law that have been implemented in the community. On the basis of the summary, the rate of people who have been implemented and the rate of people who have done well in implementing the conservation of this species are assessed. This is only a general assessment, not going into the personal thoughts of the person being assessed.



Figure 2. Survey of the population of the Horse Bat species.

### 2.4. Species Identification Method

Identification of bat species is carried out in the field with the help of binoculars and cameras with large focal

length lenses that allow close-up shots of the external morphology of individuals in the flock. Using documents<sup>[23,24]</sup> to identify by external morphology. The purpose of species identification was to determine whether meat products used

as food and horse bat products were of the species under study. There was no purpose to assess the owner's awareness, and sampling was conducted with the consent of the interviewed owner. The purpose of species identification was to determine whether meat products used as food and horse bat products were of the species under study. There was no purpose to assess the owner's awareness, and sampling was conducted with the consent of the interviewed owner.

## 2.5. Method of Drawing a Distribution Map of Bat Colonies

The map of the campus of La Ca Pagoda (old), where bat colonies reside, is determined by aerial photography with the support of a flycam. The location of bat colonies on the campus is determined by the coordinates of the trees that bats use as daytime habitats. The coordinates are recorded by a handheld GPS device. The map is drawn by software.

## 2.6. Plant Identification Method

Identify the plant species used by horse bats as habitat according to the document "Vietnam's Timber Resources"<sup>[26]</sup> and "Dictionary of Common Plants"<sup>[27]</sup>.

## 2.7. Roost Height Measurement Method

Roost height was recorded using an SNDWAY SW-M50 handheld height meter made in Taiwan, with a measuring distance of up to 50m and an accuracy of 1mm. The measured parameters include the lowest roost height and the highest roost height. In the roosting area, roosting location parameters were collected on 20 trees currently occupied by bats.

# 3. Results

## 3.1. Horse Bat Community

### 3.1.1. Species Composition and Number of Horse Bats

The survey results at La Ca Pagoda (old) recorded 2 species THB (*Pteropus lylei*) and LHB (*Pteropus vampyrus*) (Figure 3). The total number is 1239 individuals, including

1072 THB and 168 LHB. Both of these species have been recorded in previous surveys by Tra Vinh Provincial Forest Rangers and have been recorded. Compared to the count in August 2022, the results of this survey were significantly different. The number of individuals counted was larger than the previous survey (1,239 individuals compared to 957 individuals); the number of LHB in this survey was much smaller than the previous count (168 individuals compared to 820 individuals); the number of THB was 1072 individuals compared to 137 individuals (Figure 4, Table 2). Species variation in the populations of HB has been recorded. The number of species in each colony fluctuates seasonally, irregularly, and weekly<sup>[28]</sup>. The causes of variation are thought to be influenced by food sources (seasonal variation) and the influence of temple visitors (irregular variation, weekly variation). HB are capable of moving an average of 28.3 km, and there have been recorded cases of moving up to 105 km per night. Some individuals do not return to their old colony, while others reside in other bat colonies<sup>[29]</sup>. The THB is thought to move continuously between sites, as indicated by low genetic sequence diversity between sites<sup>[30,31]</sup>. The THB is thought to move continuously between sites during the late gestation period and the period when the young are still dependent on their mothers. In Sarawak (Malaysia), this migration period ranges from about August to January of the following year<sup>[32]</sup>. Roosting is thought to be continuous in some other species of the genus horse bat<sup>[33]</sup>. The main factors leading to fluctuations and declines in bat populations are migration due to changes in food sources, hunting, and habitat destruction<sup>[31]</sup>. In particular, migration due to changes in food sources leads to cyclical fluctuations in population. Species in the genus HB usually feed on fruits, nectar, petals, and pollen. Therefore, they live in groups and migrate from one place to another in response to seasonal changes in food sources<sup>[34-36]</sup>. Hunting and habitat destruction often cause irregular population fluctuations, which are also the main impacts leading to the decline in the number of individuals in current bat populations<sup>[37,38]</sup>. During the breeding season, horse bats often gather in large flocks to mate, leading to larger and noisier populations than usual, making hunting easier; horse bats not only eat fruits in the wild but also eat fruits in farmers' gardens. To protect crops, people often use traps to catch bats<sup>[39]</sup>.



Figure 3. Species of Horse Bat recorded at La Ca (old).

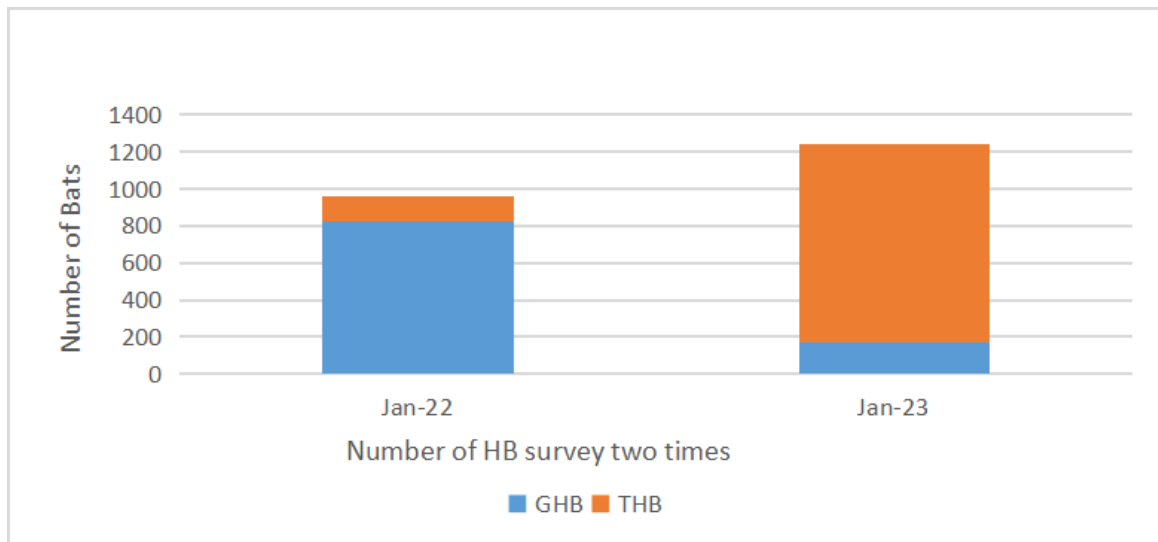


Figure 4. Number of Horse Bats at the La Ca Pagoda (old) at 2 different times.

