The NEF Bio-ecological Nature Conservation Project in Mountainous Region of North Vietnam

FINAL REPORT FOR 2018-2021

FISH GROUP

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1. GENERAL INFORMATION

1.1 Member of the project

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2. RESEARCH

2.1 Abstract

This is the final report of an ichthyofauna research in notthern Vietnam, which has been funded by the Nagao Natural Environment Foundation, Japan. This project attempts to elucidate the diversity, community structure and the distribution of the ichthyofauna in the karst forests of northeastern Vietnam based on morphological and molecular data; and to examine some biological characteristics of several fish species in the study site. The present study also indicates the importance of fisheries as well as conservation status of these animals in the study site. In addition, the project will help to strengthen the professional capacity of young researchers in ichthyology in Vietnam. One master student and four students from Hanoi National University of Education will involve in this study in order to complete their master and bachelor degrees.

Eight field surveys were conducted from October 2018 to November 2021 in northern Vietnam: two field trips in Cham Chu Nature Reserve (NR) of Tuyen Quang Province, two field trips in Bac Me NR of Ha Giang Province, two field trips in Phia Oac-Phia Den National Park (NP) of Cao Bang Province, and two field trips in Nam Xuan Lac Habitat and Species Conservation Area (HSCA) of Bac Kan Province. Taxonomic identification was based on morphological and molecular characteristics. The role of fisheries for local residents and status of fisheries resources were collected from the interview. Also, conservation concerns were evaluated based on direct observation in the field and interview with local authorities and residents.

Ichthyofauna: Based on laboratory analysis and direct observation in the field, a total of 75 species or more in 25 families and 8 orders were recorded from four study sites in northeastern Vietnam. Importantly, one new species was discovered from Phia Oac-Phia Den NP, *Euchiloglanis nami* sp.n., and many of them were unidentified species, which need to be further checked. In Cham Chu NR, a total of 49 species or more were obtained and all of them were new records for the study site. In Bac Me NR, a total of 39 species or more were documented, with many additional records for the study site. There were 19 species or more in Phia Oac-Phia Den NP (Cao Bang Province), and 24 species or more were obtained from Nam Xuan Lac HSCA (Bac Kan Province). The Cypriniformes were the most diverse with 8 families (accounting for 38%) in Bac Me NR, 7 families (accounting for 41%) in Cao Duong, and 6 families (accounting for 40%, 46% and 38%) in Phu Luu, Phia Oac-Phia Den NP and Nam Xuan Lac HSCA.

According to the IUCN Red List, four species classified as VU level occurring at sites: Cao Duong, Bac Me NR, Phia Oac-Phia Den NP. In Bac Me NR, Phia Oac-Phia Den NP, Nam Xuan Lac HSCA areas, there was also species *Onychostoma gerlachi* as NT level and the species *Pseudohemiculter dispar* only found in Cao Duong. The species *Rhinogobius lineatus* as EN was found in Nam Xuan Lac HSCA. Vulnerable species are distributed mainly in Cao Duong, followed by Bac Me NR, Phia Oac-Phia Den NP with 1 species.

The present study provides morphometrics of *S. namxamensis*, *N. benasi* and *R. similis*, which will be useful data for further studies on identification.

The *b* was higher than the isometric value of 3, indicating that *S. namxamensis* revealed a positive allometric growth, which implies the high adaptability of the species to the environment in the surveyed areas. It also shows that *R. similis* is positive allometric growth

(b > 3) and the condition factor (K) value is 1, indicating that this species is well adapted to the environmental conditions across northern Vietnam.

Several results of interviewees in the four areas reveal that fish were quite an important source of protein for the local community. Almost all interviewees recognized that income from aquatic products from the two rivers had been declining rapidly. The rates of decline during the past five and ten years ranged from 32-50% to 45-79%, respectively.

Some differences could be found among interviewed sites. In Cham Chu NR, many interviewees agreed that destructive gears used to catch fish is the reason to reduce the fishery resources, followed by the over-exploitation, introduced fish species, deforestation and water pollution, which are the two most important reasons in Bac Me. In Bac Me, the tourism activity is a different reason from the Cham Chu NR. However, interviewees from Cham Chu NR and Nam Xuan Lac HSCA said that fisheries production has recently recovered because destructive gears are forbidden and the awareness of local people to protect the resources is increasing.

Education and training:

- Chu Hoang Nam, a PhD student and Nguyen Trong Nghia, a master student of the Hanoi National University of Education, could be trained in sampling, fixation, photography, identification and making report.
- Tran Trung Thanh PhD, a young researcher, from the University of Science, Vietnam National University, Hanoi, could learn about studying on freshwater fishes.
- Nguyen Quang Huy, an undergraduate student, from Hanoi National University of Education, used materials from Cham Chu NR for his bachelor thesis.
- Vu Trung Hieu, an undergraduate student, from Hanoi National University of Education, used materials of *Rhinogobius* from the study site for his bachelor thesis.
- Nguyen Le Hoai Thuong, a master student of Hanoi National University of Education, has used the collection of *Rhinogobius* specimens from northeastern Vietnam for her master thesis. Her master course was completed in the middle of 2022.
- Duong Thi Huyen, an undergraduate student, from Hanoi National University of Education, will use materials of *Parazzaco* from the study site for her bachelor thesis.

- Nguyen Minh Thuy, an undergraduate student, from Hanoi National University of Education, will use materials of *Gambusia affinis* from the study site for her bachelor thesis.

Conservation concern: Data about species richness, new findings and conservation value of fish species from Cham Chu NR, Bac Me NR, Phia Oac-Phia Den NP and Nam Xuan Lac HSCA indicate an important role of limestone karst forests in biodiversity conservation in northern Vietnam. Based on this data, local authorities and decision makers can develop a conservation plan for each species and an appropriate operational program for each nature reserve. In the study sites, four species listed in the IUCN Red List should be priority to be protected. They are *Leptobotia elongata*, *Cyprinus carpio*, *Pseudohemiculter dispar*, and *Oreochromis mossambicus*. Especially, *Rhinogobius lineatus* as EN level needs to be further studied. Among four study sites, several sampling sites in Cham Chu NR and Bac Me NR should be in priority of conservation because vulnerable species are mainly reported from these two areas.

The project delivers several proposed recommendations for biodiversity conservation and planning. Firstly, further identification of unknown species should be done to have a full picture of species composition of fish in the study sites. Next, workshops with local residents and local authorities about fish diversity and fisheries resources will increase their awareness of conservation. Further investigations into the impacts of exotic fish species on native ecosystems will be important to propose a suitable conservation planning. Last, applying remote sensing will take in advantage to have a map for conservation.

Publications: As a result of our research, we published one paper on national conference in Vietnam, a new species for science was submitted and another manuscript using materials of *Rhinogobius* was accepted to publish in journal Acta Zoologica Bulgarica. Several papers will be published in the near future using the present study materials.

2.2 Background of the study

Tropical rain forests are recognized as ideal natural laboratories for taxonomic, natural history, and bio-geographic research (Dirzo & Raven 2003). Vietnam contains a large proportion of tropical rain forests, which are mainly located on high mountains in the northern part of the country and Truong Son Range. A wide range of elevations and the complexity of landforms have given the montane region a great diversity of natural habitats and a high level of biodiversity (Sterling et al. 2006). At present, a total of 700 species of freshwater fish have

been recorded in Vietnam (Tran et al., 2013). However, previous works on ichthyofauna indicate that many unidentified taxa still remain, and have problem in taxonomy, which should be further investigated.

The NEF Bio-ecological Nature Conservation Project in Mountainous Region of North Vietnam aims to explore the biodiversity and evaluate the conservation potentials of limestone karst forests of northeastern Vietnam. As a part of this project, the fish group intends to evaluate the species diversity, distribution pattern and conservation value of fish in four target protected areas, namely Phu Luu and Cao Duong commune in Cham Chu NR (Tuyen Quang Province), Bac Me NR (Ha Giang Province), Phia Oac-Phia Den NP (Cao Bang Province) and Nam Xuan Lac HSCA (Bac Kan Province).

2.3 Literature review

2.3.1 Natural features of the study area

Northern Vietnam has a high diversity in geology and environment, with a mixture of granite and limestone, uplands and delta, jagged peaks and humid lowlands, which is a potential to have high biodiversity. This diversity reflects northern Vietnam’s position near the intersection of the tropical and subtropical zones and the biotic influence of three biogeographic units: Indochina, south China, and coastal Indochina (Sterling et al., 2006). More importantly, there are several river basins in northern Vietnam, such as the Red River including the Lo and Gam tributaries and Thai Binh River, which flow through different topographic features, making the difference in aquatic environments.

The limestone mountains in the North of Vietnam are considered as one of the biodiversity hotspots. However, the data on fish here are very poor. In the context of increasing biodiversity losses, more comprehensive studies, including several regions, are required. Together with studies on economic and social aspects, this study will allow making a full assessment of the status of biodiversity as well as the pressures on the ecosystem.

2.3.2 Overview of study sites

Cham Chu Nature Reserve

Cham Chu was established under Decision No. 1536/QĐ-UBND dated 21/09/2001 of the People's Committee of Tuyen Quang. The geographical coordinates of the NR from

22°14’17” to 22°21’307”N, and from 104°53’27” to 105°14’16”E. The protected area with a total of 15,902.1 hectares is located in the five communes: Yen Thuan, Phu Luu in Ham Yen district, Ha Lang, Trung Ha and Hoa Phu in Chiem Hoa district. There are 29,703 persons belonging 6,832 families of eight groups people living in the Cham Chu NR. The most group people are Tay with about 15,522 persons, Dao with 7,343 persons, and Kinh with 4,749 persons. Almost local peoples are living based on agriculture and forestry.

There is no data on ichthyofauna and fisheries status in this study site until now.

Bac Me Nature Reserve

Bac Me NR was established under Decision No. 648/QD-UBND dated November 24, 1994 of the People's Committee of Ha Giang Province with a total natural area of 9,016.3 hectares. The Nature Reserver is located in the three communes: Lac Nong, Minh Ngoc and Thuong Tan in Bac Me district. The geographical coordinates according to VN2000 of the protected area are from 22°38’59” to 22°45’47”N, and from 105°07’40” to 105°16’35”E.

In this study site, there are two river basins, the Gam and Lo Rivers. In a review paper, Nguyen and Vo (1999) reported a total of 70 species, but they did not provide the sampling sites. Hence, it can be said that data on fish in Bac me NR still needs to explore.

Phia Oac - Phia Den National Park

Phia Oac - Phia Den National Park was established under Decision No. 57/QD-TTg of the Prime Minister, signed on January 11, 2018. The special mission is conservation of 90 threatened plant species. Phia Oac - Phia Den National Park has a total natural area of 10,593.5 hectares in 5 communes, Thanh Cong, Quang Thanh, Phan Thanh, Hung Dao and Tinh Tuc town of Nguyen Binh district, Cao Bang Province.

There is no data on ichthyofauna and fisheries status in this study site until now, though Nguyen (2018) make a list of fish from Bang Giang River, since a small part of this river basin is present in Phia Oac – Phia Den National Park.

Nam Xuan Lac HSCA

Nam Xuan Lac SHCA was approved by the People's Committee of Bac Kan province in Decision No. 342/QD-UB dated March 17, 2004, with a total natural area of 1,788 hectares,

located on the two Na Da and Ban Khang villages, Xuan Lac commune, Cho Don district, Bac Kan Province.

There is no data on ichthyofauna and fisheries status in this study site until now.

2.4 Group's purpose and subjects

Purpose

Purpose and subjects

1. This project aims to explore the diversity, the community structure and distribution of the ichthyofauna in the karst forests of northeastern Vietnam based on morphological and molecular data; and to examine some biological characteristics of several fish species in the study site;
2. The present study also indicates the importance of fisheries as well as conservation status of these animals in the study site;
3. In addition, the project will help to strengthen the professional capacity for young researchers in ichthyology in Vietnam. Five students from Hanoi National University of Education will involve in this study in order to complete their master and bachelor degrees.

Objectives

Specific objectives of this study are:

1. To evaluate the species diversity of fish in karst forests of northeastern Vietnam.
2. To understand distribution of fish species in different areas and river basins.
3. To examine biological traits of several fish species, which will be fundamental information for conservation;
4. To determine the importance of fisheries as well as conservation status of these animals in the study site.
5. To provide essential data for biodiversity conservation of the region. Based on the results of our surveys and referred to the published literature we will define the hot spots for the ichthyofauna conservation in northern Vietnam.

Subjects

Fish diversity value: Focussing on species diversity and their distribution.

Biological characteristics of some species.

Importance of fishery resources and conservation status.

Training: The research assistants were trained in the field work and in laboratory, especially in fixation, taking photos, data analysis and identification.

2.5 Materials and methods

2.5.1 In the field

Sampling sites

Eight field surveys were conducted in Tuyen Quang Ha Giang, Cao Bang, and Bac Kan provinces in the three years, from October 2018 to November 2021 (Figs. 1-5). Because two field trips in Cham Chu NR were conducted in different areas (Phu Luu and Cao Duong), this report will present ichthyofauna separately.

- Trip 1 from 24 to 31 October 2018 in Cham Chu Nature Reserve, Phu Luu Commune, Ham Yen District, Tuyen Quang Province.
- Trip 2 from 19 to 26 April 2019 in Cham Chu Nature Reserve, Cao Duong Village, Yen Thuan Commune, Ham Yen District, Tuyen Quang Province.
- Trip 3 from 5 to 12 July 2019 in Bac Me Nature Reserve, Minh Ngoc, Thuong Tan, Lac Nong communes, Bac Me District, Ha Giang Province.
- Trip 4 from 24 to 31 December 2019 in Bac Me Nature Reserve, Minh Son and Minh Ngoc communes, Bac Me District, Ha Giang Province.
- Trip 5 from 23 to 30 July 2020 in Phia Oac-Phia Den National Park, Nguyen Binh District, Cao Bang Province.
- Trip 6 from 23 to 30 July 2020 in Nam Xuan Lac Habitat and Species Conservation Area, Cho Don District, Bac Kan Province.
- Trip 7 from 5 to 12 May 2021 in Phia Oac-Phia Den National Park, Nguyen Binh District.
- Trip 8 from 5 to 12 November 2021 in Nam Xuan Lac, Cho Don District.

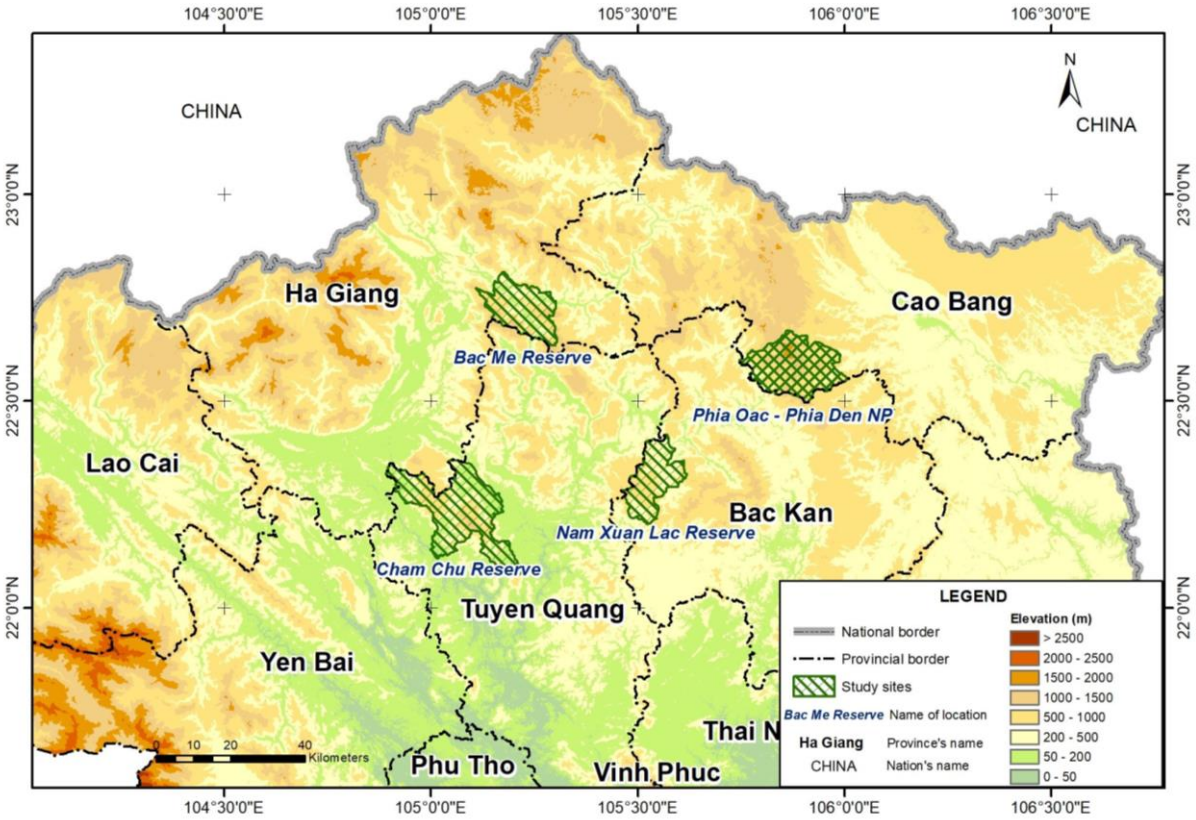

Figure 1. Four sites for ichthyofauna studies in northern Vietnam.

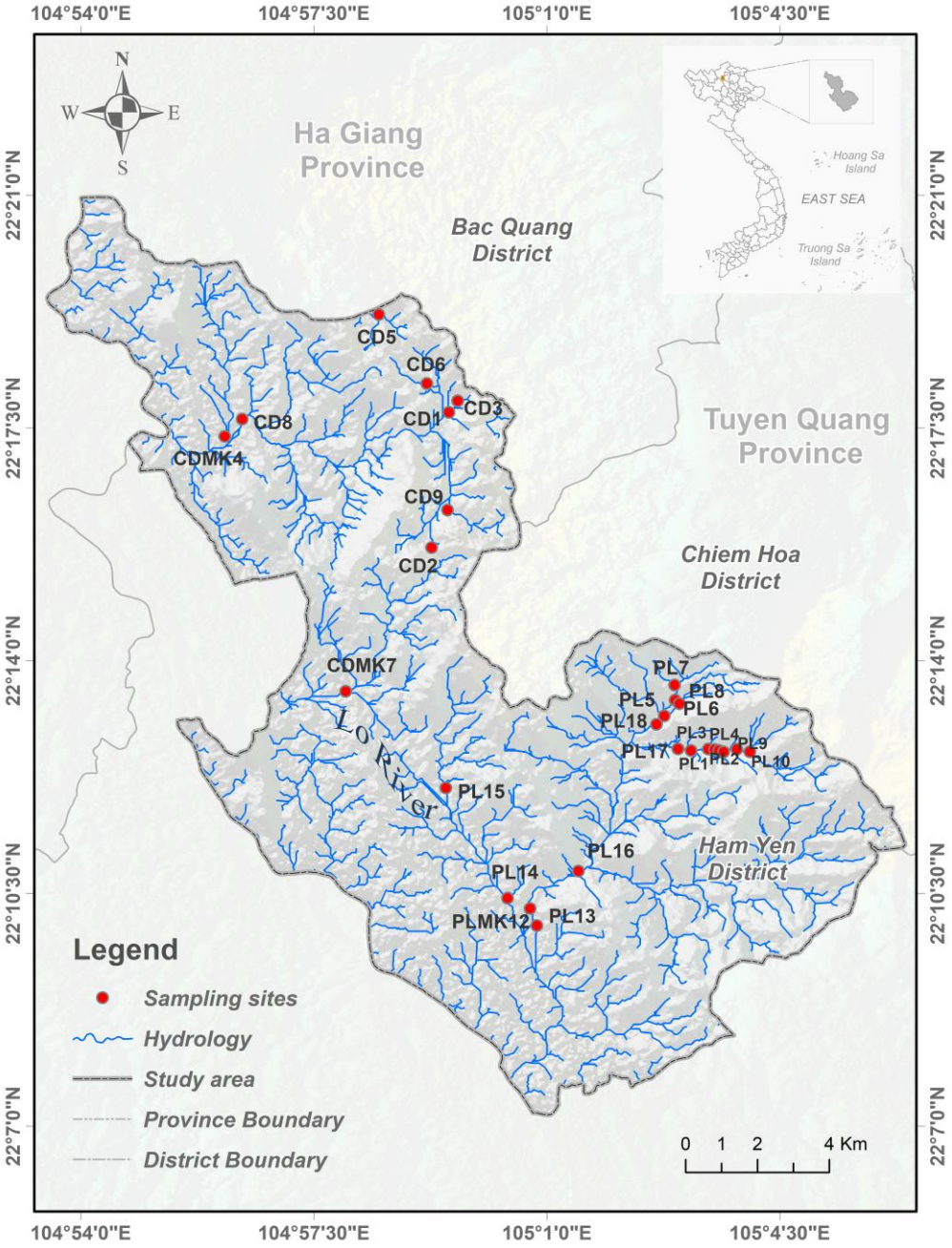

Figure 2. Sampling sites for ichthyofauna study in Cham Chu NP (Tuyen Quang Province) in 2018 and 2019. All these sampling sites belong to the Lo river basin.

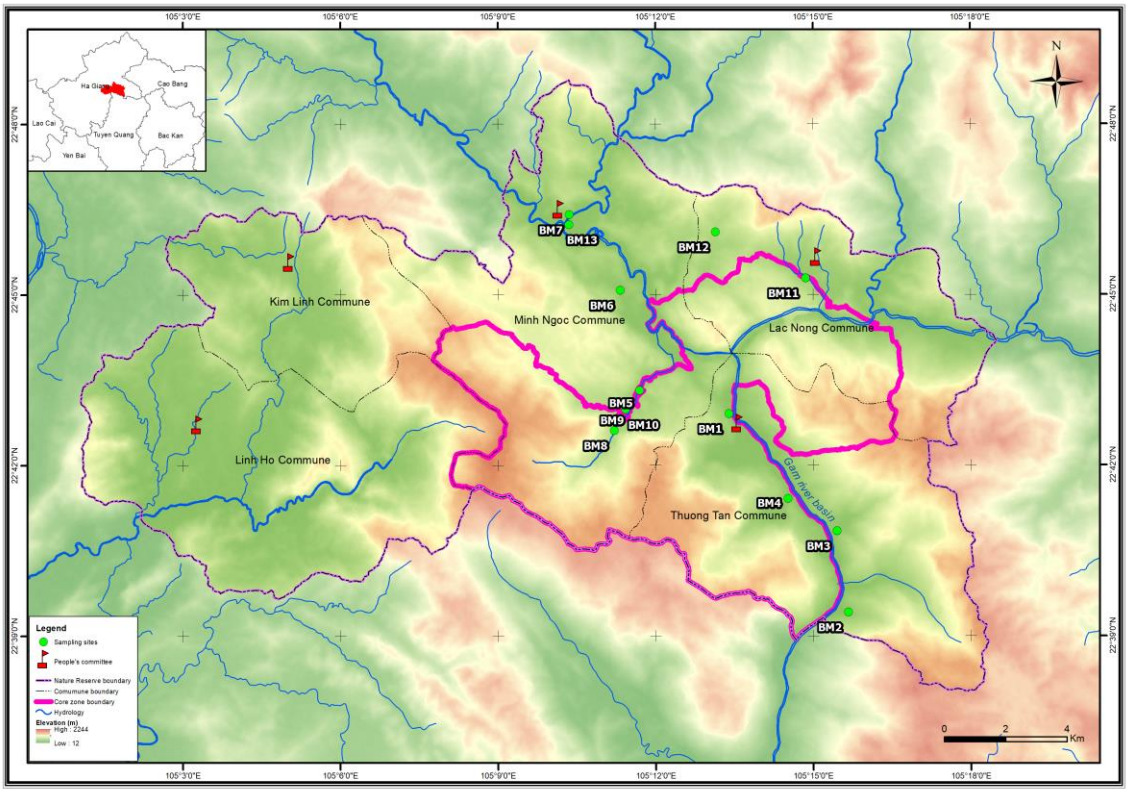

Figure 3. Sampling sites for ichthyofauna study in Bac Me NP (Ha Giang Province) in 2019. All these sampling sites belong to the Gam river basin.

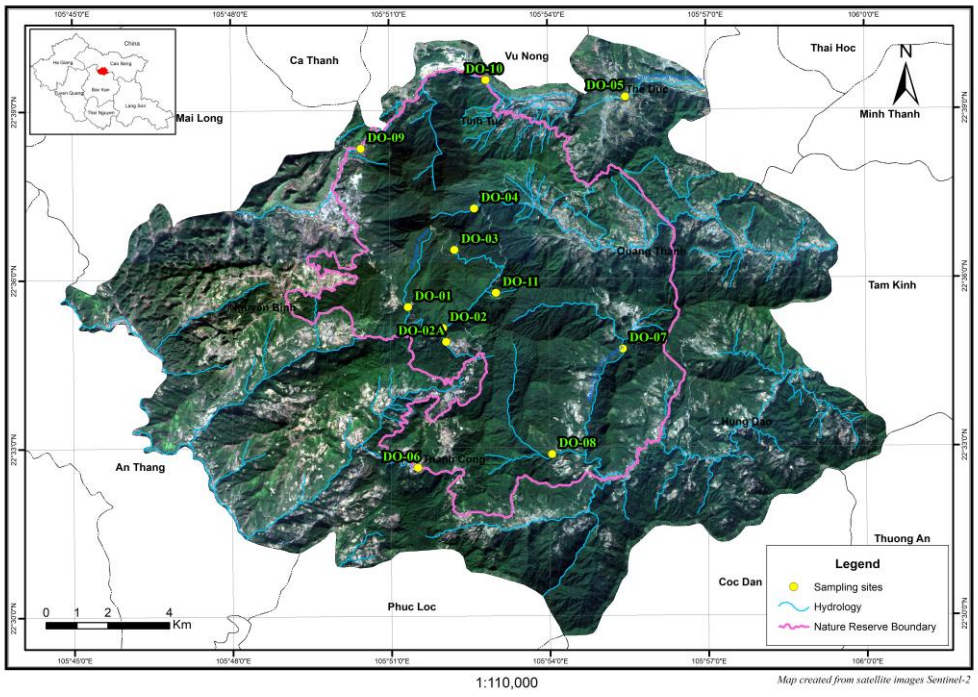

Figure 4. Sampling sites for ichthyofauna study in Phia Oac-Phia Den NP (Cao Bang Province) in 2020 and 2021. Sampling sites DO-01-04, DO-06 are in the Gam river basin, and the rest in Bang Giang river basin.

