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Sustainable Natural Resource Management Project (SNRM)

FINAL REPORT

"BIODIVERSITY BASELINE SURVEY FOR SUSTAINABLE NATURAL RESOURCE MANAGEMENT PROJECT (COMPONENT 3)"

by

SOUTHERN INSTITUTE OF ECOLOGY

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List of Abbreviations

DBH	Diameter at Breast Height
BDNB	Bidoup-Nui Ba National Park
DARD	Department of Agriculturre and Rural Development
DONRE	Department of Natura Resource and Environment
GBIF	Global Biodiversity Information Facility
GIS	Geographic information system
GPS	Global Positioning System
JICA	Japan International Cooperation Agency
LBBR	Lang Biang Biosphere Reserve
MARD	Ministry of Agriculturre and Rural Development
MONRE	Ministry of Natura Resource and Environment
NK	Nippon Koei Co., Ltd.
NP	National Park
SIE	Southern Institute of Ecology
SNRM	Sustainable Natural Resource Management Project
SNRMP	Sustainable Natural Resource Management Project
SPOT	Système Pour l'Observation de la Terre
UNESCO	United Nations Educational, Scientific and Cultural Organization
UTM	Universal Transverse Mercator
WGS	World Geodetic System

I. INTRODUCTION

1 LANGBIANG BIOSPHERE RESERVE AND THE TARGET AREA

1.1 DESIGNATION, AREA AND LOCATION

The Lang Biang Biosphere Reserve (LBBR) in the Lam Dong Province, the ninth biosphere reserve of Vietnam and the first one in Central Highland was designated in 2015 by UNESCO. Its total area is 275,429 ha including a 34,943-ha core zone, 72,232-ha buffer zone and a 168,264-ha transition zone. The biosphere reserve situates in the five districts of Lac Duong, Lam Ha, Don Duong, Duc Trong and Dam Rong, and Da Lat City. The geographical location of the biosphere reserve is illustrated in Table 1 and Figure 1.

Table 1. The geographical coordinates of the Lang Biang Biosphere Reserve

Cardinal points	Latitude	Longitude
Most central point:	$12^0$01’ 02” N	$108^0$27’ 33” E
Northernmost point:	$12^0$20’ 12” N	$108^0$29’ 19” E
Southernmost point:	$11^0$41’ 52” N	$108^0$21’ 19” E
Westernmost point:	$11^0$52’ 50” N	$108^0$09’ 18” E
Easternmost point:	$12^0$09’ 29” N	$108^0$45’ 48” E

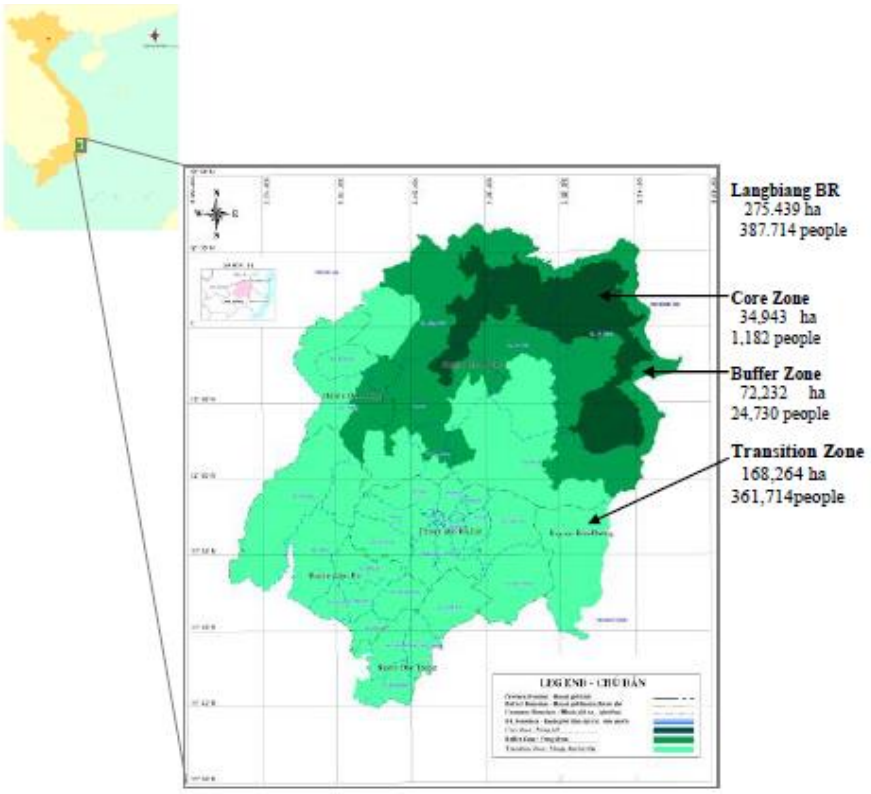


Figure 1. Map showing the core and buffer zones of LBBR.