Table 2. Number of individuals of each species of horse bats counted on trees at La Ca Pagoda (old).

No.	Tree Symbol	Thai Horse Bat (THB)	Large Horse Bat (LHB)
1	C1	3	18
2	C2	156	15
3	C3	59	5
4	C4	35	3
5	C5	25	4
5	C6	20	2
6	C7	24	5
7	C8	60	13
8	C9	13	4
9	C10	7	4
10	C11	27	5
11	C12	16	3
12	C13	15	2
13	C14	7	3

Table 2. Cont.

No.	Tree Symbol	Thai Horse Bat (THB)	Large Horse Bat (LHB)
14	C15	14	2
15	C16	70	6
16	C17	13	2
17	C18	72	15
18	C19	26	4
19	C20	22	7
20	C21	54	3
21	C22	46	2
22	C23	53	18
23	C24	58	16
Average number per tree		25.5	4
Number of each species on a total of 42 trees		1071	169
Total number of bats		1239	

### 3.1.2. About Reproduction

The breeding season of HB usually starts from March to May every year. In particular, the LHB usually ends earlier from March to early April, the THB from March to May, and later in the LHB from April to May. The gestation period usually starts from November, the latest from January every year. Each litter of HB usually gives birth to 1 baby. The baby will be carried by the mother bat in the first days after birth, but then they stay in the habitat when the mother bat goes out to find food. The duration of nursing ranges from 2 to 3 months or longer, depending on the species. Although the THB is nocturnal, it makes noise throughout the day, especially when the mother is nursing. Both male and female HB reach sexual maturity after one year<sup>[23,40-42]</sup>.

Comments: In the August 2022 survey, the total individuals (I) was 957 I (THB 137 I, LHB 820 I). In December 2023, the total individuals is 1240 I (THB 1072 I, LHB 168 I); LHB decreased is 79.51%, and THB increased is 682% by 6.8 times. The general comment on the community is an increase of 252 I by 26%, but the population of LHB decreases by 79.51%. If the maximum score is 1, the score of LHB of *Pteropus vampyrus* is 0.21 points, and *Pteropus lylei* is 1.

## 3.2. Horse Bat Habitat

### 3.2.1. Habitat Characteristics of the La Ca Pagoda (old)

At the time of the survey, the location of the horse bat colony was in the central area of the pagoda grounds, with the current area of the horse bat colony occupying about 0.32 ha. The height at the survey site was about 12 m above sea level

(Figure 5). In the pagoda grounds, the bat colony used 42 big trees as daytime habitats. The bat colony lived on trees in the same cluster of trees growing close together, continuously, not divided into groups. The large trees used by the bats are *Dipterocarpus alatus*. These trees were planted about 40 years ago. In addition to *Dipterocarpus alatus*, large trees also include *Hopea odorata*, which grows in the area where the Horse bat lives (Figure 5, Table 3). However, the *Hopea odorata* trees are shorter and are not used by the Horse bats. The height of the *Dipterocarpus alatus* trees is from 16 to 18 m, while the height of the intercropped *Hopea odorata* trees is from 14 to 15 m. On each *Dipterocarpus alatus* tree, the location of the Horse bat individuals resides at the top of the tree, where they can catch the sunlight. The average number of Horse bats on each tree is about 25 individuals, ranging from a few individuals to several dozen individuals. There are some trees with a very large number of perches, about 156 individuals.

The temple grounds are a favorite habitat for the Horse bat<sup>[43]</sup>. According to interviews with the abbot, the bats have existed for over 40 years. In the past, the bats were more numerous than they are now, and there was a time when their numbers were severely reduced to only a few dozen due to illegal hunting.

### 3.2.2. Forest Resources

According to People Committee of Tra Vinh Province<sup>[44]</sup> (Table 3), Decision No. 265/QD-UBND dated March 3, 2023, of the People's Committee of Tra Vinh province, the total forest area of Tra Vinh province in 2022 is 9538.74 ha, and the mangrove forest is 8756.82 ha (4977.13 ha is protection forest and 3790.72 ha is production forest).



Figure 5. Habitat of the bat in La Ca Pagoda (old).

Table 3. Forest cover in Tra Vinh to 2022.

No.	District Administrative Units	Forest Areas (ha)	Forest Areas (ha)	
			Natural Forest	Plantation
1	Cau Ngang	1382.22	307.02	1075.20
2	Chau Thanh	601.69	282.71	318.98
3	Duyen Hai	5113.46	1446.73	3666.73
4	Duyen Hai Town	1911.20	628.47	1282.73
5	Tra Vinh city	145.85	59.7	86.15
6	Cang Long District	49.73	38	11.73
7	Tra Cu District	132.26	51.2	81.06
8	Cau Ke District	134.79	108.2	26.59
9	Tieu Can District	21.39		21.39
Total		9492.58	2922.03	6570.55

Source: No. 265/QĐ-UBND, dated March 3, 2023.