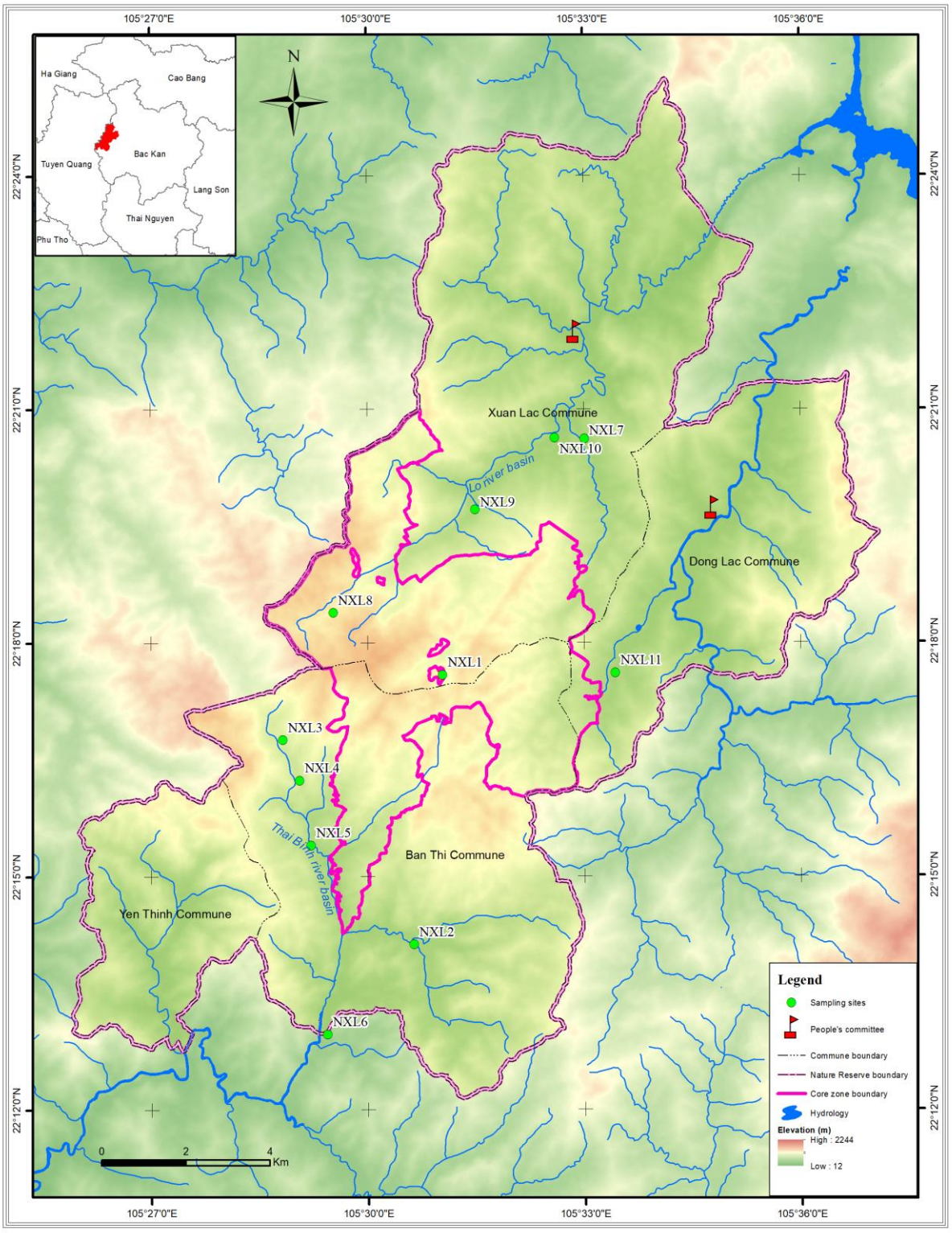

Figure 5. Sampling sites for ichthyofauna study in Nam Xuan Lac HSCA (Bac Kan Province) in 2020 and 2021. Sampling sites NXL2-6 are in the Lo river basin, and the rest in Thai Binh river basin.

Table 1. Sampling sites at the four study sites in 2018 to 2021.

Site	N	E	Elev. (m)	Habitats
Field trip 1 from 24th to 31st October 2018 in Tuyen Quang Province				
P1	22°12'37"	105°03'28"	198	Narrow stream inside the forest; medium speed current; gravel and sandy bottom; both the sides fringed by plant
P2	22°12'39"	105°03'32"	175	Upper reach of Kieng stream inside the forest; large; strong speed current; gravel, sand, and aquatic plant such as mosses in bottom; both the sides fringed by plant
P3	22°12'38"	105°03'35"	176	Upper reach of Kieng stream inside the forest; large; strong speed current; gravel, sand and aquatic plant such as mosses in bottom; both the sides fringed by plant
P4	22°12'38"	105°03'39"	180	Upper reach of Kieng stream inside the forest; large; strong speed current; stone, sand and aquatic plant such as mosses in bottom; both the sides fringed by plant; near a dam
P5	22°13'12"	105°02'44"	145	Narrow branch of Kieng stream flowing into Stn. P2, 3, 4; medium speed current; small pits on the bottom
P6	22°13'38"	105°02'56"	314	Large and inflow cave
P7	22°13'24"	105°02'56"	197	Narrow, turbid and medium speed current stream flows through orange farm into the Kieng stream
P8	22°13'21"	105°02'59"	189	Narrow, turbid and medium speed current stream flows through orange farm into the Kieng stream
P9	22°12'36"	105°03'52"	239	Narrow stream near the orange farm in the forest
P10	22°12'38"	105°04'03"	341	Waterfall in the forest, strong current. Water body was green tea color and composed by some layer
P11	22°12'39"	105°02'58"	106	Kieng stream; near the center of commune; large stream flows through the orange farm, gravel, sand, aquatic plant such as mosses in bottom, both the site fringed by plant
P12	22°10'01"	105°00'51"	64	Local market near the People's Committee of Phu Luu Commune

P13	22°10'16"	105°00'45"	17	Medium stream flows through the orange farm; muddy and sandy bottom; slow current
P14	22°10'26"	105°00'26"	22	Medium stream; sandy bottom; slow current; 15-20 km from the camp
P15	22°12'05"	104°59'29"	36	Medium stream near the residential compound; sandy bottom composed some depth (0-1 m) pits; slow current
P16	22°10'52"	105°01'27"	42	Narrow stream belongs to the Kieng stream system; near the road (from People's Committee to the camp); both the sides fringed by plant; slow current; sandy and muddy bottom; following a dam
P17	22°12'38"	105°03'10"	165	Kieng stream near the camp; large; gravel and sandy bottom
P18	22°13'02"	105°02'39"	140	Large stream near the cave flows into the Kieng stream; medium speech current; bottom with some depth pits
Field trip 2 from 19th to 26th April 2019 in Tuyen Quang Province				
P1	22°17'44"	104°59'32"	610	Small stream, low water current, sandy bottom, shallow water. Fringed by secondary forest, shrubs
P2	22°15'41"	104°59'16"	662	Xuan Nhay stream Small stream, slow water current, sandy-muddy bottom with larger stones. Secondary forest, aquatic plants. Small ponds.
P3	22°17'29"	104°59'29,2"	648	Water cave
P4	22°17'22,3"	104°56'10,4"	61,2	Yen Thuan market
P5	22°19'12,4"	104°58'29"	672	Nam Huc stream Small stream, slow water current, sandy-muddy bottom, with large stones. The sides fringed by shrubs, bamboo forest
P6	22°18'9,6"	104°59'14,6"	725	A reservoir, with 1 km length and 100 widths.
P7	22°13'32,2"	104°57'59,2"	84	Minh Khương market
P8	22°17'38,2"	104°56'26,3"	54	Yên Thuận stream Large stream, medium water current gravel bottom, water grass
P9	22°16'13"	104°59'34"	678	Xuân Nhảy stream, another branch. Many aquatic plants, large stone and water cavity. Above with water fall, clear water

Field trip 3 from 5th to 12th July 2019 in Ha Giang Province				
BM0	22°46'241"	105°10'209"	133	Minh Ngoc market (all fish collected from Na Hang reservoir)
BM1	22°51'551"	105°52'774"	92	Na Hang reservoir in Ha Giang province, stillness water, fish cage farming
BM2	22°41'001"	105°15'444"	161	Water fall, sandy and rocky bottom, secondary forests, clear water
BM3	22°40'599"	105°15'272"	156	Quite large stream, lower part with water fall, rocky bottom and the higher part with paddy field, quite clear water, near residential
BM4	22°41'470"	105°14'401"	133	Large stream, medium speed water current and sharp rocky at the bottom, clear water
BM5	22°43'335"	105°11'536"	223	Quite large stream, slow water current, muddy and sandy bottom, with paddy rice field, quite clear water.
BM6	22°45'120"	105°11'197"	149	Small stream, slow water current, sandy and muddy bottom, with residential houses, shallow water
BM7	22°42'665"	105°11'096"	243	Quite large stream, water fall, medium water current, rocky bottom, both the sides fringed by plants, clear water
BM8	22°43'201"	105°11'441"	207	Small stream, medium water current, sandy and gravel bottom, fringed by plants, clear water
BM9	22°43'121"	105°11'419"	232	Small stream, slow water current, rocky bottom, fringed by shrubs, clear water
BM10	22°43'044"	105°11'308"	238	Small stream, water fall, rocky and muddy bottom, inside forest, clear water
BM11	22°45'355"	105°14'744"	208	Small stream, medium water current, gravel bottom, quite high turbidity, one side with paddy field and the other one with shrubs
Field trip 4 from 24th July to 31st December 2019 in Ha Giang Province				
BM5	22°43’335”	105°11’536”	223	Quite large stream, slow water current, muddy and sandy bottom, with paddy rice field, quite clear water.
BM7	22°42’665”	105°11’096”	243	Quite large stream, water fall, medium water current, rocky bottom, both the sides fringed by plants, clear water
BM11	22°45’355”	105°14’744”	208	Small stream, medium water current, gravel bottom, quite high turbidity, one

				side with paddy field and the other one with shrubs
BM12	22°46’132”	105°10’211”	121	Large stream, medium water current, gravel and sandy bottom, some ponds next to the main course, with rice field.
BM13	22°45’365”	105°14’796”	325	Narrow stream, medium speed current, gravel and stone bottom, very clean water, both the sides fringed by plants
Field trip 5 from from 20th to 27th May 2020 in Cao Bang Province				
DO.01	22°44’181”	105°13’038”	1062	Narrow stream, medium speed current, stone and sandy bottom. Places where fishes collected were slow water current in the rice field, next to aquaculture pond
DO.02	22°35’197”	105°51’903”	1005	Narrow stream inside the forest; medium speed current with sandy bottom, and some parts with high speed current in stone and gravel bottom; both the sites fringed by plants
DO.03	22°36’555”	105°52’083”	1603	Narrow stream inside the forest; medium speed current; gravel and sandy bottom; both the sites fringed by plants, next to the Tungsten mine. **No fish**
DO.04	22°37’300”	105°52’489”	1202	Narrow stream inside the forest; high speed current; stone and sandy bottom; both the sites fringed by plants. **No fish**
DO.05	22°39’289”	105°55’339”	503	Wide stream near the local village; medium speed current; gravel, muddy and sandy bottom, next to the aquaculture pond
DO.06	22°32’708”	105°51’422”	686	Narrow stream next to local residents; medium speed current; gravel, muddy and sandy bottom.
DO.07	20°34’731”	105°55’407”	762	Wide stream inside the forest; medium speed current; gravel and sandy bottom.
DO.08	22°32’53”	105°54’03”	741	Narrow stream inside the forest; medium speed current; gravel bottom.
DO.09	22°38’378”	105°50’339”	1008	Narrow stream next to rice field; medium speed current; gravel, sandy bottom. **No fish**
DO.10	22°39’599”	105°52’710”	726	Wide stream next to main road; slow speed current; gravel sandy bottom, next to the Cao Bang Tungsten mine. **No fish**
DO.11	22°39’599”	105°52’709”	1281	Narrow stream inside the forest; slow

				speed current; gravel, stone bottom. **No fish**
Field trip 6 from 23rd to 30th July 2020 in Bac Kan Province				
NXL.01	22°17'35.292"	105°31'2.717"	760	Ponds in a valley, swamp, corn field
NXL.02	22°14'7.638"	105°30'38.507"	342	Narrow stream, slow speed current, gravel, muddy bottom.
NXL.03	22°16'45.210"	105°28'49.884"	531	Narrow stream inside forest, medium speed current, gravel, sandy bottom.
NXL.04	22°16'13.949"	105°29'3.690"	514	Narrow stream next to the corn field, medium speed current, gravel, sandy bottom.
NXL.05	22°15'24"	105°29'13"		Narrow stream next to agricultural land, high speed current, gravel, stone bottom.
NXL.06	22°12'58.271"	105°29'26.429"	277	Wide stream next to local resident, falls, stone bottom, some stillness water with muddy bottom.
NXL.07	22°20'37.115"	105°33'0.972"	307	Narrow stream next to the local residents and agricultural land, medium speed current,
NXL.08	22°18'23.1839"	105°29'31.818"		Narrow stream in the core zone of the protected area, stillness water, muddy-sandy bottom
NXL.09	22°19'42.623"	105°31'29.957"		Wide stream inside the forest, medium speed current, gravel and stone bottom.
NXL.10	22°17'36.720"	105°33'26.244"		Narrow stream, medium speed water, gravel and sandy bottom.
NXL.11	22°17’370”	105°33’260”		Wide stream, rain, high speed current, gravel bottom.
Field trip 7 from from 5th to 12th May 2021 in Cao Bang Province				
DO-01	22.59291º	105.85365º	1062	Narrow stream, medium speed current, stone and sandy bottom. Places where fishes collected were slow water current in the rice field, next to aquaculture pond.
DO-02	22.58666º	105.86500º	1005	Narrow stream inside the forest; medium speed current with sandy bottom, and some parts with high-speed current in stone and gravel bottom; both the sites fringed by plants.
DO-02A	22.58241º	105.86557º	967	Narrow stream next to the ricefield and ponds; slow speed current with sandy bottom

DO-06	22.54510º	105.85658º	686	Narrow stream next to local residents; medium speed current; gravel, muddy and sandy bottom.
DO-07	22.58033º	105.92156º	762	Wide stream inside the forest; medium speed current; gravel and sandy bottom.
Field trip 8 from 5th to 12th November 2021 in Bac Kan Province				
NXL.03	22⁰16'14"	105º29'02"	531	Wide stream, rain, high speed current, gravel bottom.
NXL.05	22º15'22"	105º29'20"	466	Narrow stream, medium speed water, gravel and sandy bottom.
NXL.06	22º12'53"	105º29'25"	277	Wide stream inside the forest, medium speed current, gravel and stone bottom.
NXL.07	22º20'04"	105º34'54"	307	Narrow stream next to the local residents and agricultural land, medium speed current.
NXL.09	22º19'45"	105º31'27"	281	Wide stream inside the forest, medium speed current, gravel and stone bottom.
NXL.10	22º21'57"	105º32'48"	181	Narrow stream, medium speed water, gravel and sandy bottom.
NXL.11	22º17'37"	105º33'26"	306	Wide stream, rain, high speed current, gravel bottom.

Fish collection and fixation

Fish were collected by hand nets, casting nets and gill nets during day time. Specimens caught by local people or collected from local markets were also used for the study. Specimens were initially fixed in 10% formalin solution in the field, and subsequently preserved in 5% formalin in the laboratory. About three days later, they were transferred in to 70-80% ethanol solution and stored in the lab. For molecular study, muscle and pectoral or pelvic fins were cut when fish were still alive and preserved in 99% ethanol, and stored in suitable conditions.

Specimen photography

We conducted underwater observations to observe their natural life and take photographs. After collection, some fish were taken photos through a small transparent aquarium. Preserved specimens were put in a tray and photographed in daylight. We additionally prepared a light system at the night time or in a dark place. Photos of some fish in four protected areas are present in appendices 1 and 2.

Interviews

Interviews with questionnaires from local people and fishers were carried out from 18 interviewees for Cham Chu NR, 18 for Bac Me NR, 02 for Phia Oac-Phia Den NP and 6

for Nam Xuan Lac HSCA. Interviews with questionnaires about role, status, exploitation and protection of fishery resources in the area were made with local people and fishers who have had good experiences in fishing at the site. The questionnaire (Appendix 1) was designed partly according to previous literatures (e.g. Toi et al. 1996, Hori et al. 2006, Tran and Ta, 2014).

We carried out the following activities for the above surveys: issuing questionnaires in combination with interviews with fishers or local residents in the research; organizing some gatherings of interviewees and chairing the discussion in each area.

2.5.2 Methods used in the lab

Observation, Measurement and Counting. Measurements followed main documents of ichthyology and using a binocular microscope for small fish and a caliper for large specimens. Measurements and counting are different from fish groups (Figs. 6-8).

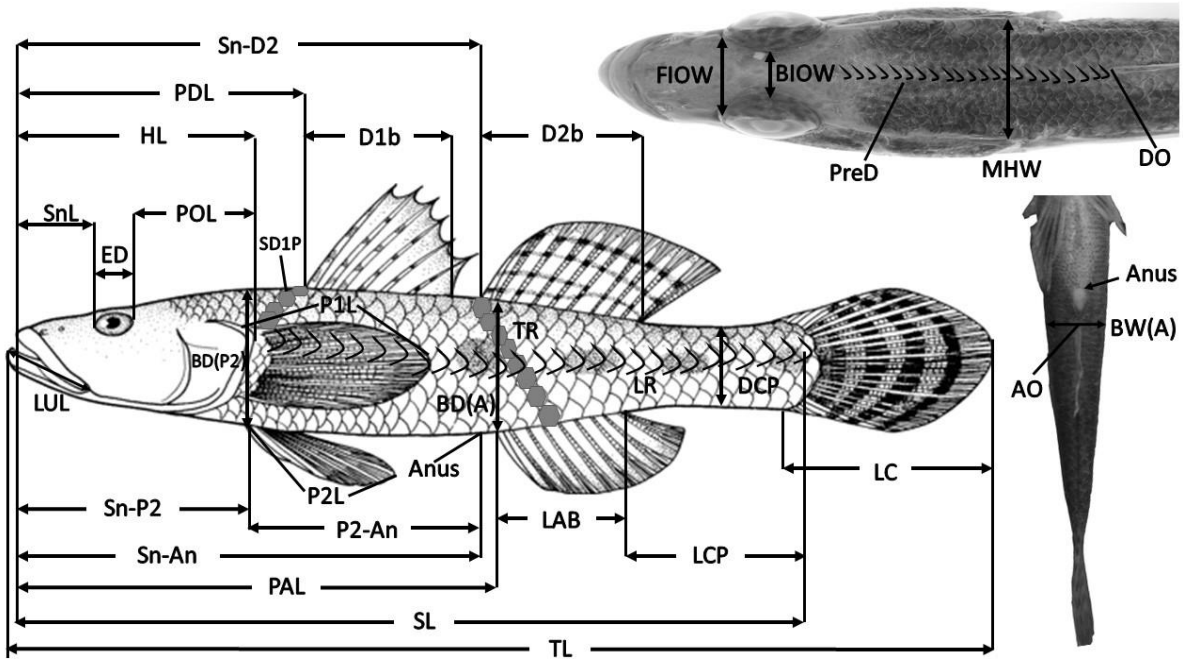

Figure 6. Measurement and counting of a goby (Modification from Nakabo, 2002)

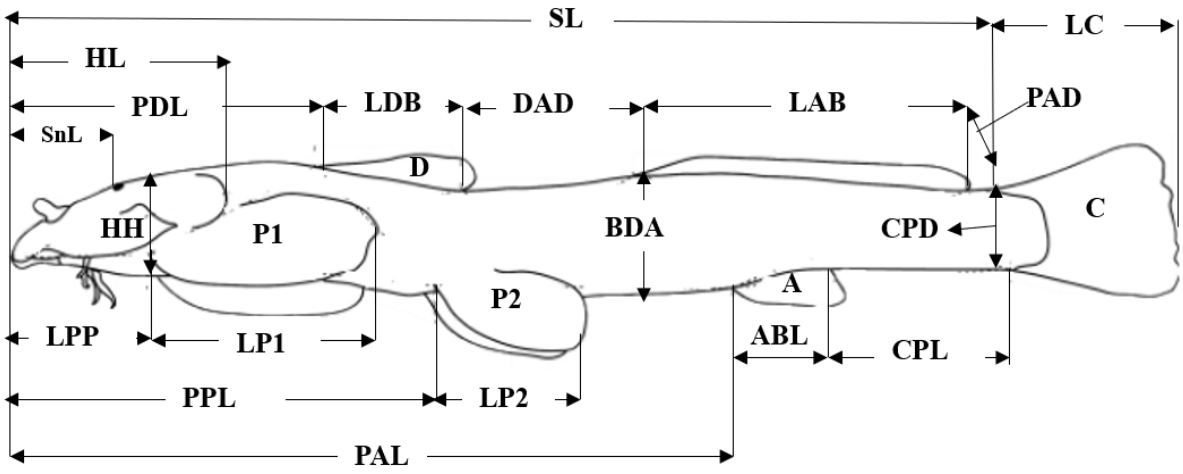

Figure 7. Measurement and counting of a catfish (Modification from Kang et al., 2016)

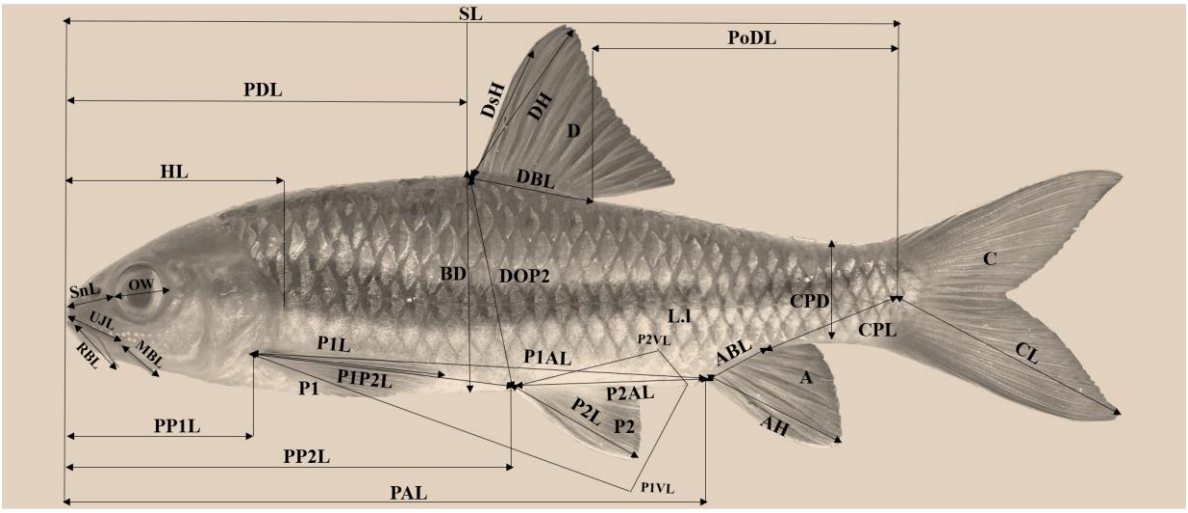

Figure 8. Measurement and counting of mahseer (Modification from Rainboth, 1996)

HL: head length; PDL: predorsal length; BDA: Body depth at anus; PAL: Preanal length; PPL: Prepelvic length; LPP: Prepectoral length; LDB: Length of dorsal-fin base; LAB: Length of adipose-fin base; DAD: Dorsal to adipose distance; PAD: Post-adipose distance; ABL: anal base length; LP2: Pelvic-fin length; LP1: Pectoral-fin length; CPL: caudal peduncle length; CPD: caudal peduncle depth; LC: Caudal-fin length; SnL: Snout length. Other measurements: ED: Eye diameter; IOW: Interorbital distance; HW: head width at pectoral-fin base; HH: head height at pectoral-fin base; NBL: Nasal barbel length; MBL: Maxillary barbel length; OMBL: Outer mandibular barbel length; IMBL: Inner mandibular barbel length. MHW, maximal head width; AO, anal fin origin; DO, dorsal fin origin; TR, transverse scale series; LR, longitudinal scale rows; PreD, predorsal scale rows; SD1P, scale series from origin of first dorsal fin to upper pectoral origin.

Identification. Identification was done based on morphology and main documents of ichthyology in Vietnam and nearby areas, including Mai (1978), Chen et al. (1998), Yue et

al. (2000), Nguyen & Ngo (2001), Nguyen (2005), Kottelat (2001a, b) and several recent publications. All specimens were deposited in the Department of Zoology, Faculty of Biology, Hanoi National University of Education, Vietnam.

Classification. The arrangement of orders and families followed Eschmeyer (online version November 2021), genus and species were ordered alphabetically.

Conservation status of threatened species was referred to the Vietnam Red Data Book (2007); IUCN Red List (2021); CITES appendices (2019); the Governmental Decree No. 06/2019/ND-CP; and the Governmental Decree No. 64/2019/ND-CP. The endemic species of Vietnam are species that currently known only from Vietnam.

Length weight relationship and condition factor. Four species, *Sinileotris namxamensis*, *Gambusia affinis*, *Rhinogobius* sp. and *Rhinogobius similis* collected from the study site were used to examine length-weight relationship and condition factor.

Data analysis

DNA

DNA sequencing of 18 individuals of *Rhinogobius* spp. collected from Bac Me, Phia Oac-Phia Den and Nam Xuan Lac and four specimens of *Neolissochilus* collected from Bac Me and Nam Xuan Lac were conducted and compared with available data from gen banks in order to determine species level.

BLAST: Using Geospiza's FinchTV software, the DNA sequencing chromatograms are interpreted to eliminate the baseline noise and obtain more reliable results. The chosen sequences are exported in FASTA format. Obtained sequences are individually analyzed with Nucleotide BLAST using the web platform of National Center for Biotechnology Information (NCBI) to find regions of similarity between sample sequences and the other sequences published on GenBank Database. "Standard databases" is chosen for the search set with Megablast in the Program Section. Three out of among received results, which have the highest score with 100% query cover and highest identity percent, will be chosen to be reported.

Phylogenetic trees construction: Based on DNA sequencing and BLAST results, phylogenetic trees are constructed using MEGA X Software (Molecular Evolutionary Genetics Analysis). First, all obtained sequences from DNA sequencing are aligned, using Align DNA function. ClustalW algorithm with default settings is used in creating

alignments. Then, a Neighbor – Joining phylogenetic tree is constructed (the applied settings are described on the Fig. 9). Finally, based on obtained BLAST results and constructed phylogenetic tree, 1 to 2 sequences from each group of samples, which seem to be most reliable, are chosen to construct a general phylogenetic tree with other 5 most similar species in *Rhinogobius* genus.

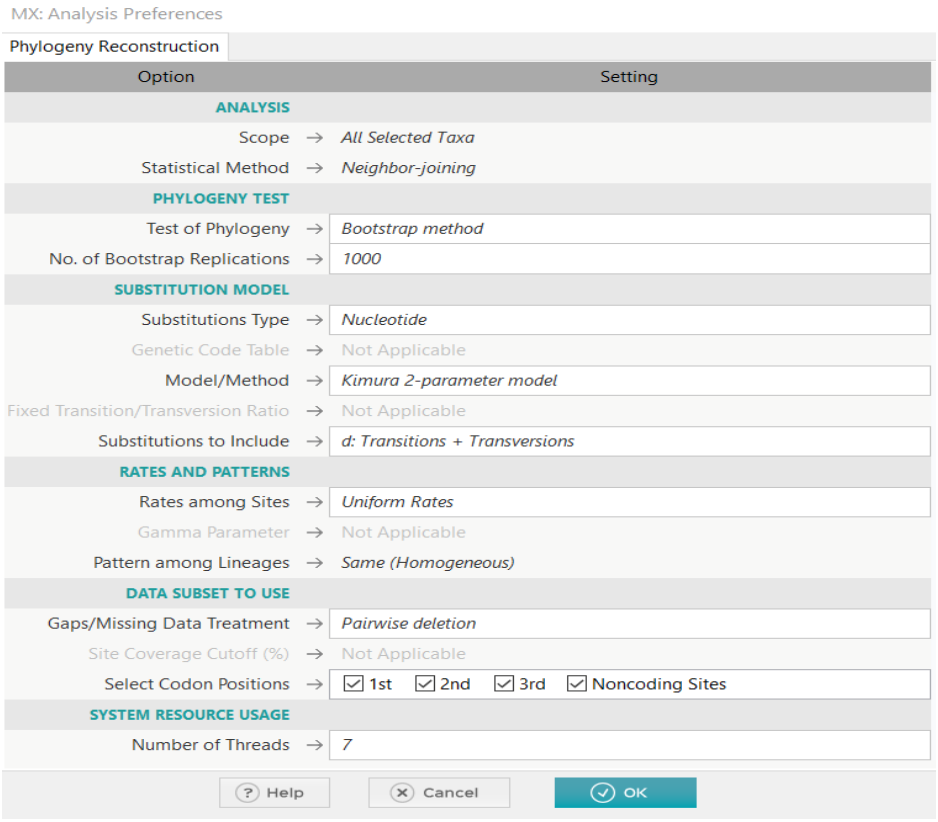

Figure 9. The setting for phylogenetic trees construction using MEGA X Software

LWR and K

The LWR for each species was estimated by the regression equation $W = aL^b$ where a and b are parameters of the equation (Le Cren, 1951; Ricker, 1973; Froese 2006). Before regression analysis, obvious outliers were removed by linear regression of the log-transformed equation (Froese, 2006). In addition, the 95% confidence interval (CI) of the parameters and the statistical significance of the regression relationships (R^2) were calculated and statistically. Fish were divided into isometric (I) growth types if the slope value was equal to three , positive allometric growth (+A) type if the slope was higher than three, and negative allometric growth (-A) if the slope was lower than three (Froese, 2006).

The K of the fish was estimated following Le Cren (1951) using the equation $K = \frac{W}{aSL^b}$, where W is the fish weight (g), SL is the standard length (cm), and a and b are the regression coefficients. The K value of each fish group (divided by location, sex,

developmental stage, and season) was compared with the ideal value of one ($K = 1$) using a one-sample t-test, and values were compared among fish groups by t-test, Wilcoxon test, or Kruskal-Wallis test depending on the distribution of data and equality of sample sizes among groups. R software version 4.0.5 was used for statistical analyses (R CORE TEAM 2021); the FSA package was used to perform regression analyses (OGLE et al. 2020) and the ggplot2 package to produce the figures (WICHKHAM 2016). The level of significant difference for all statistical tests was set at $p < 0.05$.

Similarity index: Using of Primer 6 to understand the similarity of ichthyofauna between areas and river basins.

2.6 Results

2.6.1 Fish diversity and distribution in 4 protected areas

DNA analysis of *Rhinogobius* spp. collected from northern Viet Nam

Initially, DNA data show that *Rhinogobius* collected from Nam Xuan Lac HSCA seemed close to *R. virgigena*, those from Phia Oac-Phia Den NP as *R. duospilus*, and from Bac Me as either *R. virgigena* or *R. duospilus* (Table 2). Morphometrics reveals different results when the population from Bac Me NR is *R. mekongianus* and that from Phia Oac – Phia Den NP as *R. duospilus*. Sequences of these two species are not available on the gen bank. In addition, *Rhinogobius* in Nam Xuan Lac HSCA could be identified as *R. Lineatus* and one unknown species. Hence, we will compare our dataset with those from Japanese ichthyologists to provide exact taxonomic position of these collections. These data are under preparation for publication.

Table 2. Details of DNA analysis of *Rhinogobius* from northern Vietnam

Sample	BLAST					
	CytB			R-RAG2		
	Scientific Name	E value	Per. Ident	Scientific Name	E value	Per. Ident
NXL 27	***R. virgigena***	2.E-111	91.44%			
	R. duospilus	4.E-108	90.03%			
	R. cliffordpopei	2.E-70	82.99%			
NXL 28	***R. virgigena***	1.E-117	95.57%			

	R. duospilus	1.E-112	94.46%			
	R. ogasawaraensis	2.E-74	85.98%			
NXL 29	***R. virgigena***	2.E-140	95.33%			
	R. duospilus	4.E-137	94.70%			
	R. rubromaculatus	7.E-100	87.81%			
NXL 30	***R. virgigena***	4.E-86	91.19%			
	R. duospilus	1.E-76	88.65%			
DO 35	***R. duospilus***	0.E+00	96.74%			
	R. virgigena	0.E+00	95.01%			
	R. changtinensis	0.E+00	89.62%			
DO 36	***R. duospilus***	2.E-156	96.48%			
	R. virgigena	1.E-152	95.88%			
	R. changtinensis	1.E-118	89.97			
DO 39	***R. duospilus***	3.E-71	98.12%			
	R. virgigena	4.E-64	95.60%			
	R. rubromaculatus	2.E-52	91.67%			
DO 39[2]	***R. duospilus***	1.E-100	97.29%			
	R. virgigena	7.E-99	96.83%			
	R. changtinensis	3.E-82	92.31%			
BM 54	***R. duospilus***	2.E-114	95.79%			
	R. virgigena	4.E-111	95.02%			
	R. changtinensis	3.E-93	91.12%			
BM 54[2]	***R. duospilus***	2.E-52	95.56%			
	R. virgigena	2.E-52	95.56%			
	R. changtinensis	4.E-44	91.85%			
BM 55	***R. virgigena***	3.E-103	94.35%			
	R. duospilus	3.E-103	93.38%			
	R. changtinensis	6.E-80	88.71%			
BM 55[2]	***R. virgigena***	5.E-157	95.73%	***R. similis***	5.E-100	97.29%
	R. duospilus	2.E-150	94.59%	*R. brunnues*	2.E-94	95.48%
	R. changtinensis	2.E-121	89.71%	*R. kurodai*	2.E-93	95.48%
BM 56	***R. duospilus***	8.E-56	95.74%			
	R. virgigena	8.E-56	95.74%			
	R. changtinensis	2.E-47	92.20%			
BM 59	***R. duospilus***	2.E-140	95.33%			
	R. virgigena	2.E-140	95.33%			
	R. changtinensis	3.E-109	89.66%			
BM 60	***R. virgigena***	2.E-68	95.32%			
	R. duospilus	8.E-67	94.74%			
	R. changtinensis	4.E-60	92.40%			
BM 61	***R. virgigena***	4.E-96	95.58%			
	R. duospilus	2.E-94	95.13%			
	Fusigobius melacron	8.E-73	89.38%			

Blast results

Obtained BLAST results with name of the scientific name of species, E value and identity percentage are reported in table 3 and Fig. 10.

Table 3. **BLAST results.**

Sample	**BLAST Results**		
	Scientific Name	**E value**	**Per. Ident**
NXL 27	*R. virgigena*	2.E-111	91.44%
	R. duospilus	4.E-108	90.03%
	R. cliffordpopei	2.E-70	82.99%
NXL 28	*R. virgigena*	1.E-117	95.57%
	R. duospilus	1.E-112	94.46%
	R. ogasawaraensis	2.E-74	85.98%
NXL 29	*R. virgigena*	2.E-140	95.33%
	R. duospilus	4.E-137	94.70%
	R. rubromaculatus	7.E-100	87.81%
NXL 30	*R. virgigena*	4.E-86	91.19%
	R. duospilus	1.E-76	88.65%
DO 35	*R. duospilus*	0.E+00	96.74%
	R. virgigena	0.E+00	95.01%
	R. changtinensis	0.E+00	89.62%
DO 36	*R. duospilus*	2.E-156	96.48%
	R. virgigena	1.E-152	95.88%
	R. changtinensis	1.E-118	89.97
DO 39	*R. duospilus*	1.E-100	97.29%
	R. virgigena	7.E-99	96.83%
	R. changtinensis	3.E-82	92.31%
BM 54	*R. duospilus*	2.E-114	95.79%
	R. virgigena	4.E-111	95.02%
	R. changtinensis	3.E-93	91.12%
BM 55	*R. virgigena*	5.E-157	95.73%
	R. duospilus	2.E-150	94.59%
	R. changtinensis	2.E-121	89.71%
BM 56	*R. duospilus*	8.E-56	95.74%
	R. virgigena	8.E-56	95.74%
	R. changtinensis	2.E-47	92.20%
BM 59	*R. duospilus*	2.E-140	95.33%
	R. virgigena	2.E-140	95.33%
	R. changtinensis	3.E-109	89.66%

BM 60	*R. virgigena*	2.E-68	95.32%
	R. duospilus	8.E-67	94.74%
	R. changtinensis	4.E-60	92.40%
BM 61	*R. virgigena*	4.E-96	95.58%
	R. duospilus	2.E-94	95.13%
	Fusigobius melacron	8.E-73	89.38%

Phylogenetic trees construction

Overall, the phylogenetic tree (Fig. 11) showed that there are noticeable differences between three groups of specimens, as generally each group belong to a separate branch. The branch with BM61 and NXL30 can be considered as an error due to the baseline noise in their sequencing results, which affects greatly to the tree construction. Besides, the NXL specimens and DO specimens likely to share more common in comparison to the specimens of BM group. However, there are inconsistences in the specimens of BM group position in the tree, hence further analyze should be conducted. Five different alignments were built to construct phylogenetic trees.

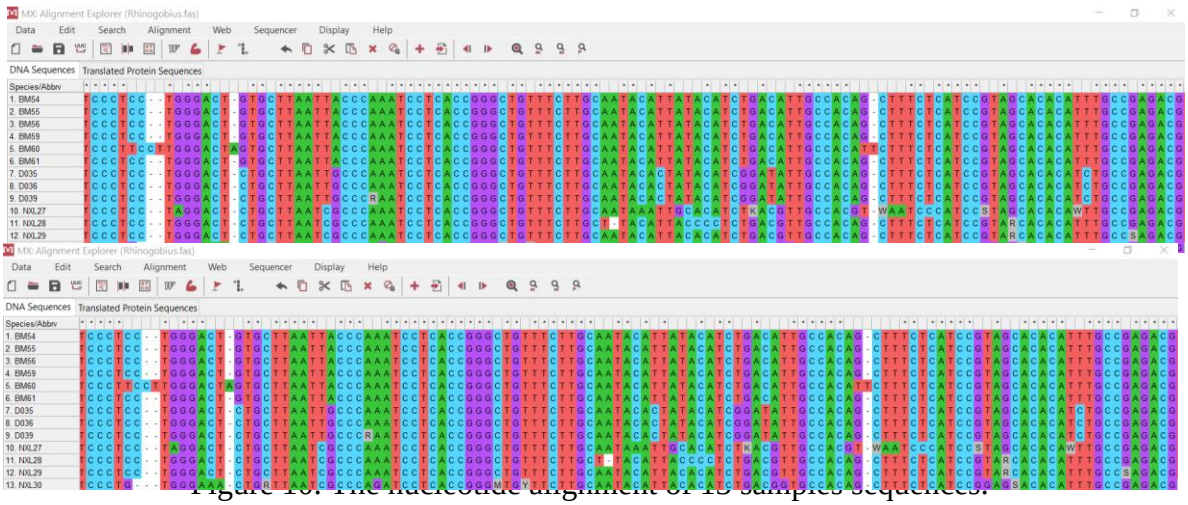

Figure 10. The nucleotide alignment of 13 samples sequences.

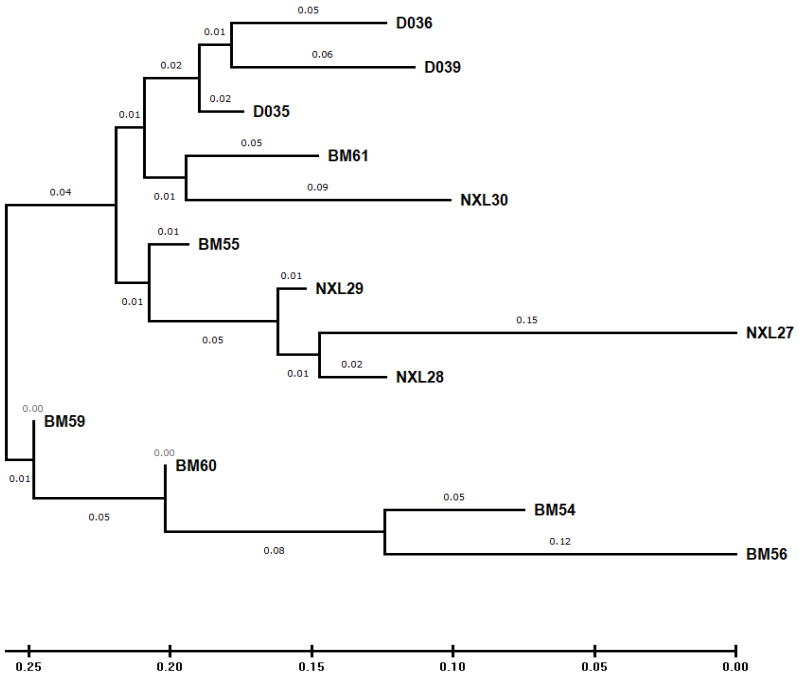

Figure 11. Phylogenetic tree of the collected specimens based on partial cytB sequence data.

Finally, based on obtained BLAST results and constructed phylogenetic trees, five specimens, which seem to have the most reliable sequencing data, were selected to build a phylogenetic tree in relate to others 5 identified species of *Rhinogobius* (Fig. 12). The tree showed that the specimen captured from Phia Oac - Phia Den NP (DO35) has the nearest relationship with *R. duospilus*. Otherwise, specimens collected from Bac Me NR (BM 54, BM 55) and Nam Xuan Lac HSCA (NXL 28, NXL 29) have a high similarity but they still belong to another branch, which is closely related to *R. virgigena*. Four specimens of *Neolissochilu*s collected from Bac Me NR and Nam Xuan Lac HSCA were identified as *Neolissochilus benasi* (Table 4). All these data will be published in the near future.

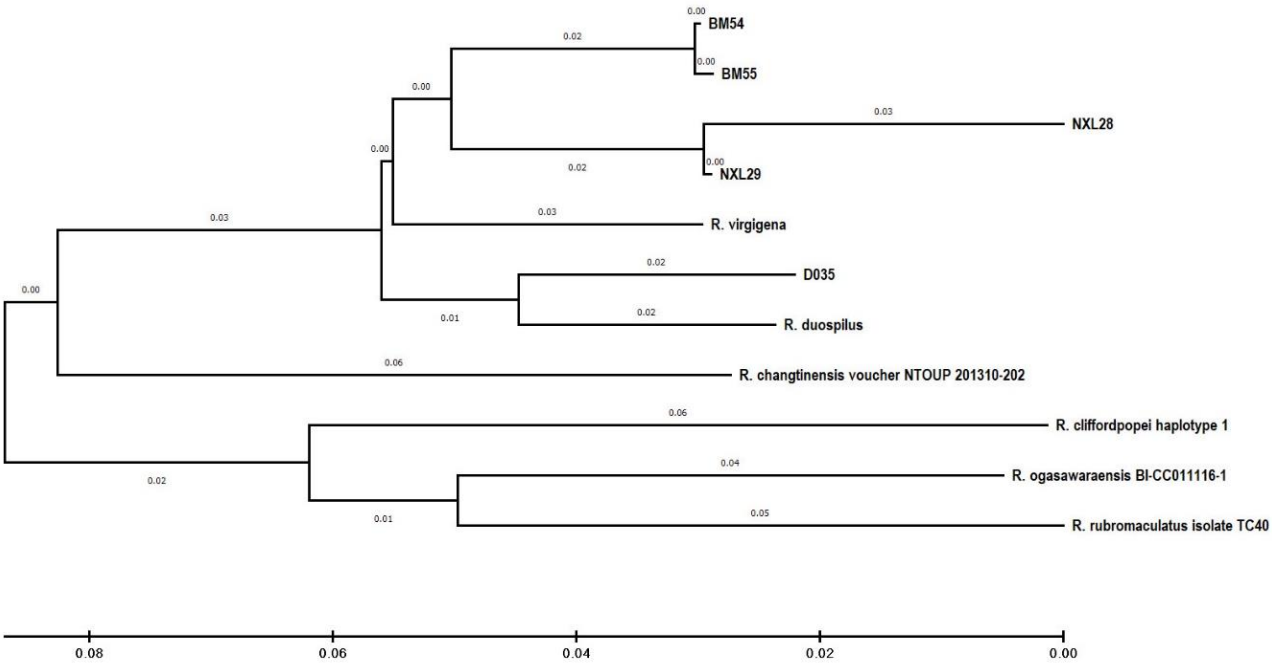

Figure 12. Phylogenetic tree of selected samples and *Rhinogobius* species based on partial cytB sequencing data.

Table 4. Sequenced results of *Neolissochilus* sp. collected from Bac Me NR and Nam Xuan Lac HSCA, northern Vietnam.

No	Site	Species	Gen	Base (bp)	Compared sequence in Gengank
1	Nam Xuan Lac	*Neolissochilus benasi*	COI	628	99,68%
2	Nam Xuan Lac	*Neolissochilus benasi*	COI	628	99,68%
3	Bac Me	*Neolissochilus benasi*	COI	630	99,68%
4	Bac Me	*Neolissochilus benasi*	COI	629	99,68%

Ichthyofauna characteristics

Based on the analysis results of 2319 specimens collected in the study area during the period from 2018 to 2021, we have built a list of fish in 4 nature conservation areas in northern Vietnam, with 75 species belonging to 25 families and 8 orders (Table 5). As can be observed from table 5, there are numerous unknown species, which will require more investigations based on morphometrics and molecular to identify them.

Table 5. A list of fish collected in the four protected areas, northern Vietnam.

	Scientificname	Vietnamese name	Study areas					IUCN	NĐ 26
			1	2	3	4	5		
	I. Cypriniformes	**Bộ Cá Chép**							
	1. Botiidae								
1	*Leptobotia elongata* (Bleeker, 1870)	Cá Chạch cát đốm		+				VU	
	2. Cobitidae	**Họ cá Chạch**							
2	*Misgurnus anguillicaudatus* (Cantor, 1842)	Cá Chạch bùn		+	+				
	3. Gastromyzontidae	**Họ Cá chạch bám**							
3	*Liniparhomaloptera* cf. *qiongzhongensis*		+		+	+	+		
4	*Vanmanenia* cf. *caldwelli*					+	+		
	4. Balitoridae	**Họ cá Chạch vây bằng**							
5	*Beaufortia pingi* (Fang, 1930)	Cá Bám khuyết pingi				+			
	5. Nemacheilidae	**Họ Cá Chạch suối**							
6	*Schistura* spp.	Cá Chạch suối	+	+	+	+	+		
7	*Traccatichthys taeniatus* (Pellegrin & Chevey 1936)	Cá Chạch cật		+					
	6. Cyprinidae	**Họ Cá Chép**							
8	*Barbodes semifasciolatus* (Günther 1868)	Cá Đòng đong	+		+	+	+		
9	*Carassius auratus* (Linnaeus, 1758)	Cá Diếc mắt đỏ		+		+			
10	*Cyprinus carpio* Linnaeus, 1758	Cá Chép		+	+	+		VU	
11	*Garra orientalis* Nichols, 1925	Cá Sứt mũi		+					
12	*Neolissochilus benasi* (Pellegrin & Chevey, 1936)	Cá Rai	+	+	+		+		I
13	*Neolissochilus* sp.	Cá Mi					+		
14	*Onychostoma gerlachi* (Peters, 1881)	Cá Sỉnh gai nhỏ			+	+	+	NT	II
15	*Onychostoma lepturus* (Günther, 1896)	Cá Phao			+		+		
16	*Osteochilus salsburyi* Nichols & Pope 1927	Cá Dầm đất		+	+				
17	*Spinibarbus hollandi* Oshima, 1919	Cá Chày đất			+				II
	7. Danionidae								
18	*Rasbora steineri* Nichols &	Cá Mại sọc			+				

	Pope, 1927								
	8. Xenocyprididae								
19	*Aphyocypris normalis* Nichols & Pope, 1927	Cá Dầm suối thường		+					
20	*Chanodichthys erythropterus* (Basilewsky, 1855)	Cá Thiểu		+					
21	*Culter flavipinnis* Tirant, 1883	Cá Ngão gù		+					
22	*Hemiculter elongatus* Nguyen & Ngo, 2001	Cá Vền dài?			+				
23	*Hemiculter leucisculus* (Basilewsky, 1855)	Cá Mương xanh		+	+				
24	*Megalobrama terminalis* (Richardson, 1846)	Cá Vền			+				
25	*Megalobrama skolkovii* Dybowski, 1872	Cá Vền			+				
26	*Metzia formosae* (Oshima, 1920)	Cá Mại bạc		+	+				
27	*Opsariichthys minutus* Nichols, 1926	Cá Cháo thường	+	+	+		+		
28	*Parazacco* sp.	Cá Chuôn				+	+		
29	*Pseudohemiculter dispar* (Peters, 1881)	Cá Dầu sông mỏng		+				VU	
30	*Sinibrama affinis* (Vaillant, 1892)	Cá Nhác		+					
31	*Toxabramis houdemeri* Pellegrin, 1932	Cá Dầu hồ cao			+				
32	*Toxabramis swinhonis* Günther, 1873	Cá Dầu hồ bằng		+					
33	*Xenocypris davidi* Bleeker, 1871	Cá Mần			+				
	9. Acheilognathidae								
34	*Acheilognathus* sp.	Cá Thè be	+	+					
35	*Acheilognathus tonkinensis* (Vaillant, 1892)	Cá Thè be thường		+					
36	*Rhodeus* cf. *albomarginatus*	Cá Bướm		+					
37	*Rhodeus ocellatus* (Kner, 1866)	Cá Bướm chấm	+		+		+		
	10. Gobionidae								
38	*Discogobio microstoma* (Mai, 1978)	Cá Bám sừng			+	+	+		
39	*Discogobio* spp.				+	+			
40	*Gobiobotia meridionalis* Chen & Cao, 1977	Cá Đục râu		+					

41	*Hemibarbus* cf. *umbrifer*	Cá Đục ó lạng sơn		+		+			
42	*Hemibarbus medius* Yue, 1995	Cá Đục ngộ		+					
43	*Microphysogobio elongatus* (Yao & Yang, 1977)	Cá Đục đanh chấm			+				
44	*Placogobio bacmeensis* Nguyen & Vo, 2001	Cá Thui	+	+	+		+		
45	*Saurogobio dabryi* Bleeker, 1871	Cá Đục đanh đốm		+	+				
46	*Squalidus argentatus* (Sauvage & Dabry de Thiersant, 1874)	Cá Đục trắng mỏng		+	+				
	II.Siluriformes	**Bộ Cá Da trơn**							
	1. Bagridae	**Họ Cá Lăng**							
47	*Hemibagrus centralus* Mai, 1978	Cá Lăng quảng bình	+						
48	*Hemibagrus pluriradiatus* (Vaillant, 1892)	Cá Lăng đen		+			+		II
49	*Pseudobagrus vachellii* (Richardson, 1846)	Cá Mầm			+				
50	*Tachysurus fulvidraco* (Richardson, 1846)	Cá Bò đen		+					
51	*Tachysurus kyphus* Mai, 1978	Cá Mịt tròn		+					
52	*Tachysurus virgatus* (Oshima, 1926)	Cá Mịt		+					
	2. Sisoridae	**Họ Cá Chiên**							
53	*Euchiloglanis* sp.	Cá Chiên pớm				+			
54	*Glyptothorax honghensis* Li, 1984	Cá Chiên suối sông Hồng	+	+	+		+		
	3. Siluridae	**Họ Cá Nheo**							
55	*Pterocryptis cochinchinensis* (Valenciennes, 1840)	Cá Thèo	+	+					
56	*Pterocryptis* sp.	Cá Niết			+				
57	*Silurus asotus* Linnaeus, 1758	Cá Nheo		+					
	4. Clariidae								
58	*Clarias fuscus* (Lacepède, 1803)	Cá Trê đen				+	+		
	5. Cranoglanididae	**Họ cá Ngạnh**							
59	*Cranoglanis henrici* (Vaillant, 1893)	Cá Ngạnh thường			+				
	III. Gobiiformes	**Bộ Cá bống**							
	1. Odontobutidae								
60	*Sineleotris namxamensis* Chen & Kottelat, 2004	Cá Bống nhỏ	+	+	+				

	3. Gobiidae	**Họ Cá bống trắng**							
62	*Rhinogobius duospilus* (Herre, 1935)	Cá Bống suối	+	+		+			
63	*Rhinogobius honghensis* Chen, Yang & Chen, 1999	Cá Bống khe	+						
64	*Rhinogobius lineatus* Chen, Kottelat & Miller, 1999						+	EN	
65	*Rhinogobius mekongianus* (Pellegrin & Fang, 1940)	Cá Bống mê kông			+				
61	*Rhinogobius similis* Gill, 1859	Cá Bống đá	+	+	+				
66	*Rhinogobius* sp.		+	+			+		
	IV. Synbranchiformes	**Bộ Cá Mang liền**							
	1. Mastacembelidae	**Họ Cá Chạch sông**							
67	*Mastacembelus armatus* (Lacepède, 1800)	Cá Chạch sông	+	+			+		
	2. Synbranchidae	**Họ Lươn**							
68	*Monopterus albus* Zuiew, 1793	Lươn thường				+	+		
	V. Anabantiformes	Bộ Cá rô đồng							
	1. Anabantidae								
69	*Anabas testudineus* (Bloch, 1792)	Cá Rô đồng			+				
	2. Osphronemidae	**Họ cá Tai tượng**							
70	*Macropodus opercularis* (Linnaeus, 1758)	Cá Đuôi cờ thường		+	+	+	+		
	3. Channidae								
71	*Channa gachua* (Hamilton, 1822)	Cá Chành dục			+	+	+		
	VI. Cichliformes	**Bộ Cá rô phi**							
	1. Cichlidae	**Họ Cá rô phi**							
72	*Oreochromis mossambicus* (Peters, 1852)	Cá Rô phi đen		+				VU	
73	*Oreochromis niloticus* (Linnaeus, 1758)	Cá Rô phi vằn	+	+	+		+		
	VII.Cyprinodontiformes	**Bộ Cá bạc đầu**							
	1. Poeciliidae	**Họ Cá ăn muỗi**							
74	*Gambusia affinis* (Baird & Girard, 1853)	Cá Ăn muỗi	+	+	+	+	+		
	VIII.BELONIFORMES	**Bộ Cá Nhái**							
	1. Adrianichthyidae	**Họ Cá Sóc**							
75	*Oryzias pectoralis* Roberts, 1998	Cá Sóc vây ngực	+	+					

Total	20	44	39	19	24		

Study site: 1: Phu Luu, 2: Cao Duong, 3: Bac Me NP, 4: Phia Oac-Phia Den NR, 5: Nam Xuan Lac HSCA

In Phu Luu of Cham Chu NR, a total of 20 species or more in 17 genera of 15 families were recorded (Table 6). Cypriniformes was the most diverse in the present study (6 families, accounting for 40%) with Siluriformes placed in the second (3 families, accounting for 20%) and Gobiiformes with 2 families (accounting for 13%), Synbranchiformes, Cichliformes, Cyprinodontiformes and Beloniformes (1 family, accounting for 7%). Cypriniformes were also the most common order in terms of number of species (8 species, accounting for 40%), followed by Gobiiformes (5 species, accounting for 25%) (Table 6). In Cao Duong of Cham Chu NR, a total of 44 species or more in 36 genera of 17 families were recorded. Cypriniformes, Siluriformes and Gobiiformes were the most common orders (Table 6). Synbranchiformes, Anabantiformes, Cichliformes, Cyprinodontiformes, Beloniformes recorded 1 genus for each.