### 3.2.3. Regarding Taxonomic Characteristics

In Figures 5–8, the Chiroptera is the second largest order in the Mammalia class with about 1,116 species, distributed globally, except for the Arctic and Antarctic<sup>[1]</sup>. These species, 65 in total, are similar to Pteropus, but only 22 are distributed in Southeast Asia. In Vietnam, only 3 species of this genus have been recorded: the larger Pteropus vampyrus, the lesser Pteropus hypomelanus, and the Thai Pteropus lylei<sup>[9,12]</sup>. Currently, all 3 species are at high risk of extinction<sup>[8]</sup>. In the IUCN Red List, the GHB (*P. vampyrus*) and the LHB (*P. hypomelanus*) are classified as NT (near threatened), the THB (*P. lylei*) is classified as VU (near endangered)<sup>[4]</sup>. In Decree 84/2021/ND-CP amending and supplementing<sup>[6]</sup>. Decree 06/2019/ND-CP on the management of endangered, precious and rare wild plants and animals and the implementation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora<sup>[7]</sup>, all three species are listed in Appendix IIB—a group of wild animals that are not yet threatened with extinction but are at risk of being threatened if not strictly managed, restricted from exploitation and use for commercial purposes, and species listed in Appendix II

CITES with natural distribution in Vietnam.

The GHB was discovered on the Indonesian island of Java and described by Linnaeus,<sup>[10]</sup> with the original name *Vespertilio vampyrus*. Later, the scientific name of this species was changed by Dobson and Andersen<sup>[11]</sup> to (*Pteropus vampyrus*). This is the largest of the three species. The identifying features are long and pointed ears, and the fur on the neck and shoulders is often yellow-brown, dark brown, or black. On the back of the upper half of the body, the fur is short and stiff; the fur on the lower half is softer. The fur on the belly is coarse and curly. The color and structure of the fur depend largely on age and sex. Newborns have dark brown fur on the neck and shoulders; in males, the fur gradually fades until they reach adulthood. Immature individuals usually have grayish-brown head feathers. Compared to females, males have denser fur and stiffer hair. The fur on the head ranges from dark red to blackish brown, and the pharynx usually ranges from blackish brown to brown, with scattered gray or silvery gray hairs. The GHB has patellae, while other HB of the genus Pteropus do not have this bone<sup>[8]</sup>.

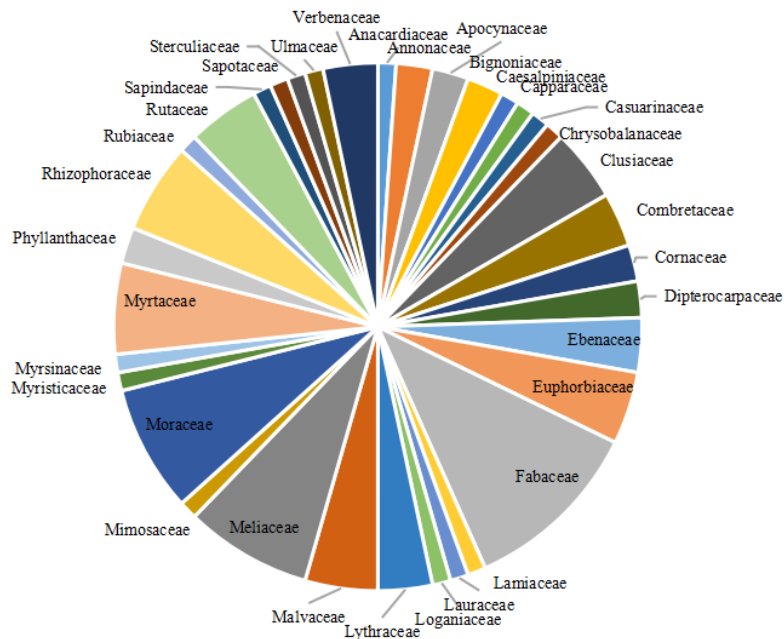


Figure 6. Percent of wood plants in Tra Vinh.

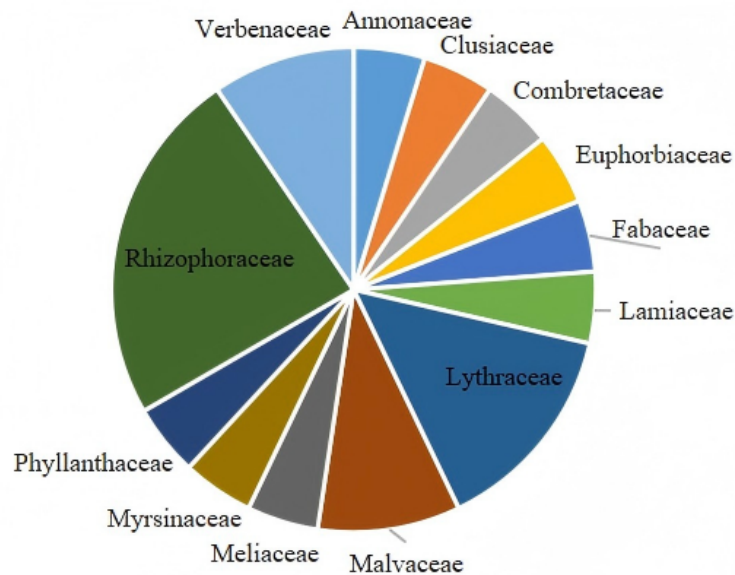


Figure 7. Percentage of plant families in the Tra Vinh mangrove ecosystem.