In Bac Me NR, 39 species or more of 35 genera in 21 families were collected. Cypriniformes was the most diverse in the present study (8 families, accounting for 38%) with Siluriformes placed in the second (4 families, accounting for 19%) and Anabantiformes, Cichliformes placed in the third with 3 families (accounting for 14%), Gobiiformes with 2 families (accounting for 10%), Cyprinodontiformes with 1 family (accounting for 5%) (Table 6). This research did not record species of Synbranchiformes and Beloniformes in Bac Me NR.

In the Phia Oac-Phia Den NP, of the 6 orders, Cypriniformes was the most diverse (6 families, accounting for 46%), followed by Siluriformes and Anabantiformes in the second (2 families, accounting for 15%) and Gobiiformes, Synbranchiformes and Cyprinodontiformes (1 family, accounting for 8%). Cypriniformes were also the most common order in terms of number of species (12 species, accounting for 63%), followed by two orders, Siluriformes and Anabantiformes (2 species, accounting for 11%) (Table 6). In Nam Xuan Lac HSCA, the species composition showed the same tendency as the four other sites since the Cypriniformes was the most diverse order in terms of families, genera, and species (Table 6).

There was a total of 8 orders that occurred in four conservation areas. The Cypriniformes were the most diverse with 8 families (accounting for 38%) in Bac Me NR, 7 families (accounting for 41%) in Cao Duong, 6 families (accounting for 46%, 40% and 38%) in Phia Oac-Phia Den NP, and 11 families (accounting for 61%) in Phu Luu and Nam Xuan Lac HSCA. The number of genera and species ranked in the first and two places in terms was Cyprinidae and Xenocyprididae of 25 families found. Table 6 shows that the number of genera obtained in the Cao Duong area is 36, being higher than in other areas, and the number of species is the most diverse in this area, with 44 species (Table 6). The H' also reveals this data, being highest in Cao Duong, followed by Phu Luu and Bac Me NR (Table 7).

Table 6. Number of genera and species in each family of fish collected from four protected areas.

#	Orders	Phu Luu						Cao Duong					
		F	%	G	%	S	%	F	%	G	%	S	%
1	Cypriniformes	6	40%	8	47%	8	40%	7	41%	24	67%	27	61%
2	Siluriformes	3	20%	3	18%	3	15%	3	18%	5	14%	7	16%
3	Gobiiformes	2	13%	2	12%	5	25%	2	12%	2	6%	4	9%
4	Synbranchiformes	1	7%	1	6%	1	5%	1	6%	1	3%	1	2%
5	Anabantiformes	0	0%	0	0%	0	0%	1	6%	1	3%	1	2%
6	Cichliformes	1	7%	1	6%	1	5%	1	6%	1	3%	2	5%
7	Cyprinodontiformes	1	7%	1	6%	1	5%	1	6%	1	3%	1	2%
8	Beloniformes	1	7%	1	6%	1	5%	1	6%	1	3%	1	2%
Total		15	100%	17	100%	20	100%	17	100%	36	100%	44	100%
	Orders	Bac Me						Phia Oac-Phia Den					
		F	%	G	%	S	%	F	%	G	%	S	%
1	Cypriniformes	8	38%	22	63%	25	64%	6	46%	11	61%	12	63%
2	Siluriformes	4	19%	4	11%	4	10%	2	15%	2	11%	2	11%
3	Gobiiformes	2	10%	2	6%	3	8%	1	8%	1	6%	1	5%
4	Synbranchiformes	0	0%	0	0%	0	0%	1	8%	1	6%	1	5%
5	Anabantiformes	3	14%	3	9%	3	8%	2	15%	2	11%	2	11%
6	Cichliformes	3	14%	3	9%	3	8%	0	0%	0	0%	0	0%
7	Cyprinodontiformes	1	5%	1	3%	1	3%	1	8%	1	6%	1	5%
8	Beloniformes	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Total		21	100%	35	100%	39	100%	13	100%	18	100%	19	100%

#	Orders	Nam Xuan Lac					
		F	%	G	%	S	%

1	Cypriniformes	6	38%	11	52%	13	54%
2	Siluriformes	3	19%	3	14%	3	13%
3	Gobiiformes	1	6%	1	5%	2	8%
4	Synbranchiformes	2	13%	2	10%	2	8%
5	Anabantiformes	2	13%	2	10%	2	8%
6	Cichliformes	1	6%	1	5%	1	4%
7	Cyprinodontiformes	1	6%	1	5%	1	4%
8	Beloniformes	0	0%	0	0%	0	0%
Total		16	100%	21	100%	24	100%

Table 7. Biodiversity indices of fish species composition in 4 nature reserves (5 areas). S: total species, N: total individuals, d: Margalef's index, J': Pielou's index, H': Shannon-Weiner's index, D: Simpson's index.

Area	S	N	d	J'	H'(log)	D
Phu Luu	22	314	3.6526	0.65385	2.0211	0.75235
Cao Duong	46	716	6.8455	0.60046	2.299	0.76019
Bac Me NR	40	1369	5.4003	0.55713	2.0552	0.72794
Phia Oac-Phia Den NP	21	778	3.0045	0.53831	1.6389	0.6839
Nam Xuan Lac HSCA	26	1612	3.3851	0.60792	1.9807	0.72907

Table 8 and Fig. 13 show the similarity of species composition within 5 study areas, Phu Luu is the most different from others. Bac Me NR and Nam Xuan Lac HSCA, and Cao Duong and Phia Oac-Phia Den NP are similar.

Table 8. Similarity coefficient of fish species composition in 5 areas.

Area	Phu Luu	Cao Duong	Bac Me NR	Phia Oac-Phia Den NP	Nam Xuan Lac HSCA
Phu Luu					
Cao Duong	42.524				
Bac Me NR	32.204	51.703			
Phia Oac-Phia Den NP	40.293	53.815	45.086		

Nam Xuan Lac HSCA	28.453	43.557	65.884	41.59	

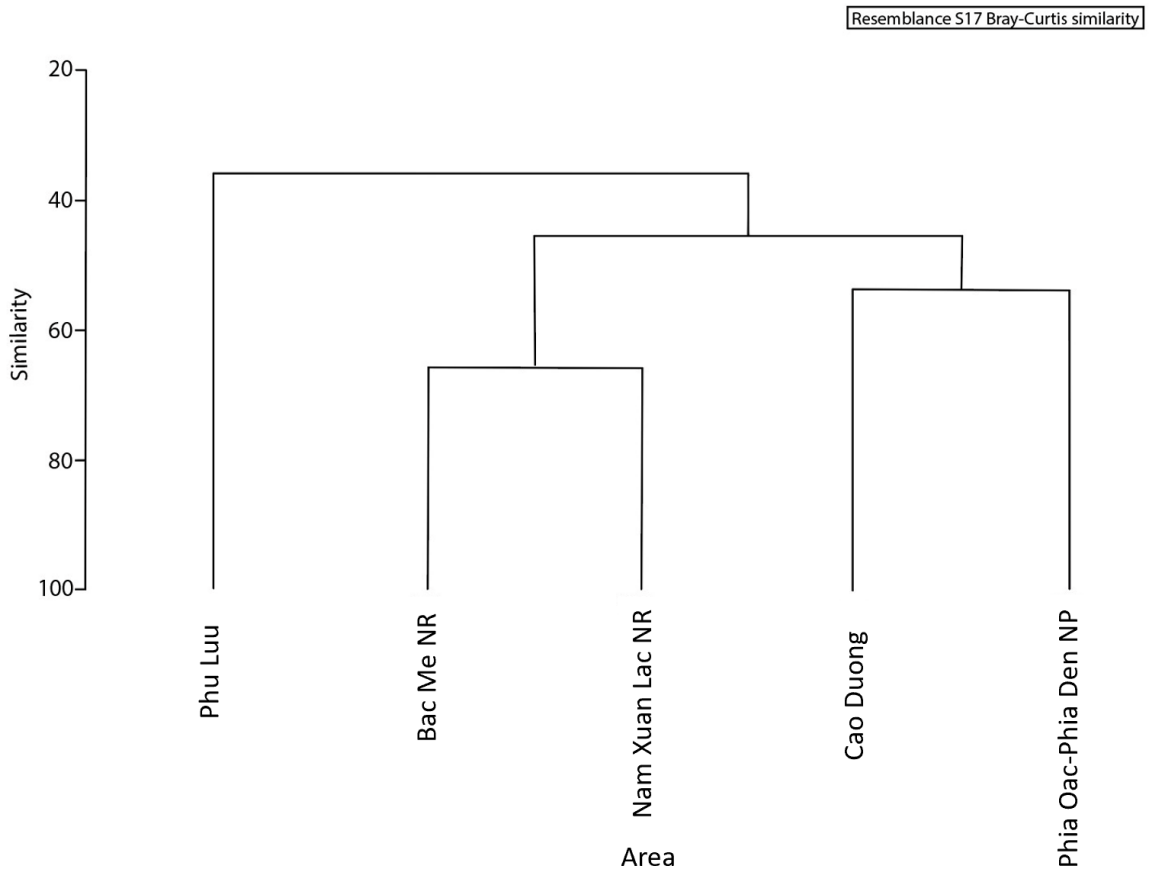

Figure 13. Diagram of similarity in species composition in 5 study areas.

2.6.2 Endangered species and species of conservation value

+ Species composition:

Among the species collected in the study area, there were no species recorded according to QĐ 82-TT01 of the Ministry of Agriculture and Rural Development and Vietnam Red Data Book. According to the IUCN Red List, there were 4 species listed as VU level occurring in the study sites: Cao Duong, Bac Me NR, Phia Oac-Phia Den NP; 1 species as NT level occurring at sites: Bac Me NR, Phia Oac-Phia Den NP, Nam Xuan Lac HSCA, and 1 species as EN level occurring at sites of Nam Xuan Lac HSCA. According to NĐ 26 of the government, the Bac Me NR and Nam Xuan Lac HSCA areas had 1 species in group I and 2 species in group II; at Cao Duong, there was 1 species in group II and 1 species in group I; and Phu Luu area had 1 species in group I, and Phia Oac-Phia Den had 1 species in group II (Table 5).

+ Distribution:

Vulnerable species are distributed mainly in Cao Duong with 3 species, followed by Bac Me NR, Phia Oac-Phia Den NP with only 1 species. The species *Rhinogobius lineatus* as critically endangered was distributed only in Nam Xuan Lac HSCA. The species *Onychostoma gerlachi* of near-threatened was recorded in Bac Me NR, Phia Oac-Phia Den NP and the species *Pseudohemiculter dispar* was only found in Cao Duong.

2.6.3 Species newly recored in the study areas

This is the first list of fish in Cham Chu, Phia Oac-Phia Den and Nam Xuan Lac HSCA. Thirty-four fresh-water fish species were found in four river basins in northern Vietnam, constituting the new records for the ichthyofauna (Table 9) (Nguyen et al., 2019; Nguyen Van Giang, 2018). The specific geographical distributions of *Opsariichthys minutus*, *Neolissochilus benasi*, *Rhinogobius honghensis*, *Rhinogobius duospilus* and *Discogobio* spp. are greatly enlarged by these observations. The records of *Gambusia affinis*, *Liniparhomaloptera* cf. *qiongzhongensis*, *Vanmanenia* cf. *caldwelli*, *Placogobio bacmeensis*, *Parazacco* sp., *Hemibagrus centralus*, *Gobiobotia meridionalis*, *Carassius auratus* and *Aphyocypris normalis* confirm increased diversity and wide distributions of these species. Among the four river basins, new records for the Lo River were highest, followed by the Gam River. There were only six species as new records for the Bang Giang and Thai Binh river basins (Table 9).

Table 9. List of some species newly recorded in the study sites.

No	**Scientific name**	River			
		Lo River	Gam River	Bang Giang River	Thai Binh River
1	*Acheilognathus* sp.	+			
2	*Aphyocypris normalis*	+			
3	*Beaufortia pingi*			+	
4	*Carassius auratus*	+	+		
5	*Discogobio microstoma*	+	+		
6	*Discogobio* spp.		+	+	
7	*Euchiloglanis* sp.		+		

8	*Gambusia affinis*	+	+	+	+
9	*Gobiobotia meridionalis*	+			
10	*Hemibagrus centralus*	+			
11	*Hemibarbus* cf. *umbrifer*	+		+	
12	*Hemiculter elongatus*		+		
13	*Liniparhomaloptera* cf. *qiongzhongensis*	+	+	+	+
14	*Megalobrama terminalis*		+		
15	*Microphysogobio elongatus*		+		
16	*Neolissochilus benasi*	+	+		
17	*Opsariichthys minutus*	+	+		
18	*Oryzias pectoralis*	+			
19	*Osteochilus salsburyi*	+	+		
20	*Parazacco* sp.	+	+		+
21	*Placogobio bacmeensis*	+	+		+
22	*Pterocryptis* sp.		+		
23	*Rhinogobius duospilus*	+	+	+	
24	*Rhinogobius honghensis*	+			
25	*Rhinogobius lineatus* Chen,				+
26	*Rhinogobius mekongianus*		+		
27	*Rhinogobius similis*	+	+		
28	*Rhinogobius* sp.	+			
29	*Rhodeus* cf. *albomarginatus*	+			
30	*Sineleotris namxamensis*	+	+		
31	*Sinibrama affinis*	+			
32	*Tachysurus kyphus*	+			
33	*Traccatichthys taeniatus*	+			
34	*Vanmanenia* cf. *caldwelli*		+	+	+
Total		24	20	6	6

2.6.4 Morphometrics of *S. namxamensis, N. benasi* and *R. similis*

+ For *Sineleotris namxamensis* collected from Cham Chu NR anh Bac Me NR. A total of 30 individuals were collected with standard lengths ranging from 36.7 mm to 109.0 mm. The present study compared with the description in Chen and Kottelat (2004) and Nguyen Xuan Khoa and Nguyen Huu Duc (2008) (Tables 10, 11).

Table 10. Measurements of *Sineleotris namxamensis* from northern Vietnam.

Sex	Male	Female

No	13			17		
	minimum	maximum	average	minimum	maximum	average
%SL						
Head length	30.4	34.5	32.1	29.4	33.4	31.1
Pre dorsal length	36.1	39.3	37.5	34	39.5	36.5
Snout to 2nd dorsal fin origin	54.3	57.5	56.0	53.2	56.8	55.2
Snout to anus	52.2	58.8	54.8	52	55.2	53.4
Snout to anal fin origin	56.7	63.3	60.1	57.5	62.2	59.2
Snout to pelvic fin origin	28.9	34.2	32.2	30.9	34.7	32.3
Caudal peduncle depth	8.0	10.9	9.3	7.8	10.2	8.6
Caudal peduncle length	23.6	28.9	26.5	25.5	29.6	27.6
1 St dorsal fin base	10.6	17.7	14.6	13.2	17.3	14.8
2nd dorsal fin base	16.4	21.1	18.6	15.9	21.0	18.7
Anal fin base	10.6	15.2	13.0	11.0	14.1	12.6
Pectoral fin length	21.6	26.4	23.5	19.9	26.4	23.6
Caudal fin length	20.7	25.8	23.4	21.1	24.0	22.3
Pelvic fin length	23.2	25.4	24.1	20.8	25.5	23.5
Body depth in pelvic fin origin	16.5	18.2	17.5	16.1	18.7	17.2
Bodv depth in anal fin origin	14.0	18.3	15.5	13.9	15.8	15.2
Body width in anal fin origin	8.9	11.9	10.5	9.1	11.7	10.2
Pelvic fin origin to anus	21.8	29.1	24.6	22.6	26.5	24.6
%HL						
Snout length	28.2	32.4	30.2	28.0	31.3	28.9
Eye diameter	19.0	26.2	22.5	20.2	33.9	24.3
Postorbital length	45.2	53.1	49.7	48.7	56.6	50.7
Maximal head width	45.7	59.0	51.4	46.1	53.1	49.0
Fleshy interorbital width	29.2	34.3	31.9	30.6	34.9	32.7
Bony interorbital width	15.1	16.9	16.3	15.8	16.8	16.3
Lower jaw length	32.3	37.9	35.1	32.1	39.7	34.3
Caudal peduncle depth/ caudal peduncle length	27.9	42.7	35.1	27.7	36.8	31.3
Pelvic fin length/pelvic fin origin to anus	84.0	111.0	98.8	78.5	109	96.0

Table 11. Fin rays and scale counts of *S. namxamensis*

Fin rays and scale counts	Female n = 17	Male n = 13
D1	VIII	VIII
D2	I,11	I,10-11
A	II,7-8	II,7-8
P1	14-15	14-15
P2	5	5
LR	38-43	34-43
TR	10-12	10-13
PreD	19-26	19-23
SD1P1	8-9	8-9

The coefficient values of the correlation line between each morphometric measurement with the total length of fish in two sexes are shown in Table 12. Most of the characteristics that were examined strongly correlated to the total length with a high r-square value ($R^2 > 0.9$) in both sexes, except for 1st dorsal-fin base, anal-fin base, and eye diameter in males ($R^2 < 0.9$).

Table 12. Morphometric variables vs. total length (*TL*) (all measurements were transformed to logarithmic scale before computation) of wild female and male *S. namxamensis*, I, -A and +A indicating isometric, negative and positive allometric growth type, respectively.

	Male						Female						*P*
Dimension	*a*	*b*	R^2	SE_b	SE_e	*G*	*a*	*b*	R^2	SE_b	SE_e	*G*	
SL	0.847	0.979	0.998	0.014	0.031	I	0.766	1.028	0.998	0.013	0.025	I	0.030
HL	0.237	1.034	0.994	0.028	0.062	I	0.253	1.003	0.983	0.036	0.070	I	0.921
PDL	0.270	1.043	0.992	0.033	0.073	I	2.753	1.013	0.985	0.034	0.066	I	0.689
Sn-D2	0.461	0.988	0.997	0.019	0.043	-A	0.396	1.066	0.997	0.014	0.028	I	0.000
Sn-An	0.394	1.057	0.993	0.030	0.068	I	0.373	1.078	0.998	0.012	0.024	I	0.000
PAL	0.468	1.020	0.991	0.034	0.077	I	0.428	1.061	0.995	0.019	0.038	I	0.013
Sn-P2	0.291	0.948	0.962	0.066	0.149	-A	0.256	1.012	0.987	0.031	0.060	I	0.775
DCP	0.051	1.154	0.939	0.104	0.232	+A	0.071	0.999	0.914	0.082	0.160	I	0.986
LCP	0.258	0.923	0.963	0.064	0.143	-A	0.248	0.938	0.971	0.043	0.085	-A	0.193
D1b	0.103	1.059	0.845	0.160	0.358	I	0.121	0.994	0.903	0.087	0.171	I	0.956
D2b	0.135	1.053	0.968	0.068	0.152	I	0.147	1.023	0.934	0.073	0.142	I	0.732
LAB	0.102	1.003	0.868	0.138	0.309	I	0.107	0.979	0.931	0.071	0.139	-A	0.814
P1L	0.231	0.904	0.964	0.062	0.138	-A	0.177	1.039	0.945	0.067	0.131	I	0.536
LC	0.185	0.992	0.970	0.061	0.138	I	0.186	0.999	0.976	0.042	0.082	I	0.979
P2L	0.178	1.037	0.991	0.035	0.078	I	0.239	0.890	0.976	0.037	0.073	-A	0.004
P2-An	0.182	1.061	0.969	0.067	0.149	I	0.151	1.134	0.979	0.045	0.087	+A	0.010

BD(P2)	0.115	1.091	0.987	0.044	0.099	I	0.131	1.035	0.986	0.032	0.064	I	0.308
BD(A)	0.110	1.061	0.966	0.070	0.156	I	0.120	1.009	0.965	0.052	0.101	I	0.861
BW(A)	0.063	1.144	0.978	0.061	0.136	+A	0.064	1.126	0.921	0.088	0.172	+A	0.113
SnL	0.059	1.120	0.984	0.051	0.114	+A	0.065	1.067	0.975	0.046	0.089	I	0.141
ED	0.159	0.541	0.853	0.079	0.177	-A	0.089	0.794	0.922	0.062	0.121	-A	0.003
POL	0.129	0.997	0.974	0.058	0.130	I	0.130	0.992	0.978	0.040	0.079	I	0.858
MHW	0.082	1.214	0.975	0.069	0.154	+A	0.106	1.086	0.971	0.051	0.099	I	0.114
FIOW	0.082	1.000	0.975	0.057	0.127	I	0.087	0.976	0.969	0.046	0.091	-A	0.604
BIOW	0.040	1.019	0.992	0.033	0.073	I	0.044	0.975	0.976	0.041	0.081	-A	0.505
LJL	0.101	0.961	0.973	0.057	0.128	-A	0.083	1.019	0.969	0.049	0.095	I	0.690

+ For *Neolissochilus* collected from Cham Chu, Bac Me and Nam Xuan Lac. A total of 36 individuals of *Neolissochilus* collected from Cham Chu, Bac Me and Nam Xuan Lac were examined (Tables 13, 14). Initially, based on measurements and counting, four species of this genus were found in the study site, i.e., *N. benasi*, *N. namlensis*, *N. stracheyi* and *N.* sp., but later based on molecular analysis, specimens of the three former species were collected from the study site are identified as *N. benasi*. Further, we need to confirm the taxonomy of this genus in northern Vietnam using materials collected in a broader sampling area.

Table 13. Morphometry of *Neolissochilus* collected from three protected areas

Measurements	**Nam Xuan Lac n = 9**			**Bac Me n = 7**			**Cham Chu n =20**		
	Average	Min	Max	Average	Min	Max	Average	Min	Max
Standard length (mm)									
% of Standard Length	70.6	24.7	137.4	63.8	49.4	90.8	74.2	20.5	207.0
Pre anal length	76.7	73.8	78.9	76.8	74.7	82.0	77.4	71.8	82.3
Pre dorsal length	51.9	48.8	53.2	53.4	51.2	57.0	52.4	48.9	55.5
Pre pelvic length	55.0	52.8	56.7	55.9	53.0	59.0	56.8	51.2	69.2
Pre pectoral length	27.7	21.9	31.6	28.3	25.9	29.5	29.2	24.1	33.8
Caudal peduncle length	17.2	16.4	18.5	17.4	16.1	19.4	16.7	14.1	19.8

Depth of caudal peduncle	12.8	12.1	13.5	13.0	12.6	13.6	12.3	11.1	14.1
Pectoral fin length	21.7	16.8	23.4	21.3	20.8	22.0	21.7	18.0	26.2
Pelvic fin length	19.4	18.5	21.0	19.0	17.1	19.8	18.9	16.2	23.0
Dorsal origin to anal fin origin	36.4	32.0	38.4	36.6	34.4	38.9	34.9	30.9	39.1
Dorsal fin base length	14.3	13.2	14.9	14.5	13.5	15.8	14.6	7.3	17.7
Anal fin base length	8.7	8.0	9.4	8.3	7.1	8.9	8.4	6.7	10.8
Post-dorsal length	38.2	36.1	41.0	38.3	36.6	39.3	33.7	7.7	38.9
Body depth	29.0	25.7	31.3	27.2	20.0	30.9	27.2	22.7	31.4
Distance from pectoral fin to vent	49.1	44.2	52.8	49.2	47.1	53.9	48.4	43.3	54.9
Distance from pelvic fin to vent	21.8	20.5	23.7	21.4	19.8	23.2	19.4	0.0	26.0
Head length (mm)	14.4	16.3	16.1	18.5	14.4	24.6	22.2	5.8	58.9
% of Head Length									
Snout length	31.8	26.6	35.3	42.4	28.8	99.3	33.6	20.7	43.6
Upper jaw length	26.4	14.0	33.2	30.5	28.7	33.5	27.1	17.7	33.9
Pre nasal length	19.7	12.7	23.0	19.8	16.0	25.7	22.5	12.9	31.6
Orbit width	25.4	20.2	31.8	26.3	23.6	29.0	25.5	18.4	33.3
Inter orbital width	13.4	11.9	15.9	11.5	10.0	12.5	13.0	8.8	17.2
Head width	53.3	48.2	58.7	60.8	50.9	99.4	53.4	44.3	59.6
Head depth at nostril	32.8	28.1	36.5	34.5	30.9	42.0	34.7	29.3	41.6
Maxillary barbel length	27.8	18.0	34.0	25.9	17.0	31.1	25.1	10.9	41.4
Rostral barbel length	34.4	24.7	41.3	32.4	24.7	37.2	28.0	10.6	43.4

Table 14. Meristics characters of *Neolissochilus* collected from three protected areas.

Meristics	**Nam Xuan Lac n = 9**	**Bac Me n = 7**	**Cham Chu n = 20**
Dorsal fin rays	3-4,8-9	3-4,9	3-4,8-10
Anal fin rays	3,5	3,5	2,5-3,5
Pelvic fin rays	1,8	1,8	1,8
Pectoral fin rays	1,15-16	1,16	1,13-16
Caudal fin rays	10+9	10+9	
Upper transverse scale rows	4,5	4,5	4,5
Lower transverse scale rows	3	3	2,5-3
Lateral line to pelvic scale row	2,5	2,5-3	2,5-3
Lateral-line scales	25-30	31-35	30-34
Pre-dorsal scales	9-10	10-12	8-10
Circumpeduncular scale rows	12	12	10-12

Circumferential scale rows	18-20	20	20
Transverse breast scale rows	7	7 to 9	9

+ *Rhinogobius* collected from Cham Chu, Bac Me and Nam Xuan Lac were used for morphological study. A total of 117 individuals of *Rhinogobius* spp. collected from Cham Chu, Bac Me and Nam Xuan Lac were examined (Tables 15). Based on measurements and counting, three species of this genus were found at the study site, i.e., *R. mekongianus*, *R. similis* in Bac Me, *R. duospilus* in Phia Oac-Phia Den and *Rhinogobius* sp. in Nam Xuan Lac. Based on the head lateral line system, *Rhinogobius* in Bac Me is identified as *R. mekongianus* and *R. similis*, from Phia Oac-Phia Den as *R. duospilus* (Fig. 14). Specimens from Nam Xuan Lac might be new species for science.

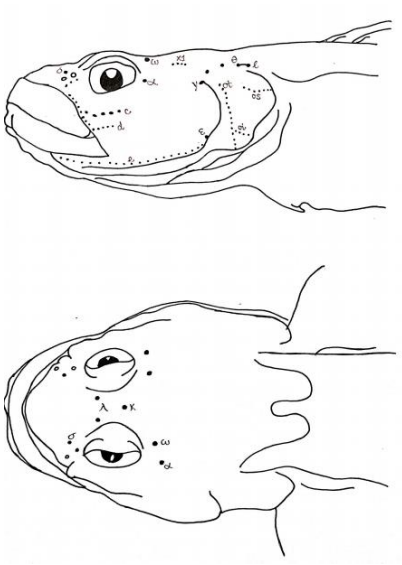

Figure 14. Head lateral line system of *Rhinogobius douspilus* from Phia Oac - Phia Den, Cao Bang province.

Table 15. Morphometrics of *Rhinogobius* spp. collected from three protected areas, northern Viet Nam.

	***R. mekongianus* in Bac Me**		***R. similis* in Bac Me**		***R. duospilus* in Phia Oac – Phia Den**		***Rhinogobius* sp. in Nam Xuan Lac**	
	Male (8)	**Female (4)**	**Male (8)**	**Female (7)**	**Male (30)**	**Female (30)**	**Male (15)**	**Female (15)**
Total length (TL) (mm)	37.9-47.5	32.3-55.6	34.5-73.7	38.8-63.2	28.4-55.6	30.6-54.0	28.0-50.3	37.1-49.0
Standard length (SL) (mm)	30.2-39.0	26.5-42.2	27.6-57.9	31.0-52.0	26.5-42.2	24.5-43.5	22.6-40.7	29.7-39.6
%SL								

Head length (HL)	28.2-32.9	27.3-30.7	28.9-35.0	29.0-31.1	26.9-38.1	25.2-30.6	26.6-31.0	29.2-33.0
Predorsal length (PDL)	37.2-40.2	35.0-37.0	35.0-40.7	27.3-38.4	33.8-39.3	31.3-44.7	34.6-38.3	35.3-38.5
Snout to 2nd dorsal origin	57.9-62.1	57.0-59.5	55.1-60.0	54.8-58.9	49.2-59.4	52.5-59.6	53.4-58.8	53.6-58.8
Snout to anus	55.6-61.9	55.7-60.5	52.3-56.9	52.3-58.2	51.4-56.3	54.3-59.7	52.3-57.1	51.6-58.5
Snout to anal fin origin	61.0-65.0	59.8-65.0	56.5-63.7	55.9-62.2	55.4-64.5	56.6-64.2	58.4-63.8	58.8-65.6
Prepelvic length	28.9-31.8	28.0-29.0	29.2-35.3	29.6-36.0	25.2-30.8	19.9-29.1	24.9-28.6	26.0-32.3
Caudal peduncle length	22.9-25.2	23.4-25.1	25.2-30.1	25.8-36.0	22.7-31.7	22.7-30.2	24.5-30.1	23.6-30.9
Caudal peduncle depth	9.3-10.3	9.8-10.0	9.1-11.1	9.6-10.6	9.7-11.3	9.7-12.0	9.3-11.3	9.6-12.1
1st dorsal fin base	11.2-17.1	13.4-15.2	11.6-17.0	12.4-20.0	11.0-19.4	12.9-18.6	13.4-18.5	13.8-18.5
2nd dorsal fin base	16.5-20.9	15.9-18.2	15.4-19.9	15.6-23.5	13.9-22.3	15.8-20.4	16.2-20.8	15.5-20.0
Anal fin base	13.4-14.8	11.6-14.8	13.9-18.8	13.8-21.6	11.6-18.7	11.3-16.0	10.7-15.5	11.2-16.0
Caudal fin length	23.1-27.1	22.7-24.8	15.9-28.5	21.6-27.5	24.5-30.4	25.7-30.9	24.5-29.4	25.4-30.1
Pectoral fin length	22.7-25.7	24.0-26.7	22.1-28.6	21.3-31.0	20.2-28.1	18.8-27.3	23.3-28.7	21.3-28.3
Pelvic fin length	13.2-16.2	15.5-16.9	18.1-24.6	20.8-22.9	16.2-19.6	12.6-18.9	15.7-18.8	15.5-19.2
Body depth at pelvic fin origin	11.8-15.8	13.5-14.7	15.2-22.2	15.5-29.5	13.2-17.4	12.8-17.6	14.2-16.8	13.7-16.7
Body depth at anal fin origin	13.3-15.3	13.5-15.8	14.9-19.2	12.4-17.0	12.0-17.1	12.8-15.8	13.8-16.2	12.7-15.6
Body width at anal fin origin	8.9-10.2	9.1-10.7	9.8-12.7	8.0-12.1	9.8-14.6	11.2-14.2	11.5-13.2	10.7-14.7
Pelvic fin origin to anus	27.1-29.2	27.3-33.6	21.5-31.9	19.3-24.9	26.1-34.1	27.9-36.3	26.0-31.5	23.5-30.8
%HL								
Snout length	30.0-34.9	30.0-32.0	28.0-39.2	22.1-35.7	26.8-36.9	25.9-36.0	24.3-30.9	27.2-32.3
Eye diameter (ED)	19.6-25.4	22.2-26.0	18.0-29.5	18.8-27.8	17.2-28.2	20.9-30.0	23.2-27.6	19.2-25.6
Postorbital length	47.4-55.6	45.0-54.5	39.3-48.6	37.7-48.9	41.4-60.7	46.9-56.0	48.3-57.1	18.4-63.3
Head width in maximum	59.7-74.8	60.0-70.8	46.6-67.3	51.9-57.1	55.2-70.9	58.5-75.5	51.4-69.0	54.8-62.5
Lower jaw Length	25.9-31.7	22.0-29.6	22.7-35.9	25.6-34.3	28.8-38.8	25.0-38.1	30.0-35.1	32.3-38.7
Fin rays and scale counts								
D1	VI	VI	VI	VI	VI	VI	VI	VI
D2	I,8-9	I,8	I,8	I,8	I,7-9	I,7-9	I,7-9	I,7-9
A	I,7-8	I,7-8	I,8	I,8	I,6-8	I,6-8	I,6-7	I,6-7
P	15-16	15-17	18-21	18-21	15-17	15-16	15-16	15-16
V	I,5	I,5	I,5	I,5	I,5	I,5	I,5	I,5
LR	30-31	30-31	29-31	29-31	30-32	30-32	30-32	30-32
TR	8	8	7-8	8	8-9	8-9	8-9	8-9
PreD	4-6	5	10-12	10-12	6-10	6-8	5-7	5-6
SDP	6-7	6	5-6	5-6	5-8	5-7	5-7	5-6

+ For *Euchiloglanis nami* sp. n. Specimens of *Euchiloglanis* collected from Phia Oac-Phia Den in Cao Bang Province were described as a new species, which has been submitted to Acta Zoologica Bulgarica.

Table 16. Counts and proportional measurements of *Euchiloglanis nami* sp. n.

	Holotype	Paratypes (n=6)	
Locality			
Dorsal-fin rays	i, 6	i, 6	
Pectoral-fin rays	i, 16	i, 15–16	
Pelvic-fin rays	i, 5	i, 5	
Anal-fin rays	i, 4	i, 4	
Branched caudal-fin rays	16	16	
in % of standard length		mean	range
Predorsal length	34.15	34.54	31.72–36.20
Dorsal-fin base length	10.19	9.88	8.96–10.53
Body depth	13.28	11.71	9.43–14.73
Head length	22.21	22.50	21.19–23.86
Maximum head width	18.90	19.93	18.32–21.59
Caudal peduncle length	20.38	20.74	20.00–21.88
Caudal peduncle depth	5.06	4.99	4.31–5.48
Dorsal-fin insertion to adipose-fin origin	16.37	14.78	12.05–15.90
Snout to adipose-fin origin	57.62	57.41	55.94–58.81
Dorsal-fin length	16.44	17.83	15.93–20.13
Pectoral-fin length	21.50	23.19	20.23–26.14
Pelvic-fin length	15.39	15.93	14.42–17.53
Anal-fin length	13.56	14.09	13.13–15.62
Anal-fin base length	6.68	6.54	6.18–6.86
Caudal-fin length	11.17	12.04	11.53–13.42
Adipose-fin base length	34.43	33.19	31.81–35.74
in % of head length			
Snout length	50.32	51.92	49.43–55.21
Eye diameter	6.33	8.05	8.00–8.71
Interorbital width	24.05	24.57	20.97–29.45
in % of Pt-Pl length			
Pectoral-fin length	85.47	86.42	71.25–97.26
Pl-A length	60.33	55.01	47.50–60.33
in % of Pl-A length			

Pelvic-fin length in % of length of caudal peduncle	101.39	108.48	92.54–126.32
Caudal-peduncle depth	24.83	24.12	20.26–27.40

2.6.5 Length weigth relationship and condition factor

+ For *Sineleotris namxamensis* collected from Cham Chu NR and Bac Me NR. The range of values for the weight (0.2-20.4 g) and total length (3.51-13.1 cm) was obtained from 37 individuals. The coefficients of determination were highly significant ($p < 0.001$), with R^2 values being greater than 0.988 (Table 17). The strong relationship between length and weight indicates that *S. namxamensis* weights could be estimated from the fish length (*LogW* = 0.0027 + 3.443**LogTL*). The *b* was higher than the isometric value of 3, suggesting that *S. namxamensis* revealed a positive allometric growth, which implies the high adaptability of the species to the environment in the surveyed areas.

Table 17. Length, weight range and regression coefficient of wild *Sineleotris namxamensis* over the sampling period. The values given are from the equation $W = aTL^b$; *n*, number of samples; *TL*, total length; *W*, weight; *a* is intercept and *b* is slope value of regression; R^2, coefficient of determination; I and +A indicate isometric and positive allometric growth type, respectively.

Sex	n	TL (cm)		Weight (g)		$W=aTL^b$				Compared sexes		
		Min	Max	Min	Max	a	b	Growth	R^2	*t*	*df*	*P*
F	23	3.51	13.1	0.2	17.4	0.0026	3.457	+A	0.990	0.667	3/33	0.00
M	14	4.68	12.7	0.5	20.4	0.0029	3.439	+A	0.985			
A	37	3.51	13.1	0.2	20.4	0.0027	3.443	+A	0.988			

The condition factor of specimens (23 females and 14 males) is shown in Fig. 15. The mean *K* values of *S. namxamensis* in the study area were found to be 0.998±0.151 SD for males, 1.01±0.031 SD for females, and 1.006±0.021 SD for combined sexes respectively. The range of condition factors for this species was 0,795-1.237 in males, 0,824-1.28 in females.

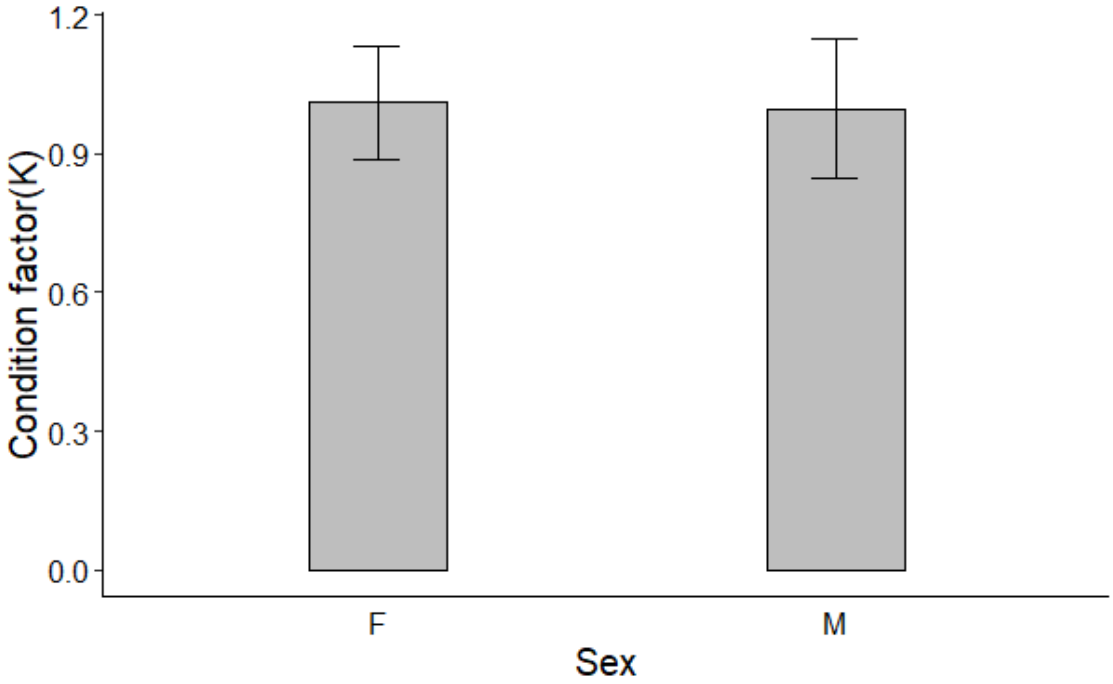

Figure 15. Condition factor (*K*) between female and male of *Sineleotris namxamensis*.

+ For *Gambusia affinis* collected from Tuyen Quang and Cao Bang province. A total of 64 individuals of *Gambusia affinis* collected from Cham Chu NR, 31 from Bac Me NR and 27 from Phia Oac-Phia Den NP were analyzed for length-weight relationship and condition factor study (Fig. 16). The slope value was 3.3, being higher than 3, showing the fish perform positive allometric growth. This result reveals that the environment from the study site is suitable for this species. This fish is an effective tool in mosquito control and widely introduced worldwide, but found to compete with indigenous fish and upset the ecological balance (Shrestha, 1990). Therefore, information on LWR will help determine growth through fish length and body weight, thereby developing measures to protect biodiversity in the study areas.

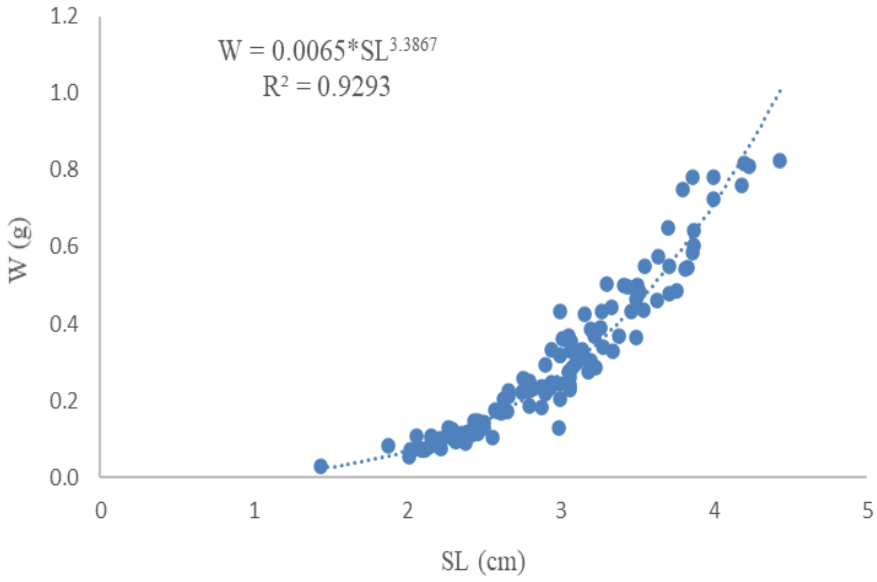

Figure 16. Length weight relationship of *Gambusia affinis* from Tuyen Quang and Cao Bang province.

+ For *Rhinogobius* collected from Nam Xuan Lac HSCA, Bac Kan Province. The data from 53 specimens were used for the length weight relationship and condition factor study of *Rhinogobius* sp. (Fig. 17). This is the first basic information of this species showing a strong correlation between total length and fish weight with a high coefficient of determination, $R^2 > 0.9$. From this parameter, we can assess the development pattern of fish and evaluate the influence of the environment. Thus, the ichthyofauna estimated by this analysis can provide effective data for fisheries management.

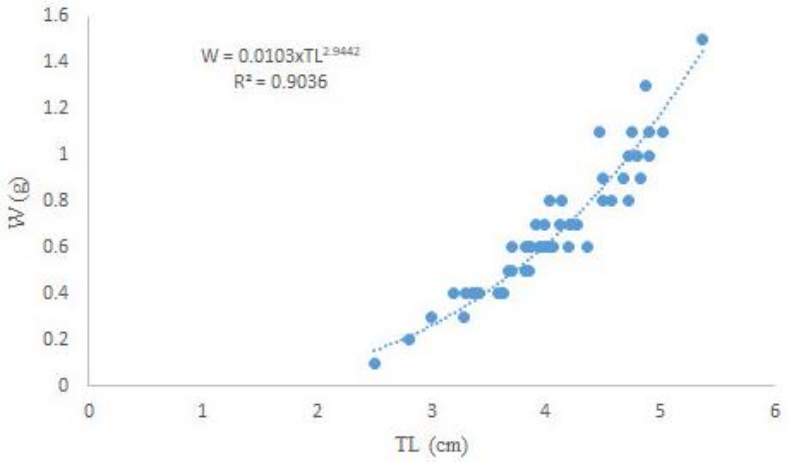

Figure 17. Length weight relationship of *Rhinogobius* from Nam Xuan Lac HSCA.

+ For *Rhinogobius similis* from different areas in Vietnam (Ha et al., 2022). A total of 195 specimens of *Rhinogobius similis* were used for the length weight relationship and condition factor studies (Figs. 18-23; Tables 18-20).

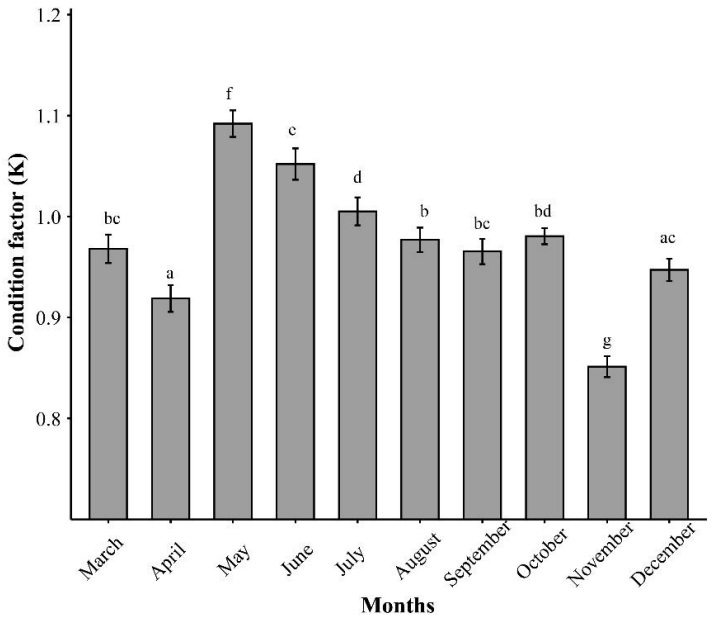

Figure 18. Variation of condition factor of *Rhinogobius similis* among locations in Vietnam.

The results showed that this fish is positive allometric growth ($b > 3$) and the K value is 1, indicating that *R. similis* is well adapted to the environmental conditions across from the northern to the highland areas of Vietnam. These findings will be valuable for further investigations into this introduced species to examine the impacts on aquatic ecosystems in Vietnam. This result was submitted to Acta Zoologica Bulgarica and received acceptance for publication.

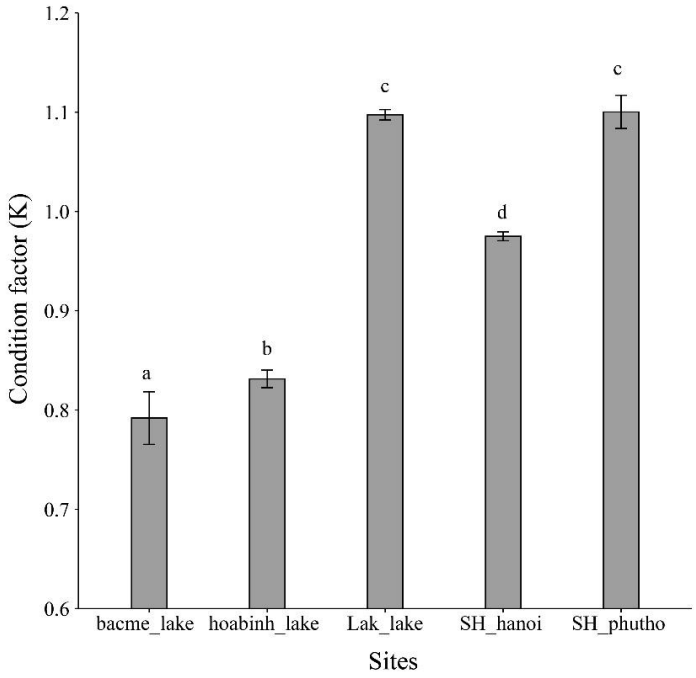

Figure 19. Monthly variation of condition factor of *Rhinogobius similis* collected from Red river, Hanoi, Vietnam.

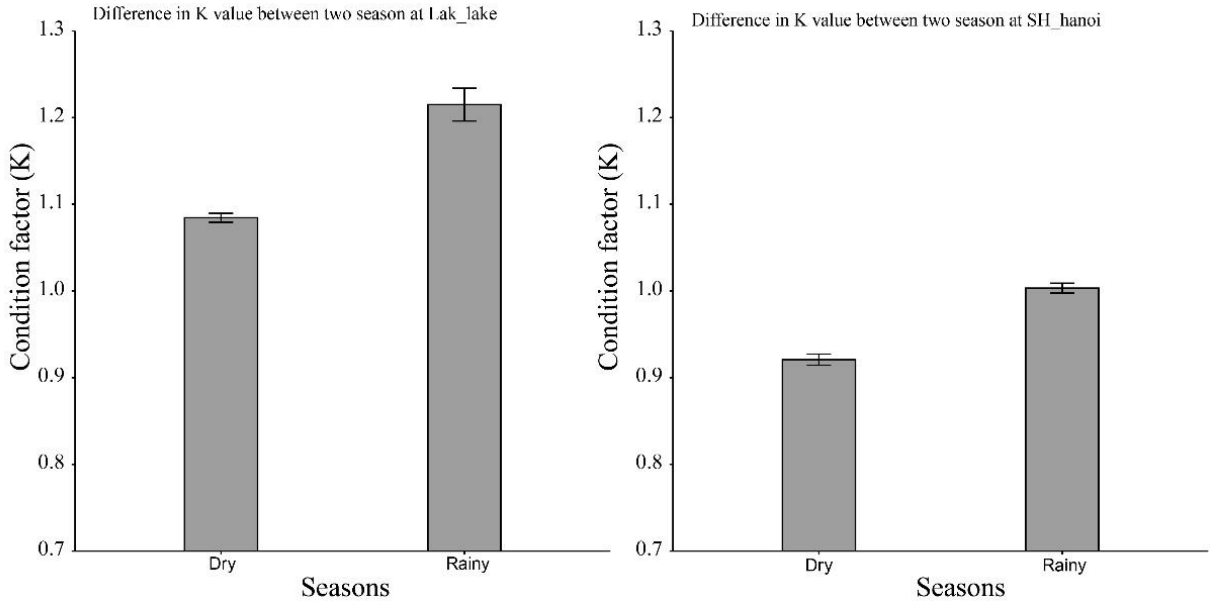

Figure 20. Seasonal variation in condition factor of *Rhinogobius similis* collected from Lak Lake and Red River, Hanoi, Vietnam

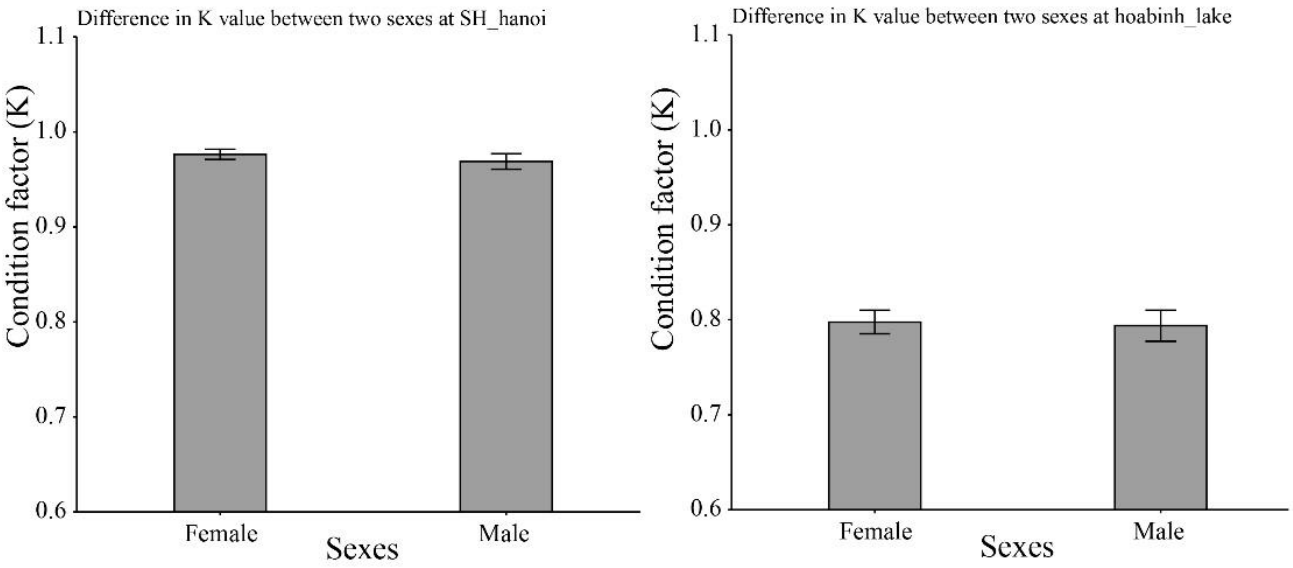

Figure 21. Sexual variation in condition factor of *Rhinogobius similis* collected from Hoa Binh Lake and Red River, Hanoi, Vietnam.

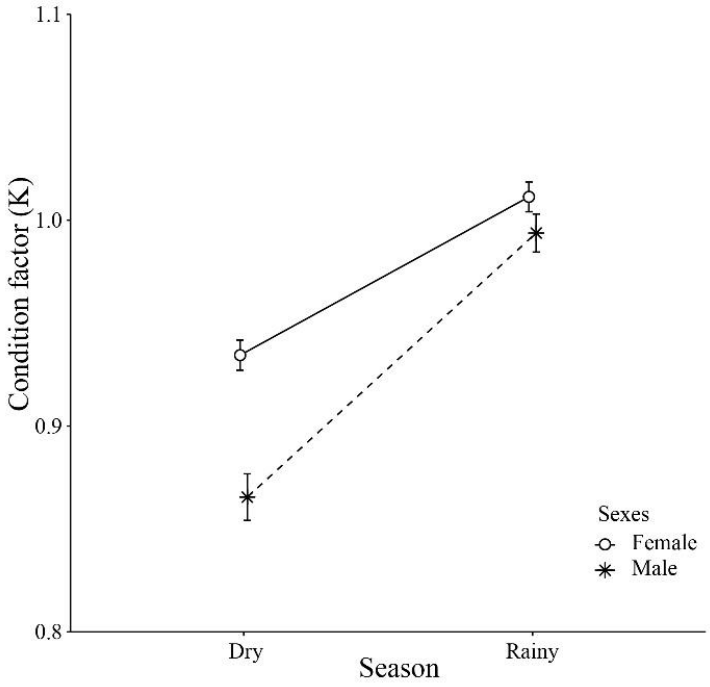

Figure 22. The effect of sex-season interaction on the change of condition factor of *Rhinogobius similis* collected from Red River, Hanoi, Vietnam.