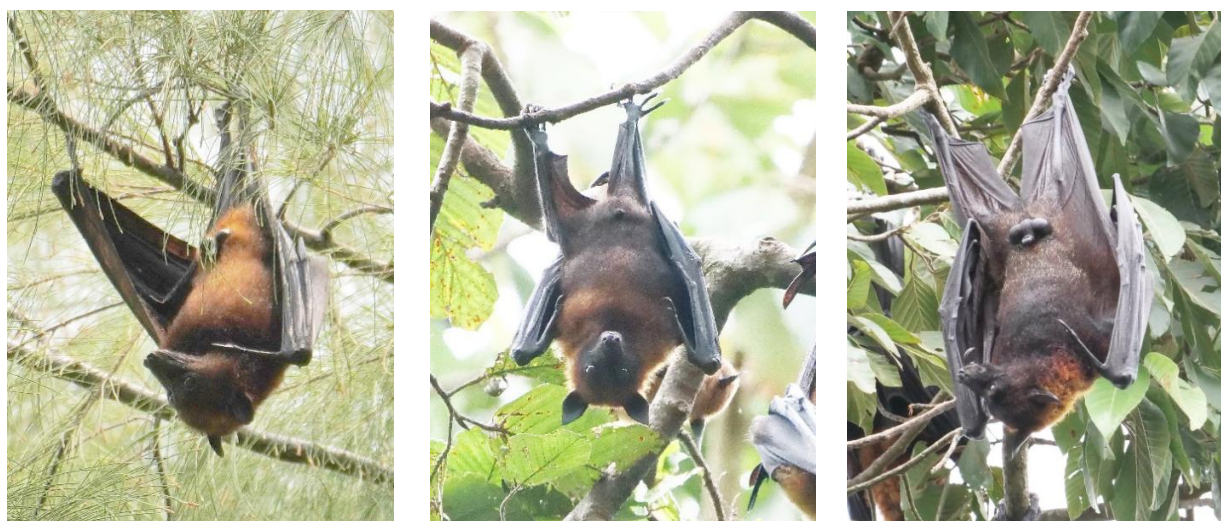
The THB (*Pteropus lylei*) is the second-largest bat species after the LHB (*P. vampyrus*) in Vietnam. The fur on the head is dark brown or light brown, the nape is yellowish brown, and the shoulders are lighter yellow. The fur is light silvery in the middle of the back and gradually darkens on both sides. Around the neck to the chest and head is dark yellow, and the belly is dark. There is no tail. The skull of the THB has a similar morphology to the LHB<sup>[9]</sup>.

The LHB (*Pteropus hypomelanus*) has a similar exter-

nal morphology to the THB but is smaller in size. The fur on the forehead is thick and gradually longer towards the neck and ears. The fur on the back is short, and the fur on the belly is longer than the fur on the back. The wing membrane is attached to the midline of the back and the first phalanx of the second toe. The characteristic fur color of the LHB is dark brown on the head. The fur on the neck and shoulders is usually in the range of light yellow to brown. The fur on the back is usually in the range of light brown to reddish brown.

The fur on the belly is usually buff brown. The flank fur is similar in color to the fur on the back. The fur around the eyes is light gray. The upper incisors are semicircular and separate from the canines. The canines are large and strong,

with a deep, longitudinal groove on the front. The canines curve backwards. P1 is tiny and often not visible in adults. The remaining premolars often have a very prominent ridge on the back<sup>[8]</sup>.



(a) Little horse bat (*P. hypomelanus*). (b) Thai horse bat (*P. lylei*). (c) Large horse bat (*P. vampyrus*).

Figure 8. External morphology of three species of (*Pteropus*) in Vietnam.

The mangrove ecosystem is a typical forest ecosystem of Tra Vinh province. The 90 recorded woody plant species, 21 species of 13 families, belong to this ecosystem. The main species are the Rhizophoraceae family, with 5 species accounting for 23.8%.

### 3.2.4. Distribution and Habitat

Usually, horse bats choose places that are safe from predators, have abundant food sources, and are less affected by human impact on their habitat<sup>[12]</sup>. According to the study of Nowak, Lam, and Ly<sup>[3,45]</sup>, horse bats often perch on trees belonging to the families Combretaceae, Annonaceae, Rutaceae, Caesalpiniaceae, Sapotaceae, Myrtaceae, Anacardiaceae, Meliaceae, Fabaceae, Verbenaceae, Bombacaceae, Bignoniaceae, and Moraceae. In the world, GHB is distributed in the following countries: Brunei, China, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, East Timor, and Vietnam. In Vietnam, this species has been recorded in the provinces: Thua Thien–Hue, Ba Ria–Vung Tau, Soc Trang, Kien Giang, and Ca Mau<sup>[15–24]</sup>. This species lives in a variety of habitats, including primary forests, mangroves, palm forests, scrub forests, and orchards. The open canopy of mangroves and palm clumps is a suitable habitat for them. The GHB usS., Suyanto, A., Suyanto, A., Lam

and Ly, usually choose trees with few leaves and roosts in the treetops in groups of a few to several thousand individuals<sup>[45]</sup>.

The THB (*P. lylei*) was discovered in Bangkok, Thailand by Anderson<sup>[46]</sup>. In the world, the THB is distributed in the following countries: China, Vietnam, Thailand, and Cambodia<sup>[47]</sup>. In Vietnam, the first data on the THB was recorded in Saigon (Ho Chi Minh City) in the research by Waldien and Tsang,<sup>[47]</sup>. After that, this species was recorded in the provinces: Thua Thien–Hue, Soc Trang, Kien Giang, and Ca Mau<sup>[20–24]</sup>. Soc Trang has been the place with the most frequent records of the Thai flying foxes in Vietnam since 1908. THB are recorded in many remote tropical forest habitats, and some are also found in urban areas, where they often roost in ancient pagodas. This species often roosts in large flocks on tall trees<sup>[40]</sup>.