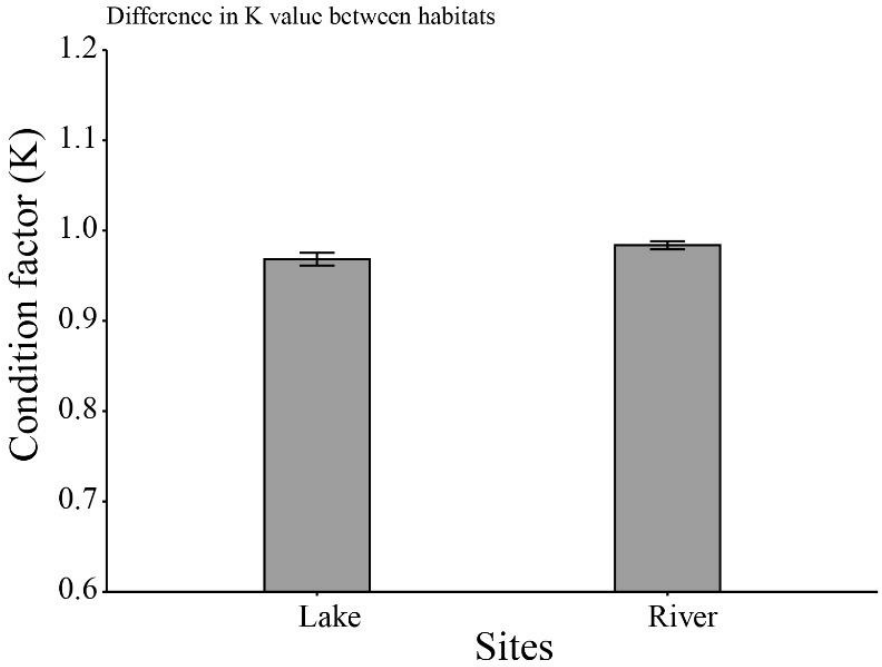

Figure 23. Variation of condition factor among different habitats of *Rhinogobius similis* in Vietnam.

Table 18. Monthly changes of length, weight range and regression coefficient of *Rhinogobius similis* amongst in the Red River and Lak Lake in Highland. The values given are from the equation $W = aSL^b$; N, number of samples; SL, standard length; W, weight; a is intercept and b is slope value of regression; R^2, coefficient of determination, respectively.

Site	Time	**N**	Range of TL and W							Intercept (lna)			slope(b)			t	F	DF	R-Square	*P* of regression	Compare to 3		
			TL (cm)		W (gr)			a													t	df	P
			min	max	min	max	a	2.50%	97.50%	lna	2.5%	97.5%	b	2.5%	97.5%								
Red River in Hanoi	**May**	71	3.4	7.9	0.5	5.8	0.0	0.0	0.0	-4.8	-5.0	-4.6	3.1	3.0	3.2	49.3	2427.0	1/69	1.0	0.0	1.8	69	0.1
	Jun	150	2.8	7.1	0.2	4.2	0.0	0.0	0.0	-4.5	-4.8	-4.3	2.9	2.8	3.1	37.8	1430.0	1/148	0.9	0.0	-0.8	148	0.4
	Jul	174	2.3	8.3	0.1	5.3	0.0	0.0	0.0	-5.3	-5.4	-5.1	3.4	3.3	3.5	66.0	4350.0	1/172	1.0	0.0	7.7	172	0.0
	Aug	220	2.6	7.0	0.2	2.8	0.0	0.0	0.0	-4.7	-4.9	-4.5	3.0	2.9	3.1	41.7	1741.0	1/218	0.9	0.0	0.0	218	1.0
	Sep	149	2.9	6.8	0.3	2.9	0.0	0.0	0.0	-4.9	-5.2	-4.6	3.1	2.9	3.3	31.9	1015.0	1/147	0.9	0.0	1.4	147	0.2
	Oct	107	3.9	6.0	0.4	2.0	0.0	0.0	0.0	-4.8	-5.1	-4.6	3.1	2.9	3.2	39.3	1544.0	1/105	0.9	0.0	1.1	105	0.3
	Nov	123	4.0	6.8	0.4	2.9	0.0	0.0	0.0	-5.1	-5.4	-4.7	3.1	2.9	3.4	29.7	880.4	1/121	0.9	0.0	1.4	121	0.2
	Dec	132	2.9	7.0	0.2	3.4	0.0	0.0	0.0	-5.2	-5.4	-5.0	3.3	3.1	3.4	51.2	2617.0	1/130	1.0	0.0	4.3	130	0.0
	March	111	3.2	6.6	0.3	2.7	0.0	0.0	0.0	-4.6	-5.0	-4.3	3.0	2.8	3.2	28.4	804.7	1/109	0.9	0.0	-0.4	109	0.7
	April	89	3.3	6.3	0.2	2.5	0.0	0.0	0.0	-4.9	-5.2	-4.5	3.1	2.9	3.3	29.5	871.8	1/87	0.9	0.0	0.7	87	0.5
	Rainy	871	2.3	8.3	0.1	5.8	0.0	0.0	0.0	-5.0	-5.1	-4.9	3.2	3.1	3.3	109.2	11920.0	1/869	0.9	0.0	6.9	869	0.0
	Dry	457	2.9	7.0	0.2	3.4	0.0	0.0	0.0	-4.9	-5.0	-4.7	3.1	3.0	3.2	64.7	4180.0	1/455	0.9	<2e-16	1.7	455	0.1
	total	1326	2.3	8.3	0.1	5.8	0.0	0.0	0.0	-	-5.0	-4.8	3.1	3.1	3.2	124.3	15430.0	1/1324	0.9	0.0	5.2	####	1324.0

										4.9												
Lak_lake	**rainy**	63	2.9	6.3	0.4	3.2	0.0	0.0	0.0	-4.1	-4.5	-3.8	2.8	2.6	3.0	23.5	551.4	1/61	0.9	0.0	-1.6	61	0.1
	dry	575	2.7	6.3	0.2	3.1	0.0	0.0	0.0	-4.6	-4.7	-4.5	3.0	2.9	3.1	80.0	6403.0	1/573	0.9	0.0	-0.1	573	1.0
	total	638	2.7	6.3	0.2	3.2	0.0			-4.6	-4.7	-4.5	3.0	3.0	3.1	81.6	6665.0	1/636	0.9	0.0	0.7	636.0	0.5

Table 19. Spatial variation of length, weight range and regression coefficient of *Rhinogobius similis* in Vietnam. The values given are from the equation $W = aSL^b$; N, number of samples; SL, standard length; W, weight; a is intercept and b is slope value of regression; R^2, coefficient of determination, respectively.

Site	**N**	Range of TL and W							intercept(a)			slope(b)			t	F	DF	R-Square	*P* of regression	Compare to 3		
		TL (cm)		W (gr)			a													t	df	P
		min	max	min	max	a	2.50%	97.50%	lna	ln2.5%a	ln97.5%a	b	2.5%	97.5%								
SH_hanoi	1326	2.3	8.3	0.1	5.8	0.0	0.0	0.0	-4.9	-5.0	-4.8	3.1	3.1	3.2	124.3	15430.0	1/1324	0.9	0.0	5.2	1324.0	1324.0
SH_phutho	101	2.7	7.1	0.1	3.7	0.0	0.0	0.0	-4.7	-4.9	-4.5	3.1	3.0	3.2	44.5	1979.0	1/99	1.0	0.0	1.5	99.0	0.1
bacme_lake	195	2.6	7.2	0.1	3.2	0.0	0.0	0.0	-5.3	-5.7	-5.0	3.3	3.1	3.5	33.2	1104.0	1/193	0.8	0.0	2.6	193.0	0.0
hoabinh_lake	349	2.4	6.3	0.1	1.6	0.0	0.0	0.0	-5.3	-5.5	-5.1	3.3	3.2	3.5	45.8	2096.0	1/347	0.9	0.0	4.5	347.0	0.0
lak_both_lake	638	2.7	6.3	0.2	3.2	0.0	0.0	0.0	-4.6	-4.7	-4.5	3.0	3.0	3.1	81.6	6665.0	1/636	0.9	0.0	0.7	636.0	0.5

Table 20. Difference of length, weight range and regression coefficient of *Rhinogobius similis* between habitats. The values given are from the equation $W = aSL^b$; N, number of samples; SL, standard length; W, weight; a is intercept and b is slope value of regression; R^2, coefficient of determination, respectively.

Habitats	N	Range of TL and W							intercept(a)			slope(b)			t	F	DF	R-Square	*P* of regression	Compare to 3		
		TL (cm)		W (gr)			a													t	df	P
		min	max	min	max	a	2.50%	97.50%	lna	ln2.5%a	ln97.5%a	b	2.5%	97.5%								
Riverine	1427	2.3	8.27	0.1	5.8	0	0.007	0.0083	-4.9	-4.933	-4.79	3.1	3.059	3.153	129.8	1.69E+04	1/1425	0.922	2.00E-16	4.44	1425	9.74E-06
Lacutrine	1128	2.4	7.17	0.1	3.2	0	0.004	0.0049	-5.4	-5.526	-5.32	3.5	3.384	3.521	98.64	9995	1/1180	0.894	2.00E-16	13.3	1180	5.78E-38

2.6.6 Ecological and conservation aspects

+ The data about fish diversity, distribution and length weight relationship and condition factor of several species could be potential to link with those from other groups to have a large picture of biodiversity in the study site, which will be crucial to have any conservation activities. Data from all groups will be a fundamental to have a distributional picture, especially focussing on rare or commercial species utilizing GIS groups results. It means that the remote sensing data will be only the group to connect all data into one visible picture. Clearly, this picture will be a very effective tool in conservation and protection.

This is a very important point because we should approach conservations based on ecosystems when all organisms naturally have solid connections. In the same aquatic environment, the fish groups data could be shared closely with macro-invertebrates and herpetology groups that may produce some useful data in the study site. For a further aspect, full data of fish and macro-invertebrates and water parameters could be used to assess the water quality.

+ Data from fisheries status of the Fish group could be information about roles, statuses, threats and conservations of this animal in the study site (see above). Importantly, this data generates an idea to connect with social groups since many data is share between two groups. We did interviews from ourselves view and could obtain data from a different side, thus if we can share method and data, results will be more informative and this will deal with a bigger issue, which is potential to form a better publication. The combined data might bring an effective action in conservation and exploitation of fisheries resources. In addition, conservation of fish based on ecosystem services approach seems poor information in Vietnam. This approach should be considered from this project, which may open a new stage in conservation of fish in Vietnam (Tran et al. 2021).

In the study sites, there are several river basins, which show an interesting data when we compare among sampling sites. Based on the ichthyofauna, we could understand the ecological connections. In the present report, this aspect will be present. Furthermore, interview data will

be finalized to show the importance of fisheries for local residents, providing benefits from the ecosystems. This data clearly shows the linkages between ecology and society. In addition, workshops organization for local authorities and residents, which were conducted during the survey in Cao Bang Province, could be another link in conservation activities.

+ Clearly, the number of fish species in Cao Duong was much higher than that of the other areas (Tables 5, 6). It can be seen from fig. 24, there is a clear relationship between the number of species and the average elevation where the fish were collected. In Phia Oac-Phia Den, there were five stations where no fish were collected. Most of these sampling sites were above 1000 m a.s.l. The survey was conducted in different habitat types and some findings on fish distribution will be presented in tables 5, 6, 21. Hill stream loach and stone loach (*Liniparhomaloptera* and *Schistura*) are popular in strong water current with rocky and sandy bottom sediments. Similar to species of *Placogobio*, *Euchiloglanis nami* sp.n. prefer living in medium and high-water current with stone bottom as they can use their large pectoral fins to attach the bottom. *Rectoris* sp. and *Neolissochilus benasi* could be found in the medium and high-speed current, with gravel bottom. On the other hand, in slow water current, some typical fish could be observed, such as *Parazacco* sp., *Opsariichthys*, *Gambusia affinis* and *Rhinogobius* (Tables 5, 6).

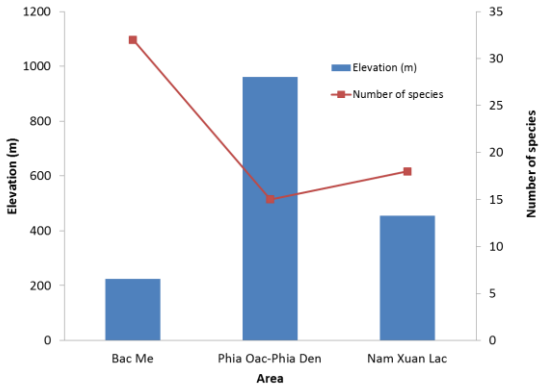

Figure 24. **Number of species according to average elevation in the three areas in the period of 2019 to 2020 surveys.**

Table 21. **Some examples of fish distributional patterns in different areas in the three areas in the period of 2019 to 2020 surveys.** ***Area 1 DO.02; Area 2 (NXL02,05,06,09,11; DO.05,07); Area 3 (NXL.03-06,09); Area 4 (NXL.02,06,09,10; DO.01). Please see figure 1 for the four areas.***

Area	Habitat	Order	Family	Example genus/species
1	Narrow stream inside the forest; medium and high speed current; gravel, stone and sandy bottom.	Siluriformes	**Sisoridae**	*Euchiloglanis* sp. 
2	Wide stream; medium and high speed current; gravel, muddy and sandy bottom.	Cypriniformes	**Cyprinidae**	*Discogobio* sp. 
3	Medium speed water, gravel, sandy and stone bottom.	Cypriniformes	**Cyprinidae**	*Neolissochilus benasi* 
	Slow speed current water, gravel and sandy and muddy bottom	Cypriniformes	**Xenocyprididae**	*Parazacco* sp. 

2.6.7 Natural and socio-economic context and main human impacts/threats on biological group

The importance of fish for local residents

Several results of interviewees in the four areas are summarized in Table 22. The results of the interview surveys indicate that fish were quite an important source of protein for the local community as fish consumed per week were 1 to 3 days (Table 22). However, fish were not the main income for local people as the ratio of fisher per total interviewees was low in Cham Chu and Bac Me, and no fishers in the rest of the study sites. Fish consumed are mainly from aquaculture and the local markets, such as common carp, grass carp, silver carp, mrigal carp, tilapia and marine fish.

Table 22. Information on fisher and fishing based on the interviews with fishers in the Cham Chu NR. and Bac Me NR (these data will be published in the near future).

	Content		Cham Chu	Bac Me	Phia Oac - Phia Den	Nam Xuan Lac
Fisher	Number of interviewees		18	17	2	6
	Ratio of fisher/total local people (%)		5.6	5.6	0	0
	Residence in the region (year)		34.4	44	32	45.5
	Education level (in 12 grade)		8.3	7.7	7	8.8
	Fishing experience (year)		20.1	29	0	12.8
	Fish consumed per week (day)		2.5	3.4	1	3
Fishing	Worker/trip		1.5	1.5	1	1
	Distance (km/trip)		1.0	1.7	0,5	2.6
	Season (%)	Dry	25.0	19	No data	20
		Rain	12.5	40	No data	80
		Both dry and rain	62.5	42	No data	0
	Frequency	Day per week	2.9	1.6	No data	1
		Tim of fishing (hour/trip)	2.1	1.5	0.8	3.2
	Ratio of gear used in fishing (%)	Electro-fishing	12.5	10	0	0
		Gill net	25.0	33	0	83.3
		Fishing line	25.0	48	50	33.3
		Others	37.5	29	50	50
	Product (kg/trip)		1.2	3.1	1	1
Decline of fisheries Product	During past 5 year (%)		48.5	41	50	32.5
	During past 10 year (%)		78.5	51	45	No data

Current status of fishery resources

Wild fishery resources. According to fishers and local residents, there were no established programs or guidelines for local people regarding the use and protection of fish species in Bac Me NR, Phia Oac-Phia Den NP, Nam Xuan Lac HSCA. Almost all interviewees recognized that fishing products from the two rivers had been declining rapidly. The rates of decline during the past five and ten years ranged from 32-50% to 45-79%, respectively (Table 22). Although the total products have greatly declined, many species still have high production values. In Cham Chu NR, there are some commercial fish namely *Neolissochilus benasi*, *Hemibarbus labeo*, *Schistura* spp., common carp, hongkong catfish. Many interviewees agreed that *Neolissochilus* species play an important role for fisheries resources in the local community. In Bac Me NR, some followings are important for the local people: *Onychostyoma gelarchi*, *Opsariichthys minutus*, *Hemiculter leucisculus*, *Cranoglanis bouderius*, *Hemibagrus guttatus*, gobies, tilapia, common carp and grass carp.

Cultured fishery resources. There were some cultured species in the research area, such as *Cyprinus carpio*, *Ctenopharyngodon idellus, Hypophthalmichthys molitrix*, *Oreochromis* spp., *Prochilodus argenteus*, *Cirrhina molitorella*, *Clarias fuscus*, *Channa maculata*, *Cranoglanis bouderius* and *Carassius auratus auratus*. Seed of many species are charged from local people and but few from the wild.

Status of exploitation fishery resources

Information on fishers. Few interviewees were working as fishers at the study site. The educational attainment of interviewees in the four sites was the same (Table 22). None of the interviewees were working as fishers at the study site. A few people use it for commercials, the rest do it for daily food. Average educational attainment ranges from 7 to 8 out of 12, and most of them are from ethnic minorities.

Fishing. Fish consumption in Bac Me NR and Nam Xuan Lac HSCA was three times higher than at Phia Oac -Phia Den NP (Table 22). Fish were caught mainly in the rainy season in the Nam Xuan Lac HSCA and were caught more evenly throughout the year in the Bac Me NR. Fish were caught mainly in the rainy season in the Nam Xuan Lac HSCA and were caught

more evenly throughout the year in the Bac Me NR. According to villagers in Nam Xuan Lac HSCA, they can catch fish in the fields during the rainy season when floods rise. The frequencies for fishing were from 1 to 1.5 days/week in around 1 hour for a trip. Fishers frequently caught fish by gill nets in Bac Me NR and Nam Xuan Lac HSCA, and fishing lines were more frequently used in Phia Oac-Phia Den NP. Electro-fishing was sometimes used in Bac Me NR (Table 22). The efficiency of fishing in the Bac Me NR was the highest than in all areas (Table 22).

Some possible impacts on fishery resources

As mentioned previously the fishery resources have been declining in the study site. The followings are some possible reasons. Some differences could be found among the four sites. In Cham Chu NR, many interviewees agreed that destructive gears used to catch fish is the reason to reduce the fishery resources, followed by the over-exploitation and water pollution, which are the two most important reasons in Bac Me NR. In Bac Me, the tourism activity is a different reason from the Cham Chu NR. From Cham Chu NR, interviewees said that the fisheries production has been recently recovered because destructive gears are forbidden and the awareness of local people to protect the resources are increasing. What is more, in Bac Me NR, deforestation and destructive gear have reduced fish production there. In Nam Xuan Lac HSCA, water pollution is caused by using mosquito repellent, insecticides, and herbicides by local people, and the treatment of wastewater from ore mines leads to a decline in fish stocks. Some villagers at Bac Me NR and Nam Xuan Lac HSCA claim that the number of stream fish species has increased compared to three to four years ago thanks to positive management measures (banned electric stimulators, the transmission of fish resources protection).

It is interesting to note that introduced fish species such as *Gambusia affinis*, which could be found abundantly in a few sampling sites from Phia Oac-Phia Den (2 sites) and Nam Xuan Lac (1 site). Thus, further investigations need to be conducted to understand the impact of exotic species on native ecosystems.

2.7 Discussion

2.7.1 Comparison of fish diversity in four river basins

This is the first list of fish in Cham Chu, Phia Oac-Phia Den and Nam Xuan Lac HSCA, which are fundamental data for further studies as well as for the whole NEF project. Several species may be new records for Vietnam and new species for science (Table 5), which will be further checked by morphological and molecular examinations. Other species such as *Parazacco* sp., *Discogobio* spp., *Placogobio* sp. also need to be confirmed in morphology and molecular. These taxa might increase the diversity and the value of ichthyofauna from northern Vietnam.

The number of fish species in the two areas was little diverse compared with Bac Me and Cham Chu. It is clear that the water surface area in Bac Me is much higher than Phia Oac-Phia Den and Nam Xuan Lac. In Bac Me NR, many species were collected from Na Hang Reservoir (Thuong Tan Lake). In the Phia Oac-Phia Den, no fish in five sampling sites might relate to the high elevation, and another possibility is that this time survey during the rainy season, so the water was present in all sampling sites. However, during the dry season, there will be no water. It means that the water level in these sampling sites is changeable and significantly different between seasons; hence fish could not be distributed there. This could lead to few numbers of fishers in this area and fisheries resources are not so important for local residents.

From Phia Oac-Phia Den and Nam Xuan Lac, sampling sites are in the Red River, the Thai Binh, both flowing into Gulf of Tokin, and from Bang Giang River, which flows into China. Therefore, we examined species compositions and fish distribution in the two areas (Table 23). *Discogobio microstoma* is a species only distributed in the Bang Giang River, which was also found in the previous work (Nguyen Van Giang, 2018). The Gam and Lo rivers are the biggest tributaries of the Red river basin, but they share a few freshwater fish species (only 4 species) (Table 23). This may be related to differences in the number of sampling sites in each river basin.

Table 23. Fish distribution in different river basins in Phia Oac-Phia Den (2020) and Nam Xuan Lac (2020), northern Vietnam.

≠	**Species**	**PO-PD**	**NXL**

		Gam	Bang Giang	Thai Binh	Lo
1	*Barbodes semifasciolatus*	+	+	+	+
2	*Beaufortia pingi*	+	+		
3	*Carassius auratus*	+	+		
4	*Channa gachua*			+	
5	*Cyprinus carpio*	+			
6	*Discogobio microstoma*		+		+
7	*Discogobio* spp.		+		
8	*Gambusia affinis*	+	+	+	
9	*Glyptothorax honghensis*			+	+
10	*Hemibarbus* cf. *umbrifer*		+		
11	*Hemibagrus pluriradiatus*				+
12	*Liniparhomaloptera* cf. *qiongzhongensis*			+	+
13	*Macropodus opercularis*		+	+	+
14	*Mastacembelus armatus*				+
15	*Monopterus albus*	+			
16	*Neolissochilus benasi*			+	+
17	*Neolissochilus* sp.				+
18	*Onychostoma gerlachi*		+	+	+
19	*Onychostoma lepturus*			+	+
20	*Opsariichthys minutus*			+	+
21	*Parazacco* sp.	+		+	+
22	*Placogobio bacmeensis*			+	+
23	*Euchiloglanis* sp.	+			
24	*Rhinogobius duospilus*	+	+		
25	*Rhinogobius lineatus*			+	+
26	*Rhinogobius* sp.				+
27	*Rhodeus ocellatus*			+	
28	*Schistura* spp.	+	+	+	+
29	*Vanmanenia* cf. *caldwelli*	+	+	+	+
Total		**11**	**12**	**16**	**18**

Sampling sites belong to four river basins, Lo, Gam, Bang Giang and Thai Binh Rivers. Fish were mainly distributed in the Lo and Gam Rivers, one of the largest tributaries of the Red

River, where the number of species ranged from 65 to 69, with the H' being higher than 3.00 (Table 24, 25). The lowest number of fish was collected in the areas belonging to the Bang Giang River, which flows in to China (Tables 24, 25).