The LHB (*P. hypomelanus*) is widely distributed on both the mainland and islands. Worldwide, the LHB has been recorded in the following countries: India, Indonesia, Malaysia, Maldives, Myanmar, Papua New Guinea, Philippines, Solomon Islands, Thailand, and Vietnam<sup>[48]</sup>. In Vietnam, the little horse bat was first recorded in Con Dao, now part of Con Dao National Park, Ba Ria–Vung Tau province<sup>[49]</sup>. This is also the first published record of a

bat in Vietnam<sup>[50,51]</sup>. Since 1869, there have been additional records of the LHB in the two provinces of Ba Ria–Vung Tau and Ca Mau<sup>[20–23,52]</sup>. Thus, the LHB has a known scattered distribution range on the mainland and remote islands (Thua Thien - Hue, Ba Ria–Vung Tau, Ca Mau), and this species has never been recorded in Soc Trang province. The LHB is often recorded in urban habitats and agricultural lands. They live alone or in groups of 10 to hundreds of individuals. This species has never been recorded in primary forests<sup>[23]</sup>.

Comments: This is the old Khomer Pagoda, so planted *Dipterocarpus alatus* and *Hopea odorata* when it was established; the Khomer Pagoda is strictly protected; the thinking of Buddhism so killing animals is taboo in the pagoda; so in this section, the score is 1 point, *Pteropus vampyrus* is 1, and *Pteropus lylei* is 1.

### 3.3. Horse Bat Food Sources

#### 3.3.1. Distribution Range of Horse Bats in Tra Vinh

Due to their habit of moving long distances when searching for food at night, the distribution range of the Horse bat was recorded through interviews with 36 people in districts such as Cang Long, Cau Ngang, Chau Thanh, Tra Cu, and Tieu Can districts. Of these, 7 people did not know about Horse bat, and the remaining 29 people knew about Horse bat that had appeared in their locality. The areas with the highest recorded population of Horse bat were in Cang Long (22 points), Cau Ngang (5 points), Tieu Can (1 point), and Tra Cu (1 point)<sup>[45,53]</sup>. Of the 29 interviewees who knew about Horse bat, 7 people said that horse bats are currently present. Except for 3 people living around La Ca Pagoda (old), the remaining 4 said that horse bats are currently foraging at night in Cang Long and Tieu Can districts. 2 interviewees said that in the past 2 years, they have begun to see Horse bats appearing again in Duc My commune, Cang Long district. Notably, 1 of these 2 people is setting up nets to catch them at night in Cang Long district. There were 22 local people who reported seeing a Horse bat in the area, but they have not been seen for about 20 years. They said the reason was the reduction of fruit trees, massive construction, and overpopulation, which have destroyed the suitable habitat for the Horse bat. The number of recorded points is quite small and not completely random, so it cannot

represent the distribution of the Horse bat at these points. However, information provided by local people shows that Horse bats are often recorded in fruit gardens. Although most of the interviewees said that they have not seen a Horse bat for about 20 years, there is also positive information that they are still seeing them and have seen more in the past 2 years. From this interview information, it is not possible to confirm whether Horse bats are recovering their population numbers or not. It is possible that other impacted areas have driven the bats here to find food<sup>[54,55]</sup>.

#### 3.3.2. About Diet

Most bats in the Megachiroptera suborder are herbivorous, feeding mainly on nectar, pollen, and also on flower petals, fruits, seeds, and leaves<sup>[56]</sup>. The Moraceae family has the largest number of species that provide fruit for HB, mainly species of the genus *Ficus*. In addition, some species of the Anacardiaceae, Annonaceae, Ebenaceae, Guttiferae, Meliaceae, and Sapotaceae families also provide food for these species<sup>[57]</sup>. The GHB feeds on pollen, nectar, and flowers of coconut (*Cocos nucifera*), durian (*Durio zibethinus*), and on fruits of rambutan (*Nephelium lappaceum*), fig (*Ficus* sp.), and longan (*Lansium domesticum*). It also feeds on wild mango (*Mangifer indica*) and banana (*Muca*) trees in the wild or in orchards<sup>[41]</sup>. This bat can carry fruits weighing up to 200 g<sup>[56]</sup>. The LHB feeds on the fruits of papaya (*Carica papaya*), mango (*Mangifera indica*), linden (*Musa*), fig (*Ficus*), and Calophyllum inophyllum trees, and the flowers of banyan, kapok (*Ceiba*), and coconut (*Cocos nucifera*) trees<sup>[21,51,56]</sup>. Meanwhile, the food of THB is usually bananas, mangoes, and longans<sup>[18]</sup> (Vu Dinh Thong, 2004). They also eat some seeds, which play an important role in plant dispersal. The main sense of this species when searching for food is vision; they do not have the ability to locate by sound like insectivorous bats<sup>[40]</sup>.

#### 3.3.3. About the Disease

To date, researchers have identified two types of viruses that parasitize species of the HB genus, namely Nipah and Hendra viruses. According to Olson et al.<sup>[58]</sup> out of a total of 96 samples of THB in Cambodia, 11 samples contained antibodies to the Nipah virus. Sendow, et al. surveyed<sup>[59]</sup> 106 samples of GHB randomly purchased from markets in Java and Sumatra, Indonesia. The results showed that 32 samples were positive for Nipah virus and 19 samples con-

tained Hendra virus. Also in 2002, Nipah and Hendra viruses were isolated from the LHB and the GHB in Malaysia<sup>[60]</sup>.

Comments: Bats have two food sources: orchards and forest trees in natural and mangrove forests; orchards are paid attention to by farmers to prevent damage, natural forests are increasingly narrow due to the impact of aquaculture; so the food supply capacity is 50%, the scores of *Pteropus vampyrus* and *Pteropus lylei* are -0.5 points.

### 3.4. Horse Bat Protection Levels

#### 3.4.1. Current Status of Illegal Hunting and Trading

Within the scope of the project, the field survey team focused on collecting information on HB meat trading establishments and wild HB hunters provided by local people. At the business establishments, the survey content aimed to record the ability to trade HB meat, the source of HB supply,

and awareness of illegal trading behavior. For subjects who hunt wild HB, the focus was on recording information on the form of trapping, trapping location, consumption location, and trading price. The results of the information interviews revealed that there were 3 bat meat businesses and 1 wildlife hunter who had traps for wild HB, and 1 person was setting nets to trap bats. Information about the businesses and hunters for wild HB is listed in **Table 4**.

The 3 establishments that sell bat meat, 2 establishments in Tra Vinh city, have obscured the advertising information related to bats on their billboards. There is still 1 establishment in Cau Quang town that advertises on its signboard (**Figure 9**). All 3 establishments refused to supply wild horse bat meat for the reasons that horse bats are banned from trading, and they do not have horse bats to supply. However, the business activities and trade of wild fruit bats at these establishments with pre-processed specimens or live ones are still recorded.

**Table 4.** Information about businesses and illegal hunters.

Owner	Name	Coordinates	Activities	Specimen	Prices
Restaurant	Restaurant 1	9.921274, 106.355500	Wild Horse bats for sale	Bat meat has been pre-processed	250.000 VND/bat
Restaurant	Restaurant 2	9.912200, 106.335505	Wild horse bat advertisement on the menu	Horse bat meat has been pre-processed	250.000 VND/bat
Restaurant	Restaurant 3	9.772577, 106.132008	Hunting, Capturing, Advertising, and selling wild horse bats	30 individuals live	200.000 VND/bat
Hunter	Hunter	9.771096, 106.329647	Trapping and trading of wild horse bats	5 individuals live	200.000 VND/bat
Traps	Tranper	10.046367, 106.262727	Net trap to catch wild horse bats	A net is being spread to catch bats	300.000–500.000 VND/bat



**Figure 9.** The business advertises bat meat, and the specimens are being kept at the facility.

Regarding illegal hunting activities, there were 2 people who were hunting wild HB. Mr. Quang was a professional hunter. At the time of the survey, there were 5 THB being kept in a private home and were offered for sale to the survey team at a price of 200.000 VND/bat (Figure 9). The HB reported catching at the La Ca Pagoda (old), about 10 km away from Mr. Quang’s house. A case of hunting HB is taking place in Duc My commune, Cang Long district, using a trapping net. These people said the net was set up continuously for many days and was not banned by any authorities. The purpose of trapping HB here is to supplement family income at a price of 300.000–500.000 VND/bat. The possibility of catching HB is random, about 2–3 bats/week. Bat meat business owners are now very aware that trading in HB is illegal. There are no other food businesses supplying horse bat meat recorded in Tra Vinh province. However, illegal hunting activities still occur. So, where will illegal hunters consume it? In the future, it is necessary for the authorities to make more efforts to control the consumption of HB meat in the market.

### 3.4.2. Awareness of the Need to Conserve Horse bats

Of the 29 people who knew about HB, none thought it was necessary to conserve HB. Of the 5 people, 3 said they would be punished if they were caught hunting, trading, and consuming wild HB (17%); 24 people of them did not know that they would be punished if they hunted, traded, and consumed wild HB (83%). Thus, most interviewees, although aware that HB are rare, did not think it was necessary to conserve them and did not know that they would be punished if they participated in hunting, trading, and consuming wild HB meat. Based on the recorded data, it shows that people in areas where HB live and forage are not clearly aware of the need to conserve HB, as well as that this is a species protected by law. In the future, it is necessary to strengthen propaganda to raise awareness of people in the province to

increase people’s awareness of the conservation of wild HB.

### 3.4.3. Demand for Hunting Horse Bats

Interview information shows that the purpose of hunting is for meat, medicine, and especially for sale due to its high value. In addition, hunting is also used to protect fruit trees. On 7/29, people who know about HB think that this species is harmful to fruit gardens. Up to 17/29 people have eaten HB meat. Its source is from hunting or being given by others. There is one actively bought HB to use the meat. According to them, HB meat is delicious, nutritious, and can cure diseases. Only one person thinks that bat meat has a characteristic foul smell and is not delicious. The majority of the parts used are meat. In addition, blood is also used mixed with rice wine. Nowadays, HB are becoming increasingly rare, making it more difficult to catch them. Therefore, only a few people want to hunt them for trade due to their high market value. In Duc My commune, Cang Long district, HB has gradually appeared more in the past 2 years, and there have been cases of trapping in this locality. This shows that local people still have a need to hunt HB even though this species has not appeared in the locality for a long time.

### 3.4.4. Current Socio-Economic Situation of Tra Vinh Province

The population of Tra Vinh province is 1,009,322 people. The growth rate fluctuates at 0.05–0.07%. The majority of Tra Vinh’s population is distributed in rural areas, accounting for over 80% of the province’s total. The population structure by gender has remained almost unchanged from 2016 to the end of 2019, with males accounting for a lower proportion (49.23–49.25%) than females (50.75–50.77%). The urban population growth rate fluctuated around 0.85–1.26% from 2016 to 2019. However, in rural areas, the population growth index was negative, which shows that a part of the population is migrating from rural to urban areas at an increasing rate every year (Table 5).

Table 5. Area and population of Tra Vinh province.