Table 24. A list of fish collected in the four protected areas belonging to four river basins, northern Vietnam

#	Scientificname	Vietnamese name	River basin			
			L	G	BG	TB
	I. Cypriniformes	**Bộ Cá Chép**				
	1. Botiidae					
1	*Leptobotia elongata* (Bleeker, 1870)	Cá Chạch cát đốm	+			
	2. Cobitidae	**Họ cá Chạch**				
2	*Misgurnus anguillicaudatus* (Cantor, 1842)	Cá Chạch bùn	+	+		
	3. Gastromyzontidae	**Họ Cá chạch bám**				
3	*Liniparhomaloptera* cf. *qiongzhongensis*		+	+	+	+
4	*Vanmanenia* cf. *caldwelli*			+	+	+
	4. Balitoridae	**Họ cá Chạch vây bằng**				
5	*Beaufortia pingi* (Fang, 1930)	Cá Bám khuyết pingi		+	+	
	5. Nemacheilidae	**Họ Cá Chạch suối**				
6	*Schistura* spp.	Cá Chạch suối	+	+	+	+
7	*Traccatichthys taeniatus* (Pellegrin & Chevey 1936)	Cá Chạch cật	+			
	6. Cyprinidae	**Họ Cá Chép**				
8	*Barbodes semifasciolatus* (Günther 1868)	Cá Đòng đong	+	+	+	+
9	*Carassius auratus* (Linnaeus, 1758)	Cá Diếc mắt đỏ	+	+	+	
10	*Cyprinus carpio* Linnaeus, 1758	Cá Chép	+	+		
11	*Garra orientalis* Nichols, 1925	Cá Sứt mũi	+			
12	*Neolissochilus benasi* (Pellegrin & Chevey, 1936)	Cá Rai	+	+		+
13	*Neolissochilus* sp.	Cá Mi	+			
14	*Onychostoma gerlachi* (Peters, 1881)	Cá Sỉnh gai nhỏ	+	+	+	+
15	*Onychostoma lepturus* (Günther, 1896)	Cá Phao	+	+		+
16	*Osteochilus salsburyi* Nichols & Pope 1927	Cá Dầm đất	+	+		
17	*Spinibarbus hollandi* Oshima, 1919	Cá Chày đất		+		
	7. Danionidae					
18	*Rasbora steineri* Nichols & Pope, 1927	Cá Mại sọc		+		
	8. Xenocyprididae					
19	*Aphyocypris normalis* Nichols & Pope, 1927	Cá Dầm suối thường	+			

20	*Chanodichthys erythropterus* (Basilewsky, 1855)	Cá Thiểu	+			
21	*Culter flavipinnis* Tirant, 1883	Cá Ngão gù	+			
22	*Hemiculter elongatus* Nguyen & Ngo, 2001	Cá Vền dài?		+		
23	*Hemiculter leucisculus* (Basilewsky, 1855)	Cá Mương xanh	+	+		
24	*Megalobrama terminalis* (Richardson, 1846)	Cá Vền		+		
25	*Megalobrama skolkovii* Dybowski, 1872	Cá Vền		+		
26	*Metzia formosae* (Oshima, 1920)	Cá Mại bạc	+	+		
27	*Opsariichthys minutus* Nichols, 1926	Cá Cháo thường	+	+		+
28	*Parazacco* sp.	Cá Chuôn	+	+		+
29	*Pseudohemiculter dispar* (Peters, 1881)	Cá Dầu sông mỏng	+			
30	*Sinibrama affinis* (Vaillant, 1892)	Cá Nhác	+			
31	*Toxabramis houdemeri* Pellegrin, 1932	Cá Dầu hồ cao		+		
32	*Toxabramis swinhonis* Günther, 1873	Cá Dầu hồ bằng	+			
33	*Xenocypris davidi* Bleeker, 1871	Cá Mần		+		
	9. Acheilognathidae					
34	*Acheilognathus* sp.	Cá Thè be	+			
35	*Acheilognathus tonkinensis* (Vaillant, 1892)	Cá Thè be thường	+			
36	*Rhodeus* cf. *albomarginatus*	Cá Bướm	+			
37	*Rhodeus ocellatus* (Kner, 1866)	Cá Bướm chấm	+	+		+
	10. Gobionidae					
38	*Discogobio microstoma* (Mai, 1978)	Cá Bám sừng	+	+	+	
39	*Discogobio* spp.			+	+	
40	*Gobiobotia meridionalis* Chen & Cao, 1977	Cá Đục râu	+			
41	*Hemibarbus* cf. *umbrifer*	Cá Đục ó lạng sơn	+		+	
42	*Hemibarbus medius* Yue, 1995	Cá Đục ngộ	+			
43	*Microphysogobio elongatus* (Yao & Yang, 1977)	Cá Đục đanh chấm		+		
44	*Placogobio bacmeensis* Nguyen & Vo, 2001	Cá Thui	+	+		+
45	*Saurogobio dabryi* Bleeker, 1871	Cá Đục đanh đốm	+	+		
46	*Squalidus argentatus* (Sauvage & Dabry de Thiersant, 1874)	Cá Đục trắng mỏng	+	+		
	II.Siluriformes	**Bộ Cá Da trơn**				
	1. Bagridae	**Họ Cá Lăng**				
47	*Hemibagrus centralus* Mai, 1978	Cá Lăng quảng bình	+			
48	*Hemibagrus pluriradiatus* (Vaillant, 1892)	Cá Lường	+			
49	*Pseudobagrus vachellii* (Richardson, 1846)	Cá Mầm		+		
50	*Tachysurus fulvidraco* (Richardson, 1846)	Cá Bò đen	+			
51	*Tachysurus kyphus* Mai, 1978	Cá Mịt tròn	+			

52	*Tachysurus virgatus* (Oshima, 1926)	Cá Mịt	+			
	2. Sisoridae	**Họ Cá Chiên**				
53	*Euchiloglanis* sp.	Cá Chiên pớm		+		
54	*Glyptothorax honghensis* Li, 1984	Cá Chiên suối sông Hồng	+	+		+
	3. Siluridae	**Họ Cá Nheo**				
55	*Pterocryptis cochinchinensis* (Valenciennes, 1840)	Cá Thèo	+			
56	*Pterocryptis* sp.	Cá Niết		+		
57	*Silurus asotus* Linnaeus, 1758	Cá Nheo	+			
	4. Clariidae					
58	*Clarias fuscus* (Lacepède, 1803)	Cá Trê đen	+	+		
	5. Cranoglanididae	**Họ cá Ngạnh**				
59	*Cranoglanis henrici* (Vaillant, 1893)	Cá Ngạnh thường		+		
	III. Gobiiformes	**Bộ Cá bống**				
	1. Odontobutidae					
60	*Sineleotris namxamensis* Chen & Kottelat, 2004	Cá Bống nhỏ	+	+		
	3. Gobiidae	**Họ Cá bống trắng**				
62	*Rhinogobius duospilus* (Herre, 1935)	Cá Bống suối	+	+	+	
63	*Rhinogobius honghensis* Chen, Yang & Chen, 1999	Cá Bống khe	+			
64	*Rhinogobius lineatus* Chen, Kottelat & Miller, 1999					+
65	*Rhinogobius mekongianus* (Pellegrin & Fang, 1940)	Cá Bống mê kông		+		
61	*Rhinogobius similis* Gill, 1859	Cá Bống đá	+	+		
66	*Rhinogobius* sp.		+			
	IV. Synbranchiformes	**Bộ Cá Mang liền**				
	1. Mastacembelidae	**Họ Cá Chạch sông**				
67	*Mastacembelus armatus* (Lacepède, 1800)	Cá Chạch sông	+			+
	2. Synbranchidae	**Họ Lươn**				
68	*Monopterus albus* Zuiew, 1793	Lươn thường		+		+
	V. Anabantiformes	Bộ Cá rô đồng				
	1. Anabantidae					
69	*Anabas testudineus* (Bloch, 1792)	Cá Rô đồng		+		
	2. Osphronemidae	**Họ cá Tai tượng**				
70	*Macropodus opercularis* (Linnaeus, 1758)	Cá Đuôi cờ thường	+	+	+	+
	3. Channidae					
71	*Channa gachua* (Hamilton, 1822)	Cá Chành dục		+		+
	VI. Cichliformes	**Bộ Cá rô phi**				
	1. Cichlidae	**Họ Cá rô phi**				

72	*Oreochromis mossambicus* (Peters, 1852)	Cá Rô phi đen	+			
73	*Oreochromis niloticus* (Linnaeus, 1758)	Cá Rô phi vằn	+	+		+
	VII.Cyprinodontiformes	**Bộ Cá bạc đầu**				
	1. Poeciliidae	**Họ Cá ăn muỗi**				
74	*Gambusia affinis* (Baird & Girard, 1853)	Cá Ăn muỗi	+	+	+	+
	VIII.BELONIFORMES	**Bộ Cá Nhái**				
	1. Adrianichthyidae	**Họ Cá Sóc**				
75	*Oryzias pectoralis* Roberts, 1998	Cá Sóc vây ngực	+			
Total			55	46	13	19

Study site: L: Lo river, G: Gam river, BG: Bang Giang river, TB: Thai Binh river

Through the composition and distribution of fish species in 4 protected areas and 4 river basins, we compared with the biodiversity indices according to the Shannon-Weiner's index (H'); the Margalef's index (d), the Pielou's index (J') and the Simpson's Index (D). The results showed that, at the Lo River, the highest biodiversity index, the margalef's index (d) and the shannon-Weiner's index (H') fluctuated at a good and very good biodiversity level (d=8.1916, H '= 3,1635). In the Gam River, although the d fluctuates at a very good biodiversity level (d=6.5692), H' is only reaches quite similar of the basins (ranging from: 1 <H '<3). The reason is that the Lo and Gam rivers have a larger number of species and individuals than the Bang Giang and Thai Binh rivers (Table 25). The pielou's index (J') of the individuals of species in all river basins, the study is average, which leads to low simpson's index (D).

Table 25. Biodiversity indices of fish species composition in 4 protected areas and 4 river basins. S: total species, N: total individuals, d: Margalef's index, J': Pielou's index, H': Shannon-Weiner's index, D: Simpson's index.

Area	S	N	d	J'	H'(log)	D
Lo River	56	824	8.1916	0.78589	3.1635	0.93225
Gam River	46	944	6.5692	0.7084	2.7122	0.88034
Bang Giang River	13	106	2.5732	0.74255	1.9046	0.80305
Thai Binh River	19	380	3.0302	0.76775	2.2606	0.8573

It can be clearly seen that species composition of fish in Bang Giang River is different from the others (Table 26, Fig. 25). Although Gam and Lo Rivers are the two tributaries of the Red River, the species composition of fish in Lo River is closer to that of Thai Binh River than

to the Gam River. Table 26 shows that almost all species occurring in the Thai Binh River are distributed in the Lo River. The two river basins are present in Nam Xuan Lac HSCA (Fig. 5).

Table 26. Similarity coefficient of fish species composition in 4 river basins.

Area	Lo river	Gam river	Bang Giang river	Thai Binh river
Lo River				
Gam River	38.348			
Bang Giang River	12.688	16.19		
Thai Binh River	44.684	33.988	9.0535	

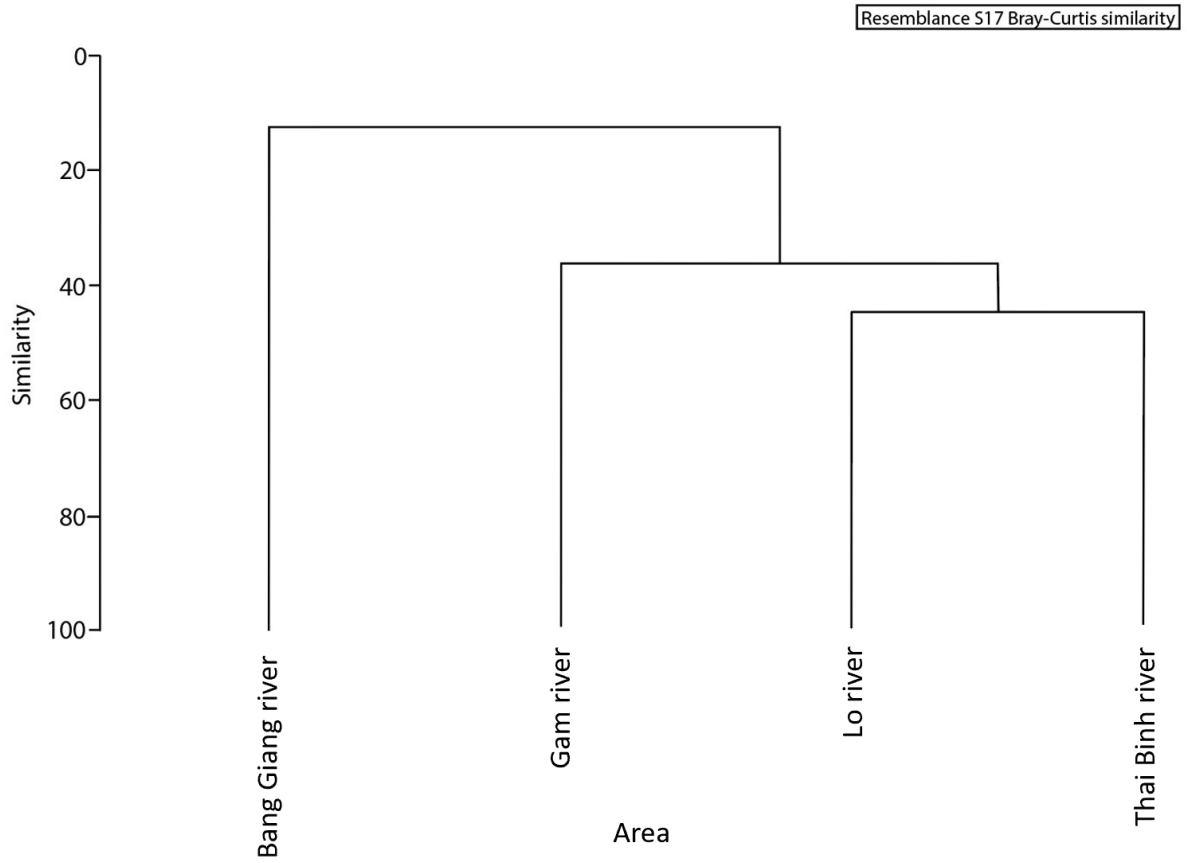

Figure 25. Diagram of similarity in species composition in 4 river basins.

2.7.2 LWR and K of an exotic goby fish, *R. similis*

This is the first LWR data for *R. similis* from a tropical region. The r^2 values of *R. similis* for all cases analyzed in this study were high (primarily > 0.88) (Table 18), suggesting that the fish's weight could be estimated from length. Similar data were observed for the same species

distributed in subtropical and temperate regions in China (Ye et al. 2007, Lei et al. 2015, Xiong et al. 2015, Heidari et al. 2018). The slope *b* ranged from 2.804 to 3.462 (Tables 18–20), which was almost within the standard range of 2.7 to 3.4 reported for 90% of fish examined by Froese (2006). Overall, the LWR regression slope (*b*) value of *R. similis* for all individuals from the present study was 3.305, which was higher than the isometric value of 3 (Table 19), indicating that this freshwater goby has positive allometric growth. This implies that smaller *R. similis* individuals tend to be more elongated, with a thinned body, and bigger individuals tend to be plumper in shape (Froese 2006).

The parameter of LWR could be a species-specific characteristic that is affected by environmental conditions (Richer 1973, Froese 2006). Of the five surveyed sites in the present study, the specimens of *R. similis* from the Red River and two reservoirs had positive allometric growth. The positive growth pattern (with $b = 3.38$) has also been reported for this species (under a synonym *R. giurinus*) in the Xiangjiang River, a tributary of the middle Yangtze River, Southern China (24°31′–29°52′ N, 110°31′ E) (Lei et al. 2015). On the other hand, an isometric growth was observed in specimens collected in the Lak Lake (highland), which was similar to the specimens collected in a shallow macrophytic Yangtze Lake in China (30°16–22′ N, 114°27–38′ E) (YE et al. 2007), and in *R.* cf. *similis* distributed in southern Caspian Sea basin (37°28′13″N, 49°20′33″E) (Heidari et al. 2018). In addition, negative allometric growth was obtained for *R. similis* collected from a wetland lake in the central Yangtze River (30°310–30°360 N; 114°210–114°280 E (Xiong et al. 2015). This difference in growth patterns also supports the fact that factors other than species uniqueness may influence this goby's growth patterns.

Since the change of *b* value can be affected by the changes in environmental conditions, the seasonal variations in growth pattern of *R. similis* differed between the Red River and the Lak Lake (Table 18) could be explained by the difference in the hydrology of the river and the lake. Seasonal change of hydrologic conditions e.g., velocity, turbidity, and water discharge in the Red River, is more pronounced than in Lak Lake might influence the growth of the fish, making the fish grow differently in two seasons in river but similarly at the lake. This result implies that this species has high plasticity in growth pattern and is likely more adapted to variable environmental conditions than stable conditions. Similarly, the seasonal difference in growth pattern was also reported for *Periophthamus modestus* collected from estuary of the

Red River, in which fish also have significantly higher *b* value grow in the rainy season than in the dry season (Tran et al. 2021). Differently, even other species namely *Glossogobius olivaceus* (Ta et al. 2020) and *Bostrychus sinensis* (Nguyen et al. 2020), also collected from the Red River, have similar growth pattern between seasons. As the *b* value is also regulated by gonadal developmental stage and reproductive investment (Froese 2006), and the spawning season of *R. similis* was reported to occur in rainy season months in Taiwan (Chang et al. 2008), the higher value of *b* in rainy season in this study might partly be a consequence of increasing in gonad volume in pre-spawning period.

The present results revealed that fish in the lacustrine habitat generally had higher *b* value than those in riverine habitat (Table 20), suggesting that fish in the lacustrine habitat (particularly in reservoir) tended to increase in thickness as they grew and thus large specimen would have plumper body shape than the smaller ones. Contrary to the present study, the fish collected in China grow in weight better in the riverine habitat (as the *b* values were higher) than in lacustrine habitat (Ye et al. 2007, Lei et al. 2015, Xiong et al. 2015, Heidari et al. 2018). A difference in morphology and pigmentation could be found in fish collected from different study areas. All above information would have demonstrated the biodiversity of this exotic goby species, which leads to its good adaptation to different habitats.

The present study contributes the first data of condition factor for this species regarding condition factor, which is related to changes of environmental conditions and fish health (Froese 2006). This *K* value estimated for all individuals averaged 0.97, which was significantly lower than the ideal threshold value of 1 ($t(2507) = -7.606$, $p < 0.001$), suggesting that, in general, the fish were not in healthy conditions at the sampling times. Given that the condition factor can be regulated by the seasonal change in environmental conditions (Froese 2006), most of the cases (fish from Bacme and Hoabinh reservoirs) in the present study which had low values of condition factor were collected during the winter month and in the north of Vietnam when the water temperature is low and food resource might be limited. The seasonal variation in *K* of fish collected in the Red River and in the Lak Lake had confirmed the significant effect of season on condition factor in this species while fish were in a better condition during the rainy season than in the dry season. Within the Red River, the higher *K* value in the riverine habitat suggests that the fish are more adaptable to this type of habitat, where environmental conditions reveal seasonal variations. The condition factor of fish in the

present study seemed to follow a latitudinal tendency while increased from north to south. Especially while compared in the same type of habitat this tendency was held, i.e., among stillness waters, the fish collected from more southward were also healthier than those in the north, suggesting this fish has potential target to adapt to different environments in the southernward distribution range. Originally, this species was considered to be distributed in the cold waters (Suzuki et al. 2016). The high *K* value in the more southern area (highland) and during the hotter period (the rainy season) might support that *R. similis* is tolerant of higher temperature, which leads to its expansion from the temperate to the tropical region (Serov et al. 2006, Tran & Ta 2014, Suzuki et al. 2016, Tran et al., 2018) and develops well after introduction (Suzuki et al. 2016, Eagderi et al. 2017). Factors such as maturity, reproduction, feeding habits and availability of food resources should be further concerned to provide insights into the growth pattern and condition factor of this species in Vietnam.

Introduced species could have inverse effect and eventually could cause the extinction of native species by as a predator, competitor, and change habitat (Workman & Merz 2007, Strayer 2010). It is reported that *R. similis* may be responsible for the disappearance of Pseudogobiopsis species in Singapore (Larson & Kim 2005, Larson et al. 2008) and adverse ecological impacts (Eagderi et al. 2017). The difference in growth parameters of this species between the present study and previous reports firmly supports the fact that this introduced species are more suitable to environmental conditions in the tropics. Furthermore, the higher *K* in the more southern population within Vietnam suggests that this goby adapts well to the higher temperature. In addition, the present study also reports the high variation in growth patterns and the condition factor (Figs. 18–23, tables 18–20). This species is an amphidromous fish that utilize estuarine habitats during a certain period of its life history, but some works indicate that it can remain in reservioirs (Lim & Ng, 1990, Tran et al., 2018), implying the biodiversity of this goby. Hence, these facts suggest that this goby potentially has impacts on native species and the ecosystems where it invades.

+ Synthesized characteristics of biological group in the limestone ecosystems in the mountainous region of North Vietnam.

The ichthyofanua in northern Vietnam shows somewhat clear typical traits of limestone ecosystems since many species from the following families, Botiidae, Gastromyzontidae,

Nemacheilidae, Sisoridae, Gobiidae, and several genera such as *Placogobio, Placocheilus*, *Rectoris*, *Onychostoma*, *Neolissochilus* and *Garra*, which are favorable for the high current water in the mountainous regions. Many species were also distributed in southern China, such as species from *Placogobio*, *Discogobio* and *Euchiloglanis* (Endruweit, 2013; Kottelat, 2013). In all four sites, the dominant order is Cypriniformes, accounting for more than 60% in Cham Chu and Bac Me, and 50% for the two other areas.

+ Brief description of socio-economic and policy context, initial description and analysis of natural and human impacts / threats on biological group.

Interview data show that pressures on fish diversity and fisheries varied between study sites. Human impacts including using destructive gears, over-exploitation and water pollution are the main causes for the decline of fisheries resources. In general, deforestation directly or indirectly impacts on the fish diversity and fisheries. For example, in Nam Xuan Lac HSCA, water pollution is caused by using mosquito repellent, insecticides, and herbicides by local people, and the treatment of wastewater from ore mines leads to a decline in fish stocks. These causes are also found in other sites in Vietnam (Tran and Ta, 2014).

Introduced animals such as *Rhinogobius similis* and *Gambusia affinis* are abundant in the study sites, which might impact on the aquatic ecosystem and native species (Larson & Kim 2005, Larson et al. 2008). Thus, further investigations need to be conducted to understand the impact of exotic species on native ecosystems.

However, some villagers at Bac Me NR and Nam Xuan Lac HSCA claim that the number of stream fish species has increased compared to three to four years ago thanks to positive management measures (banned electric stimulators, the transmission of fish resources protection).

+ Preliminary assessment sustainable use of biological resources and evaluation of biodiversity and conservation values at regional and site/protected area scale

Target species of conservation: In the study sites, four species listed in the IUCN Red List should be in priority to be protected. They are *Leptobotia elongata*, *Cyprinus carpio*, *Pseudohemiculter dispar*, *Oreochromis mossambicus*. Especially, *Rhinogobius lineatus* at CR level needs to be further studied. As mentioned previously, recently, the fisheries resources in some study sites have recovered due to the increase in human awareness. On the approach by

ecosystem services, fish diversity conservation should be in a context of a relationship with other organisms and in the whole ecosystem.

Priority sites of conservation: Among four study sites, several sampling sites in Cham Chu NR and Bac Me NR should be in priority of conservation because vulnerable species are mainly reported from the two areas. In Bac Me NR, the reservoir where provides a large proportion of fisheries production should be considered for conservation.

+ Proposed recommendation for biodiversity conservation and planning

Firstly, further identification of unknown species should be done to have a full picture of species composition of fish in the study sites. A better understanding of ichthyofauna is the first step for any conservation aspect.

Next, workshops with local residents and local authorities about fish diversity and fisheries resources will increase their awareness of conservation. Color photos of fish in the study sites with brief descriptions will be useful for local communities, especially for students, who will play an important role in any conservation programs.

Further investigations into the impacts of exotic fish species on native ecosystems will be important to propose a suitable conservation planning.

Last, applying remote sensing will take in advantage to have a map for conservation.

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2.9 Publications and products

+ Nguyen Quang Huy, Nguyen Huu Duc, Ta Thi Thuy, Tran Duc Hau (2020). An overview of goby fish *Rhinogobius* Gill, 1859 in Vietnam. Proceedings of National Conference on Resource and Environment Managements and Sustainable Development in Northwest Region, Vietnam, pp. 198-206.

+ Linh Manh Ha, Hau Duc Tran, Nam Thanh Nguyen, Thanh Trung Tran, Thuy Thi Ta, Nga Thi Nguyen, Huy Quang Nguyen (2021). Length-weight relationship and condition factor of Amur goby (*Rhinogobius similis*) from different areas in Vietnam. Acta Zoologica Bulgarica. Accepted.

+ Hau Duc Tran, Duc Huu Nguyen, Huong Thanh Thi Dang, Huy Quang Nguyen, Nga Thi Nguyen (2021). A New Species of *Euchiloglanis* (Teleostei: Sisoridae) from Viet Nam. Acta Zoologica Bulgarica. Submitted November 2021.

In preparation: Several papers will be published using materials from this report.

+ Length-weight relationship, sexual dimorphism, and condition factor of freshwater sleeper *Sineleotris namxamensis* (Odontobutidae) from northern Vietnam.

+ Description of specimens of genus *Parazacco* (Cypriniformes: Cyprinidae) from northern Vietnam.

+ New records of *Rhinogobius* Gill, 1859 in Cham Chu and Nam Xuan Lac, Northern Vietnam.

+ Identification of *Neolissochilus* collected from natural reserves in northern Vietnam.

+ *Rhinogobius* from northern Vietnam: A review and description of a new species.

+ First records of ichthyofauna and their distribution in Phia Oac-Phia Den National Park, northern Vietnam.

+ First records of ichthyofauna in Nam Xuan Lac HSCA, northern Vietnam.

+ First records of ichthyofauna in Cham Chu Nature Reserve, northern Vietnam and conservarion aspects.

+ Species diversity and current status of fisheries in Bac Me Nature Reserve, northern Vietnam.

+ Biological traits of introduced fish *Gambusia affinis* in four protected areas, northern Vietnam.

3. EMPOWERMENT OF YOUNG SCIENTISTS

3.1 Guiding principles for education and training

Key researchers in this project are required to guide and train young scientists, non-key researchers, as well as study the mountainous region of Northern Vietnam. For example, We, NEF, are expecting that such young scientists will finish their dissertations/papers through project participation. We kindly request all the key researchers to report the progress of their own research plan with name of each young scientist and the title of his/her research plan.

Seven young scientists have been involved in this project, one PhD, one PhD student, two Master student and three undergraduate students from Hanoi National University of Education. In order to strengthen the professional capacity for young researchers in ichthyology in Vietnam, students were participated in the field surveys, specimens were examined in laboratory and data analysis for publication.

3.2 Achievement of each young scientist

Chu Hoang Nam, Tran Trung Thanh, Nguyen Trong Nghia, experienced learning from the field work to the lab, including preparation, sampling, preservation, identification, preparing manuscript used materials from the study site.

Nguyen Quang Huy used the collection of fish from Tuyen Quang province for morphological analyses. He successfully defended the bachelor thesis in 2020. He is a co-author of one paper and three manuscript.

+ Nguyen Quang Huy, Nguyen Huu Duc, Ta Thi Thuy, Tran Duc Hau (2020). An overview of goby fish *Rhinogobius* Gill, 1859 in Vietnam. Proceedings of National Conference on Resource and Environment Managements and Sustainable Development in Northwest Region, Vietnam, pp. 198-206.
+ Linh Manh Ha, Hau Duc Tran, Nam Thanh Nguyen, Thanh Trung Tran, Thuy Thi Ta, Nga Thi Nguyen, Huy Quang Nguyen (2021). Length-weight relationship and condition factor of Amur goby (*Rhinogobius similis*) from different areas in Vietnam. Acta Zoologica Bulgarica. Accepted.

+ Hau Duc Tran, Duc Huu Nguyen, Huong Thanh Thi Dang, Huy Quang Nguyen, Nga Thi Nguyen (2021). A New Species of *Euchiloglanis* (Teleostei: Sisoridae) from Viet Nam. Acta Zoologica Bulgarica. Submitted.
+ Huy Quang Nguyen, Hau Duc Tran (2021). Length-weight relationship, sexual dimorphism, and condition factor of freshwater sleeper *Sineleotris namxamensis* (Odontobutidae) from northern Vietnam. In preparation.

Vu Trung Hieu used the collection of *Rhinogobius* from Bac Me, Phia Oac-Phia Den and Nam Xuan Lac as the maim part of materials for his bachelor thesis. He reported the genetic diversity of *Rhinogobius* collected from the above areas. He obtained the bachelor degree in 2020.

Nguyen Le Hoai Thuong has used the collection of *Rhinogobius* specimens from northeastern Vietnam for her master thesis and it was completed in the middle of 2022. Her thesis will focus on morphometrics, length weight relationship and condition factor.

Duong Thi Huyen will use the collection of *Parazzaco* specimens from northeastern Vietnam for her bachelor thesis and it is expected to be complete in the middle of 2022. Her thesis will focus on morphometrics, and taxonomy.

Nguyen Minh Thuy will use materials of *Gambusia affinis* collected from the study site for her bachelor thesis, focusing on length weight relationship and condition factor.

4. APPENDICES

Appendix 1. Questionnaires for local residents

(*About exploitation and protection of fisheries in the research area*)

(Fish Diversity and Conservation Status in Northern Vietnam Karst Habitats)

Date:.....; Site:.....

Interviewee's name:.....; Occupation:.....Age:.....

1. Economic-social conditions

Interviewee's information

- Residence in the region:.....years; Fishing experience:.....years; Ethnics:.....

- Education: Schoolless □; Grade:...../12

Income

- Main income of family:.....

- Income from fishing activity (per trip:....., weekly:....., yearly:.....).

- Income from other fisheries (per trip:....., weekly:....., yearly:.....).

- Percentage of income from fishing:.....%.

2. Satus of exploitation and protction of fishery resources in the research area

2.1 Fishery resource value

Usage of fish as daily food

- Fish consumed:.....days/week

- Kilo of fish consumed (daily:.....; weekly:.....; monthly:.....)

Price of fish commonly used in the region (commercial fish)

≠	Fish name	Price/kg	≠	Fish name	Price/kg

Fish from market

Source: Aquaculture □ (species.....)

Wild □ (Speice.....)

Product:.....kg/ week; Price:.....vnd/ time

2.2 Current status of fisheries resources

Conservation aspects

- Do you know any information about status of fisheries resources in the area? Yes □; No □

- Any program for conservation in the area? Yes □; No □

- How often do conservation activities organize in the area? Yes □; No □

Source of infromation: workshop □; Media □; local authority □; other □

Abundant species in the area.....

Recently extinction species.....

Currently appearing species.....

The rates of decline of fisheries resources during the last years: 5 years:.....(%); 10 years:.....(%)

2.3 Status of exploitation in fishers

Fishing

- Site:.....; Distance:.....km/trip; Time:.....hours/trip; Fishing frequency:.....days/ week; manpower:.....workers/trip.

- Habitats for fishing?

+ River:

+ Lake:

+ Reservoir:

+ Stream:

+ Ponds:

+ Ricefield:

+ Others:

- Types of forests for fishing:

+ Evergreen and semideciduous broad-leaved forests

+ Deciduous forests

+ Bamboo and palms

+ Coniferous forests

+ Open broad-leaved forests

+ Scrub

- Season fishing: dry □; rainy □; yearly □

- Fishing product:.....kg/ trip

- Gears used in fishing: Elector-fishing □; Gill nets □ (size.....); Fishingline □; Others □ (.....)

- Boat used in fishing □, No □

- Fishing purpose: food □; sale □

Aquaculture.....

- Source of seed:.....

Information about reproduction

≠	**Fish name**	**Spawning time**	**Spawning ground**

4 Some possible causes to the fisheries resources

Water pollution □; Over-exploitation □; Deforestation □; Destructive gears □; Management □; Climat change □; Tourism activity □; Other □

(.....)

5 Other information

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Appendix 2. List of fish in the four areas in northern Vietnam from 2018 to 2021

2.1. A completed list of fish collected in Cham Chu NR, Tuyen Quang Province

#	Scientific name	Vietnamese name	PL	CD
	I. CYPRINIFORMES	**Bộ Cá Chép**		
	1. Botiidae			
1	*Leptobotia elongata* (Bleeker, 1870)	Cá Chạch cát đốm		+
	2. Cobitidae	**Họ cá Chạch**		
2	*Misgurnus anguillicaudatus* (Cantor, 1842)	Cá Chạch bùn		+
	3. Gastromyzontidae	**Họ Cá chạch bám**		
3	*Liniparhomaloptera* cf. *qiangzhongensis*		+	
	4. Nemacheilidae	**Họ Cá Chạch suối**		
	Schistura spp.	Cá Chạch suối	+	+
4	*Traccatichthys taeniatus* (Pellegrin & Chevey, 1936)	Cá Chạch cật		+
	5. Cyprinidae	**Họ Cá Chép**		
5	*Barbodes semifasciolatus* (Günther, 1868)	Cá Đòng đong	+	
6	*Carassius auratus* (Linnaeus, 1758)	Cá Diếc mắt đỏ		+
7	*Cyprinus carpio* Linnaeus, 1758	Cá Chép		+
8	*Garra orientalis* Nichols, 1925	Cá Sứt mũi		+
9	*Neolissochilus benasi* (Pellegrin & Chevey, 1936)	Cá Rai	+	+
10	*Osteochilus salsburyi* Nichols & Pope, 1927	Cá Dầm đất		+
	6. Xenocyprididae			
11	*Aphyocypris normalis* Nichols & Pope, 1927	Cá Dầm suối thường		+
12	*Chanodichthys erythropterus* (Basilewsky, 1855)	Cá Thiểu		+
13	*Culter flavipinnis* Tirant, 1883	Cá Ngão gù		+
14	*Hemiculter leucisculus* (Basilewsky, 1855)	Cá Mương xanh		+
15	*Metzia formosae* (Oshima, 1920)	Cá Mại bạc		+
16	*Opsariichthys minutus* Nichols, 1926	Cá Cháo thường	+	+
17	*Pseudohemiculter dispar* (Peters, 1881)	Cá Dầu sông mỏng		+
18	*Sinibrama affinis* (Vaillant, 1892)	Cá Nhác		+
19	*Toxabramis swinhonis* Günther, 1873	Cá Dầu hồ bằng		+
	7. Acheilognathidae			
20	*Acheilognathus* sp.	Cá Thè be	+	+
	Acheilognathus tonkinensis (Vaillant, 1892)	Cá Thè be thường		+
21	*Rhodeus* cf. *albomarginatus*	Cá Bướm		+

22	*Rhodeus ocellatus* (Kner, 1866)	Cá Bướm chấm	+	
	8. Gobionidae			
23	*Gobiobotia meridionalis* Chen & Cao, 1977	Cá Đục râu		+
24	*Hemibarbus* cf. *umbrifer*	Cá Đục		+
25	*Hemibarbus medius* Yue, 1995	Cá Đục ngộ		+
26	*Placogobio bacmeensis* Nguyen & Vo, 2001	Cá Thui	+	+
27	*Saurogobio dabryi* Bleeker, 1871	Cá Đục đanh đốm		+
28	*Squalidus argentatus* (Sauvage & Dabry de Thiersant, 1874)	Cá Đục trắng mỏng		+
	II. SILURIFORMES	**Bộ Cá Da trơn**		
	1. Bagridae	**Họ Cá Lăng**		
29	*Hemibagrus centralus* Mai, 1978	Cá Lăng quảng bình	+	
30	*Hemibagrus pluriradiatus* (Vaillant, 1892)	Cá Lường		+
31	*Tachysurus fulvidraco* (Richardson, 1846)	Cá Bò đen		+
32	*Tachysurus kyphus* Mai, 1978	Cá Mịt tròn		+
33	*Tachysurus virgatus* (Oshima, 1926)	Cá Mịt		+
	2. Sisoridae	**Họ Cá Chiên**		
34	*Glyptothorax honghensis* Li, 1984	Cá Chiên suối sông Hồng	+	+
	3. Siluridae	**Họ Cá Nheo**		
35	*Pterocryptis cochinchinensis* (Valenciennes, 1840)	Cá Thèo	+	+
36	*Silurus asotus* Linnaeus, 1758	Cá Nheo		+
	III. GOBIIFORMES	**Bộ Cá bống**		
	1. Odontobutidae			
37	*Sineleotris namxamensis* Chen & Kottelat, 2004	Cá Bống nhỏ	+	+
	2. Gobiidae	**Họ Cá bống trắng**		
38	*Rhinogobius duospilus* (Herre, 1935)	Cá Bống suối	+	+
39	*Rhinogobius honghensis* Chen, Yang & Chen, 1999	Cá Bống khe	+	
40	*Rhinogobius similis* Gill, 1859	Cá Bống đá	+	+
41	*Rhinogobius* sp.		+	+
	IV. SYNBRANCHIFORMES	**Bộ Cá Mang liền**		
	1. Mastacembelidae	**Họ Cá Chạch sông**		
42	*Mastacembelus armatus* (Lacepède, 1800)	Cá Chạch sông	+	+
	V. ANABANTIFORMES	Bộ Cá rô đồng		
	1. Osphronemidae	**Họ cá Tai tượng**		
43	*Macropodus opercularis* (Linnaeus, 1758)	Cá Đuôi cờ thường		+

	VI. CICHLIFORMES	**Bộ Cá rô phi**		
	1. Cichlidae	**Họ Cá rô phi**		
44	*Oreochromis mossambicus* (Peters, 1852)	Cá Rô phi đen		+
45	*Oreochromis niloticus* (Linnaeus, 1758)	Cá Rô phi vằn	+	+
	VII. CYPRINODONTIFORMES	**Bộ Cá bạc đầu**		
	1. Poeciliidae	**Họ Cá ăn muỗi**		
46	*Gambusia affinis* (Baird & Girard, 1853)	Cá Ăn muỗi	+	+
	VIII. BELONIFORMES	**Bộ Cá Nhái**		
	1. Adrianichthyidae	**Họ Cá Sóc**		
47	*Oryzias pectoralis* Roberts, 1998	Cá Sóc vây ngực	+	+
Total			**20**	**44**

2.2. A completed list of fish collected in Bac Me NR, Ha Giang Province

≠	Scientific name	Vietnamese name	BM.1	BM.2
	I. Cypriniformes	**Bộ cá Chép**		
	1. Cobitidae	**Họ cá Chạch**		
1	*Misgurnus anguillicaudatus* (Cantor, 1842)	Cá Chạch bùn	+	+
	2. Gastromyzontidae	**Họ cá Chạch bám**		
2	*Liniparhomaloptera* cf. *qiongzhongensis*		+	+
	3. Nemacheilidae	**Họ cá Chạch suối**		
3	*Schistura* spp.	Cá Chạch suối	+	+
	4. Cyprinidae	**Họ cá Chép**		
4	*Barbodes semifasciatus* (Günther, 1868)	Cá Đòng đong	+	+
5	*Cyprinus carpio* (Linnaeus, 1758)	Cá Chép	+	+
6	*Neolissochilus benasi* (Pellegrin & Chevey, 1936)	Cá Rai	+	+
7	*Onychostoma gerlachi* (Peters, 1881)	Cá Sỉnh gai nhỏ	+	+
8	*Onychostoma lepturus* (Günther, 1896)	Cá Phao	+	
9	*Osteochilus salsburyi* Nichols & Pope, 1927	Cá Dầm đất	+	+
10	*Spinibarbus hollandi* Oshima, 1919	Cá Chày đất		+
	5. Danionidae	**Họ cá Lòng tong**		
11	*Rasbora steineri* Nichols & Pope, 1927	Cá Mại sọc	+	
	6. Xenocyprididae	**Họ cá Nhàng**		
12	*Hemiculter elongatus* Nguyen & Ngo, 2001	Cá Vền dài	+	
13	*Hemiculter leucisculus* (Basilewsky, 1853)	Cá Mương xanh	+	
14	*Megalobrama terminalis* (Richardson, 1846)	Cá Vền	+	

15	*Megalobrama skolkovii* Dybowski, 1872	Cá Vền	+	+
16	*Metzia formosae* (Oshima, 1920)	Cá Mại bạc	+	
17	*Opsariichthys minutus* Günther, 1873	Cá Cháo thường	+	+
18	*Toxabramis houdemeri* Pellegrin, 1932	Cá Dầu hồ cao	+	
19	*Xenocypris davidi* Bleeker, 1871	Cá Mần	+	
	7. Acheilognathidae	**Họ cá Thè be**		
20	*Rhodeus ocellatus* (Kner, 1866)	Cá Bướm chấm	+	
	8. Gobionidae			
21	*Discogobio microstoma* (Mai, 1978)	Cá Bám sừng		+
22	*Discogobio* spp.			+
23	*Microphysogobio elongatus* (Yao & Yang, 1977)	Cá Đục đanh chấm		+
24	*Placogobio bacmeensis* Nguyen & Vo, 2001	Cá Thui		+
25	*Saurogobio dabryi* Bleeker, 1871	Cá Đục đanh đốm		+
26	*Squalidus argentatus* (Sauvage & Dabry de Thiersant, 1874)	Cá Đục trắng mỏng		+
	II. Siluriformes	**Bộ cá Nheo**		
	1. Bargridae	**Họ cá Lăng**		
27	*Pseudobagrus vachellii* (Richardson, 1846)	Cá Mầm	+	+
	2. Sisoridae	**Họ cá Chiên**		
28	*Glyptothorax honghensis* Li, 1984	Cá Chiên sông Hồng	+	+
	3. Siluridae	**Họ cá Nheo**		
29	*Pterocryptis* sp.	Cá Niết	+	+
	4. Cranoglanididae	**Họ cá Ngạnh**		
30	*Cranoglanis henrici* (Vaillant, 1893)	Cá Ngạnh thường	+	
	III. Gobiiformes	**Bộ cá Bống**		
	1. Odontobutidae	**Họ cá Bống suối**		
31	*Sineleotris namxamensis* Chen & Kottelat, 2004	Cá Bống suối	+	+
	2. Gobiidae	**Họ cá Bống trắng**		
32	*Rhinogobius mekongianus* (Pellegrin & Fang 1940)	Cá Bống mê kông	+	+
33	*Rhinogobius similis* Gill, 1859	Cá Bống đá	+	+
	VI. Anabantiformes	**Bộ cá rô đồng**		
	1. Anabantidae	**Họ cá rô đồng**		
34	*Anabas testudineus* (Bloch, 1792)	Cá Rô đồng	+	
	2. Osphronemidae	**Họ cá tai tượng**		

35	*Macropodus opercularis* (Linnaeus, 1758)	Cá Đuôi cờ thường	+	+
	3. Channidae	**Họ cá chuối**		
36	*Channa gachua* (Hamilton, 1822)	Cá Chuối	+	+
	V. Cichliformes	**Bộ cá rô phi**		
	1. Cichlidae	**Họ cá rô phi**		
37	*Oreochromis niloticus* (Linnaeus, 1758)	Cá Rô phi vằn	+	
	VI. Cyprinodontiformes	**Bộ cá Chép răng**		
	1. Poeciliidae	**Họ cá Khổng tước**		
38	*Gambusia affinis* (Baird & Girard, 1853)	Cá Ăn muỗi	+	+
Total			**31**	**26**

2.3. A completed list of fish collected in Phia Oac-Phia Den NP, Cao Bang Province

≠	Scientific name	Vietnamese name	DO.1	DO.2
	I. Cypriniformes	**Bộ cá Chép**		
	1. Gastromyzontidae	**Họ cá Chạch bám**		
1	*Liniparhomaloptera* cf. *qiongzhongensis*			+
2	*Vanmanenia* cf. *caldwelli*		+	+
	2. Balitoridae	**Họ cá Chạch vây bằng**		
3	*Beaufortia pingi* (Fang, 1930)	Cá Bám khuyết pingi	+	+
	3. Nemacheilidae	**Họ cá Chạch suối**		
4	*Schistura* spp.	Cá Chạch suối	+	+
	4. Cyprinidae	**Họ cá Chép**		
5	*Barbodes semifasciolatus* (Günther, 1868)	Cá Đòng đong	+	+
6	*Carassius auratus* (Linnaeus, 1758)	Cá Diếc mắt đỏ	+	+
7	*Cyprinus carpio* (Linnaeus, 1758)	Cá Chép	+	+
8	*Onychostoma gerlachi* (Peters, 1881)	Cá Sỉnh gai nhỏ	+	
	5. Xenocyprididae	**Họ cá Nhàng**		
9	*Parazacco* sp.	Cá Chuôn	+	

	6. Gobionidae	**Họ cá Đục**		
10	*Discogobio microstoma* (Mai, 1978)	Cá Bám sừng	+	
11	*Discogobio* spp.		+	+
12	*Hemibarbus* cf. *umbrifer*	Cá Đục ó lạng sơn	+	
	II. Siluriformes	**Bộ cá Nheo**		
	1. Sisoridae	**Họ cá Chiên**		
13	*Euchiloglanis* sp.	Cá Chiên pớm	+	+
	2. Clariidae			
14	*Clarias fuscus* (Lacepède, 1803)	Cá Trê đen		+
	III. Gobiiformes	**Bộ cá Bống**		
	1. Gobiidae	**Họ cá Bống trắng**		
15	*Rhinogobius duospilus* (Herre, 1935)	Cá Bống suối	+	+
	IV. Synbranchiformes	**Bộ cá Mang liền**		
	1. Synbranchidae	**Họ Lươn**		
16	*Monopterus albus* Zuiew, 1793	Lươn thường	+	+
	V. Anabantiformes	**Bộ cá Rô đồng**		
	1. Osphronemidae	**Họ cá tai tượng**		
17	*Macropodus opercularis* (Linnaeus, 1758)	Cá Đuôi cờ thường	+	
	2. Channidae	**Họ cá Chuối**		
18	*Channa gachua* (Hamilton, 1822)	Cá Chành dục		+
	VI. Cyprinodontiformes	**Bộ cá Chép răng**		
	1. Poeciliidae	**Họ cá Khổng tước**		
19	*Gambusia affinis* (Baird & Girard, 1853)	Cá Ăn muỗi	+	+
Total			**16**	**14**

2.4. A completed list of fish collected in Nam Xuan Lac HSCA, Bac Kan Province

≠	Scientific name	Vietnamese name	NXL.1	NXL.2
	I. Cypriniformes	**Bộ cá Chép**		
	1. Gastromyzontidae	**Họ cá Chạch bám**		
1	*Liniparhomaloptera* cf. *qiongzhongensis*		+	+
2	*Vanmanenia* cf. *caldwelli*		+	+
	2. Nemacheilidae	**Họ cá Chạch suối**		
3	*Schistura* spp.	Cá chạch suối	+	+
	3. Cyprinidae	**Họ cá Chép**		
4	*Barbodes semifasciolatus* (Günther, 1868)	Cá Đòng đong	+	+
5	*Neolissochilus benasi* (Pellegrin & Chevey, 1936)	Cá Rai	+	+
6	*Neolissochilus* sp. (Nguyen & Doan, 1969)		+	+
7	*Onychostoma gerlachi* (Peters, 1881)	Cá Sỉnh gai nhỏ	+	+
8	*Onychostoma lepturus* (Boulenger, 1900)	Cá Phao	+	
	4. Xenocyprididae	**Họ cá Nhàng**		
9	*Opsariichthys minutus* Nichols, 1926	Cá Cháo thường	+	+
10	*Parazacco* sp.	Cá Chuôn	+	+
	5. Acheilognathidae			
11	*Rhodeus ocellatus* (Kner, 1866)	Cá Bướm chấm	+	
	6. Gobionidae			
12	*Discogobio microstoma* (Mai, 1978)	Cá Bám sừng	+	+
13	*Placogobio bacmeensis* Nguyen & Vo, 2001	Cá Thui	+	+
	II. Siluriformes	**Bộ cá Nheo**		
	1. Bagridae	**Họ cá Lăng**		
14	*Hemibagrus pluriradiatus* (Vaillant, 1892)	Cá Lường	+	
	2. Sisoridae	**Họ cá Chiên**		
15	*Glyptothorax honghensis* Li, 1984	Cá Chiên suối sông Hồng	+	+
	3. Clariidae	Họ Cá Trê		
16	*Clarias fucus* (Lacepède, 1803)	Cá Trê đen		+
	III. Gobiiformes	**Bộ cá Bống**		
	1. Gobiidae	**Họ Cá Bống**		
17	*Rhinogobius lineatus* Chen, Kottelat & Miller, 1999		+	+

18	*Rhinogobius* sp.	Cá Bống đá	+	+
	IV. Synbranchiformes	**Bộ cá Mang liền**		
	1. Mastacembelidae	**Họ cá Chạch sông**		
19	*Mastacembelus armatus* (Lacepède, 1800)	Cá Chạch sông	+	+
	2. Synbranchidae	**Họ Lươn**		
20	*Monopterus albus* Zuiew, 1793	Lươn thường		+
	V. Anabantiformes	Bộ Cá rô đồng		
	1. Osphronemidae	**Họ cá Tai tượng**		
21	*Macropodus opercularis* (Linnaeus, 1758)	Cá Đuôi cờ thường	+	+
	2. Channidae	**Họ cá Chuối**		
22	*Channa gachua* (Hamilton, 1822)	Cá Chành dục	+	
	VI. Cichliformes	**Bộ cá Rô phi**		
	1. Cichlidae	**Họ cá Rô phi**		
23	*Oreochromis niloticus* (Linnaeus, 1758)	Cá Rô phi vằn		+
	VII. Cyprinodontiformes	**Bộ cá Chép răng**		
	1. Poeciliidae	**Họ cá Khổng tước**		
24	*Gambusia affinis* (Baird & Girard, 1853)	Cá Ăn muỗi	+	
Total			**21**	**19**

Appendix 3. Photos of fish in the four protected areas in northern Vietnam

3.1. Photos of all fish collected from Cham Chu Nature Reserve, Tuyen Quang Province

Leptobotia elongata

Misgurnus anguillicaudatus

Liniparhomaloptera cf. *qiongzhongensis*

Schistura sp.

Traccatichthys taeniatus

Barbodes semifasciolatus

Carassius auratus

Cyprinus carpio

Garra orientalis

Neolissochilus benasi

Osteochilus salsburyi

Aphyocypris normalis

Chanodichthys erythropterus

Chanodichthys flavipinnis

Hemiculter leucisculus

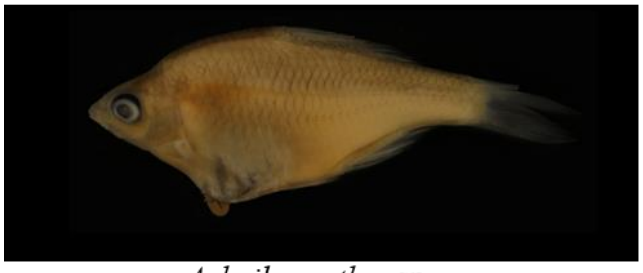
Metzia formosae

Opsariichthys minutus

Pseudohemiculter dispar

Sinibrama affinis

Toxabramis swinhonis



Acheilognathus sp.

Acheilognathus tonkinensis

Rhodeus cf. *albomarginatus*

Rhodeus ocellatus

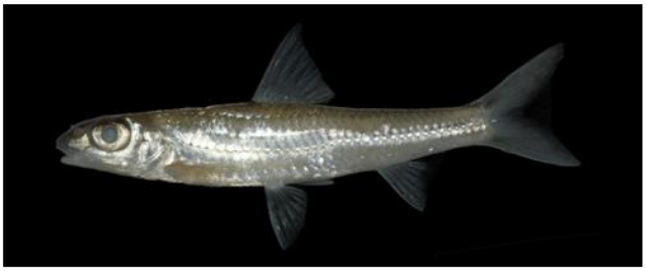
Gobiobotia meridionalis

Hemibarbus cf. *umbrifer*

Hemibarbus medius

Placogobio bacmeensis

Saurogobio dabryi



Squalidus argentatus

Hemibagrus centralus

Hemibagrus pluriradiatus

Tachysurus fulvidraco

Tachysurus kyphus

Tachysurus virgatus

Glyptothorax honghensis

Pterocryptis cochinchinensis

Silurus asotus

Sineleotris namxamensis

Rhinogobius duospilus

Rhinogobius honghensis

Rhinogobius similis

Rhinogobius sp.

Mastacembelus armatus

Macropodus opercularis

Oreochromis mossambicus

Gambusia affinis

Oreochromis niloticus

Oryzias pectoralis

3.2. Photos of some fish collected from Bac Me Nature Reserve, Ha Giang Province

Misgurnus anguillicaudatus

Liniparhomaloptera cf. *qiongzhongensis*

Schistura sp.

Babordes semifaciolatus

Cyprinus carpio

Onychostoma gerlachi

Onychostoma lepturus

Osteochilus salsburyi

Spinibarbus hollandi

Rasbora steineri

Hemiculter elongatus

Hemiculter leucisculus

Megalobrama terminalis

Megalobrama skolkovii

Metzia formosae

Opsariichthys minutus

Toxabramis houdemeri

Xenocypris davidi

Rhodeus ocellatus

Discogobio microstoma

Discogobio sp.

Placogobio bacmeensis

Squalidus argentatus

Tachysurus vachellii

Glyptothorax honghensis

Pterocryptis sp.

Cranoglanis henrici

Sineleotris namxamensis

Rhinogobius mekongianus

Rhinogobius similis

Anabas testudineus

Macropodus opercularis

Channa gachua

Oreochromis niloticus

Gambusia affinis

3.3. Photos of all fish collected from Phia Oac-Phia Den National Park, Cao Bang Province.

Liniparhomaloptera cf. *qiongzhongensis*

Beaufortia pingi

Schistura sp.

Barbodes semifasciolatus

Carassius auratus

Cyprinus carpio

Hemibarbus cf. *umbrifer*

Euchiloglanis sp.

Clarias fuscus

Rhinogobius duospilus

Monopterus albus

Macropodus opercularis

Channa gachua

Gambusia affinis

3.4. Photos of all fish collected from Nam Xuan Lac HSCA, Bac Kan Province

Liniparhomaloptera cf. *qiongzhongensis*

Vanmanenia cf. *caldwelli*

Schistura sp.

Barbodes semifasciolatus

Neolissochilus benasi

Neolissochilus sp.

Onychostoma gerlachi

Onychostoma lepturus

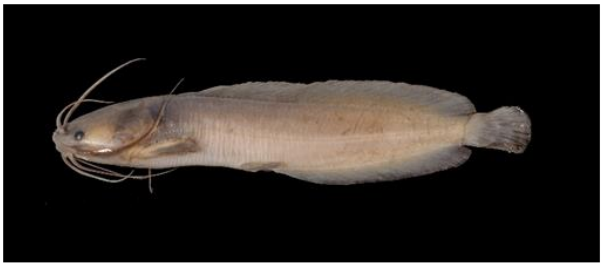
Opsariichthys minutus

Parazacco sp.

Discogobio microstoma

Hemibagrus pluriradiatus

Glyptothorax honghensis



Clarias fuscus

Rhinogobius lineatus

Rhinogobius sp. (Female)

Rhinogobius sp. (Male)

Mastacembelus armatus

Chana gachua

Oreochromis niloticus

Gambusia affinis

Appendix 4. Sampling site and field work activities

4.1. Photos of all sampling sites in Cham Chu NR (Phu Luu and Cao Duong commune)

P1

P2

P3

P4

P5

P6

P7

P8

P9

P10

P11

P12

P13

P14

P15

P16

P17

4.2. Photos of all sampling sites in Bac Me NR

BM 1

BM 2

BM 3

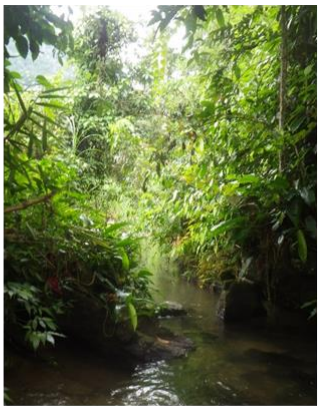
BM 4

BM 5

BM 6

BM 7

BM 8



BM 9

BM 10

BM 12

BM 11

BM 13

4.3. Photos of all sampling sites in Phia Oac-Phia Den NP

DO.07

DO.08

DO.09

DO.10

DO.01

DO.02

DO.02A

DO.06

4.4. Photos of all sampling sites in Nam Xuan Lac HSCA

NXL.01

NXL.02

NXL.03

NXL.04

NXL.05

NXL.06

NXL.07

NXL.08

NXL.09

NXL.10

NXL.11

4.5. Photos of some field work activities

Collection of specimens in the field


Fixation of specimens




Interview activities to understand the fisheries status in the study site

A fishing gun used by a local fisher

Fish diversity monitoring introduction