Administrative Unit	Area (km <sup>2</sup> )	Population (People)	Population Density (People/km <sup>2</sup> )
Tra Vinh City	68.03	112,584	1665
Duyen Hai Town	175.1	48,210	275
Cang Long District	293.9	147,694	502
Cau Ke District	245	102,767	420
Tieu Can District	227.2	107,846	474,7
Chau Thanh District	343.1	144,040	419,8

Table 5. Cont.

Administrative Unit	Area (km <sup>2</sup> )	Population (People)	Population Density (People/km <sup>2</sup> )
Cau Ngang District	328.4	121,254	369,2
Tra Cu District	317.5	146,329	460,9
Duyen Hai District	305.4	78,444	256,9
Total	2,358.2	1,009,322	428.0

Source: Provincial Statistics, 2021.

Comments: There are there issues affecting this area: population pressure, high urban population rate, the number of people who think that bats are a delicacy and and medicine, the increase in bat meat restaurants, the number of professional bat hunters, the high price of bat trapping tools, so the threat to the GHB is high, it score of *Pteropus vampyrus* and *Pteropus lylei* is  $-0.5$ .

### 3.5. Horse Bat Conservation

*Current status of management and conservation of HB in Tra Vinh province:* Lam and Ly update<sup>[45]</sup> recorded a new habitat at La Ca Pagoda (old) (Nhi Truong commune, Cau Ngang district, Tra Vinh province) with 957 individuals of 2 species identified as LHB (*P. vampyrus*) and THB (*P. lylei*). Although the habitat has long been known and managed by the Tra Vinh Provincial Forest Protection Department, this is the first time it has been announced to Science. Previously, in Tra Vinh province, HB used to live at two locations: Giac Linh pagoda (My Long Bac commune, Cau Ngang district) and Lac Hoa pagoda (Thanh Hoa Son commune, Cau Ngang district, Tra Vinh province). Through interviews, it was learned that the HB at Giac Linh Pagoda had left a long time ago due to the impact of past wars that had driven them away. Meanwhile, around 2010, the number of bats at Lac Hoa Pagoda began to decrease, and they no longer lived there since a flock of waterfowl returned to the pagoda grounds. Whether the reason was that the flock of birds residing at Lac Hoa Pagoda had disturbed and driven away the HB here or not has not been clearly studied because so far there have been no similar cases recorded in the world. Given the fact that habitats in other areas are affected by unclear causes and new bat colonies have been recorded, the question of the current status of biodiversity conservation of HB species in Tra Vinh province has been raised. There is a practical need for research on the current distribution status as well as the conservation status of HB species in Tra Vinh province.

Horse bat conservation, also known as an ecological

nest, is a protected area for horse bat communities to be protected, inhabited, reproduced, and developed, which is denoted (Ehb).

The horse bat community is the number of heterospecific populations, with 2 or more species in the investigated population, denoted (Habh), where the unit is the number of individuals, and is compared after being surveyed twice.

Horse bat protection level is an assessment of the increase or decrease in the number of horse bats, carried out by measuring the actual number compared to the previous number according to a certain survey period, at least one breeding season, usually periodically, 1 year or several years, depending on the research conditions, and is denoted (Fsohb).

Horse bats' preferred food sources include natural forest foods and foods in orchards of farmers' farms, calculated according to the radius that horse bats can travel the farthest and return at night.

Survival level calculation formula for conserving the horse bat with the proposed formula:

$$Ehb = (Hchb + Hhhb) - (Hfhb + Hphb) \text{ (Figure 10)} \quad (1)$$

Hchb is assessed by the number of individuals kept stable without decreasing compared to the previous survey. It is also scored from 0.1; 0.2; 0.3; 0.4; 0.5; 0.6 .... 1.

Hhhb is assessed by living conditions that are protected safely in accordance with natural ecological conditions and is scored from 0.1, 0.2, 0.3, 0.4, 0.5, 0.6 .... 1.

Habh + Hcohb = or  $< 1$  is denoted

$$Hc.hhb = \frac{Hchb + Hhhb}{2} = or < 1 \text{ (Figure 10)} \quad (2)$$

Hfhb (Horse bat food) is a food source for Horse Bat. It is calculated by the abundance of fruit sources from forests or farms that the HB can forage for at night. It is also scored from  $-0.1, -0.2, -0.3; -0.4, -0.5; -0.6 \dots -1$ .

Hphb (Horse bat protection) is the conservation status of the HB in the region, as assessed by the level of hunting and the increasing loss of habitat. It is also scored from  $-0.1, -0.2, -0.3; -0.4, -0.5; -0.6 \dots -1$ .

$Hf_{hb} + H_{phb} = \text{or} < -1$  is denoted

$$Hf_{.phb} = Hf_{hb} + H_{phb} = \text{or} < -1 \text{ (Figure 10)} \quad (3)$$

If:  $Hc_{.hbb} - Hf_{.pb} = 0$  is extinct

If = 0.25 is critically endangered

If 0.50 is endangered,

If 0.75 is lowly endangered,

If = 1 is not endangered

Applied in the case of Tra Vinh:

For Great horse bat

$$E_{hb} = (H_{chb} + H_{hbb}) - (H_{f_{hb}} + H_{phb})$$

$$E_{hb} = (0.21 + 1) - (0.5 + 0.5) = 0.21$$

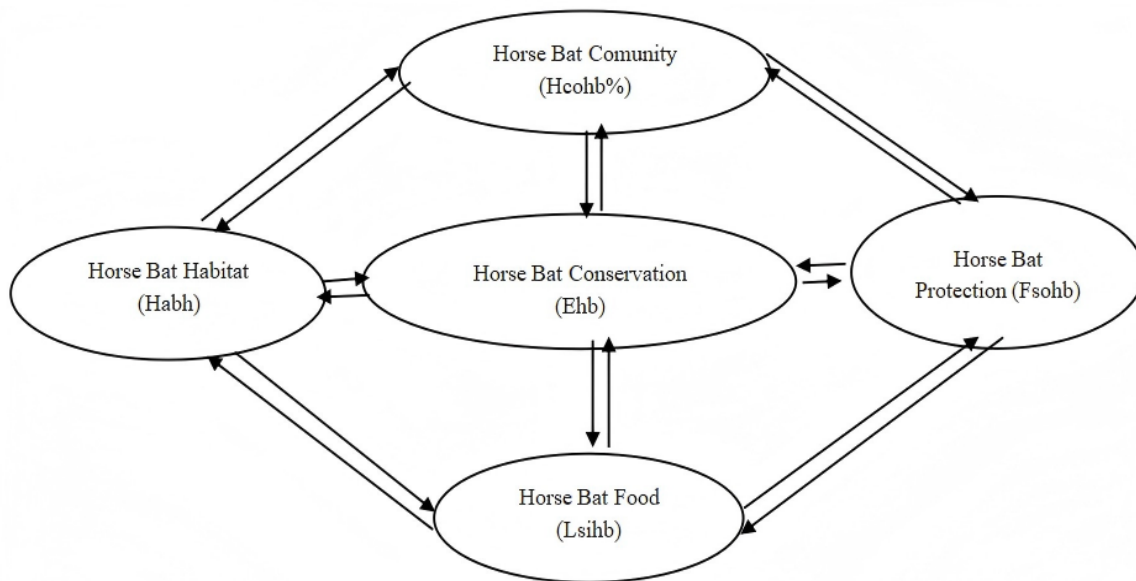
(It is in critically endangered)

For Thai horse bat

$$E_{hb} = (1 + 1) - (0.5 + 0.5) = 1$$

(It is not endangered)

This result shows *Pteropus vampyrus* is invaded by *Pteropus lylei* in the bat community in which they live.



**Figure 10.** Diagram of the mechanism of the formula for the relationship between conservation and development of horse bat communities.

## 4. Conclusions

Horse bat community (Hcohb%) in the August 2022 survey, the total bat individuals was 957; Thai Horse Bat (Thai Flying Fox) is 137 individuals, Large Horse Bat (Large Flying Fox) is 820 individuals. In December 2023, the total number of individuals is 1240 (THB 1072 individuals, LHB 168 individuals); LHB decreased is 79.51%, THB increased is 682% by 6.8 times. The general comment on the community is an increase of 252 individuals by 26%, but the population of LHB decreased by 79.51%. If the maximum score is 1, the score for LHB is 0.21 points.

Horse bat habitat (Habh). This is the old Khomer Pagoda, so planted *Dipterocarpus alatus* and *Hopea odorata* when it was established; the Khomer Pagoda is strictly protected; the thinking of Buddhism so killing animals is taboo

in the pagoda; so in this section, they can score according to the highest score system of 1 point, which is 1 point.

Horse bat food resource (Fsihb). Bats have two food sources: orchards and forest trees in natural and mangrove forests; orchards are paid attention to by farmers to prevent damage, natural forests are increasingly narrow due to the impact of aquaculture, so the food supply capacity is 50%, the score is -0.5 points.

Horse bat protection (Fsohb), there are there issues affecting this area: population pressure, high urban population rate, the number of people who think that bats are a delicacy and and medicine, the increase in bat meat restaurants, the number of professional bat hunters, the high price of bat trapping tools, so the threat to the GHB is high, its score is -0.5.

The formula for calculating the survival rate for horse

bat conservation, according to the proposed formula, applied to the case of Tra Vinh:  $Ehb = (Hahb + Hcohb) - (Fsohb + Lsihb)$  (1). The *Pteropus vampyrus*  $Ehb = (0.21 + 1) - (0.5 + 0.5) = 0.21$  is a critically endangered species, the *Pteropus lylei*  $Ehb = (1 + 1) - (0.5 + 0.5) = 1$  is a non-endangered species, and the *Pteropus vampyrus* is suddenly reduced in number due to the narrowing of food areas and hunting for food.

## Author Contributions

Conceptualization, L.T.Q., T.T.L., H.V.T., K.T.D. and D.M.; methodology, T.T.L.; validation, L.T.Q., T.T.L., H.V.T., K.T.D., D.M., P.H.G. and T.T.P.L.; formal analysis, L.T.Q., T.T.L., H.V.T., K.T.D., D.M., P.H.G. and T.T.P.L.; investigation, L.T.Q., T.T.L., H.V.T., K.T.D., D.M., P.H.G. and T.T.P.L.; data curation, L.T.Q., T.T.L., T.T.L., P.H.G. and T.T.P.L.; writing—original draft preparation, L.T.Q., P.H.G. and T.T.P.L.; writing—review and editing, L.T.Q., T.T.L., H.V.T., K.T.D., D.M., P.H.G. and T.T.P.L.; visualization, L.T.Q., H.V.T., K.T.D., D.M., P.H.G. and T.T.P.L.; supervision, H.V.T., K.T.D. and D.M.; project administration, L.T.Q., H.V.T., K.T.D. and D.M.; funding acquisition, L.T.Q., H.V.T., K.T.D. and D.M. All authors have read and agreed to the published version of the manuscript.

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Not applicable. This study does not involve humans or animals.

## Informed Consent Statement

Not applicable. All studies only study plants and soil. It is not related to humans; it only helps communities and governments to develop the economy.

## Data Availability Statement

These databases are by ourselves. Thus, we used to study and for our article, published in a Journal, can be shared

by the authors' group and the journal.

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## Conflicts of Interest

The authors declare no conflict of interest.

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