– The core zone of LBBR covers Bidoup Nui Ba National Park (BDNB), which was established according to Decision of the Prime Minister No 01/CT dated 13/01/1992 based on Bidoup Nui Ba Nature Reserve and Decision No 1240/QD-TTg dated 19/11/2004 of the Prime Minister on

the upgrading of Bidoup - Nui Ba Nature Reserve into Bidoup - Nui Ba National Park. BDNB includes strictly protected and ecologically rehabilitated sub-zones. The strictly protected sub-zone is defined to be prioritized for conservation while the ecologically rehabilitated sub-zone includes forests of high conservation value, being habitats for rare animal species in the National Park. The core zone of LBBR is functioned to contribute to the economic development for local people, especially the K'Ho people through programs of payments for forest environmental services, ecotourism and community tourism. Besides, it fulfills a function of supporting local, national and international education and scientific research activities.

- The buffer zone of LBBR is adjacent to the core zone, including agro-forestry production areas, protection forests and plantations. It contributes to the conservation of the core zone and facilitates economic development of local communities as well as education and scientific activities. Having beautiful landscape and habitats, the buffer zone is a good foundation to develop ecotourism. This is also home to indigenous peoples, especially the K'Ho community characterised by cultural features including the Central Highland Gong.

- The transition zone consists of Da Lat City and districts contiguous to the buffer zone. This is a center of economic development in the region, facilitating ecotourism, agriculture and forestry activities. It is functioned to support the implementation of projects on sustainable development and education and scientific research activities, especially environmental education.

1.2 PHYSICAL FEATURES

If Lang Biang peak is the center point, the biosphere reserve includes overlapping mountain ranges: Hon Nga range, Chu Yang Cao range with the peak of Cong Troi and Chu Yang Yu to the west; Lang Biang range and Lang Biang peak in the center; Elephant Mountains with majestic peak of Pinhatt to the south; the Bidoup range with the roof of a high plateau and Bidoup peak of 2,287 m above sea level (asl) to the southeast; and two adjacent mountain ranges of Gia Rich and Hon Giao to the east.

LBBR is actually the watersheds of two important basins: *(i)* the Dong Nai River, which plays an important role on Vietnam's economically important southeast, and *(ii)* the Srepok River, a tributary of the Mekong River.

Its complex topography ranges from about 600 m to 2.287 m asl. In general, the area has the tilted topography upward from the northeast to the southwest. The outstanding feature of the area's terrain is inclined to make up a rough gradient. In relation to geological landforms, the area's terrain can be divided in to different types:

- *Valley terrain*: Including the relatively flat surface and low slopes between mountains or accumulated from alluvial. Depending on the source of soils and extent of water saturation, soils here can be alluvium or humus, and mostly fertile for the growth of annual and perennial plants.

- *Low to medium hill terrain*: This is a kind of terrain with slightly sloping hill ranges at less than 1,000 m elevations, most of which is originated from eruptions with yellow or reddish-brown basalt soils.

- *High mountain terrain*: Mostly located above 1000 m asl with steep dissected slopes and originated from the Jurassic - Cretaceous (with Granite, Dacit or Andezite) or the Mesozoic sediments (with sand sheets and shale). It is covered mainly with yellow-red, red-yellow or grey

soils on the neutral bedrocks or shale. The soild layer is thin and the slope is normally above 30°, and thus it is suitable for few plants.

About 8 soil types have been determined existing in LBBR (Nguyễn & Kuznetsov, 2009).

1.3 CLIMATE

Despite located in the seasonal tropical climate, the geographical and topographical characteristics in a high plateau contribute to shape the local climate be sub-tropical with average temperature of 18ºC based on the Koppen climate classification. The average temperature of the warmest month is 19.3^0C and of the coldest month 15.8^0C. The data of Da Lat Meteorological station (at 1,500 m asl) has recorded data from 1964 to 1998 showing an average annual precipitation of around 2,175 mm (Table 2) that tends to be higher at higher peaks. LBBR has two seasons: rainy season in May – October and dry season in November – April. The humidity is quite stable ranging from 75% to 85% on average.

1.4 VEGETATION

Regarding the local vegetation, relevant information can be found in various publications. In fact, the vegetation of the area was described by Schmid (1974) and Rollet (1960) and inherited by many different authors, including an amendment by Thai Van Trung (1978 & 1999). The works of Schmid (1974) and Thai Van Trung (1978 & 1999) were inherited in describing the flora of BDNB in the report of *Technical and economic feasibility study* (2004) to establish BDNB by Sub-Institute for Forest Inventory and Planning of Southern Viet Nam and in the subsequent report "*Investigation and Evaluation of the current status of forest resources and biodiversity in BC sub-project areas in Lam Dong*" (Nguyễn et al, 2006) and "*Adjusting the functional sub-zones of Bidoup-Nui Ba National Park* " (BDNB, 2008).

The BDNB vegetation was also described with different key habitats by Kuznetsov & Kuznetsova (2009) in the project "*Study of the Fauna and Flora in Bidoup-Nui Ba National Park*" of the Vietnam-Russia Tropical Center. In 2009, a report by Nguyen & Kuznetsov analysed the influence of the local terrain on vegetation in BDNB. The report "*Adjusting the functional sub-zones of Bidoup-Nui Ba National Park*" shows that having a 90% forest coverage, BDNB is one of Vietnam's special use forests having highest forest coverage. The broadleaf evergreen forest, coniferous and broad-leaved mixed forest and natural three-leaved pine (*Pinus kesiya*) forest (occupying about 60% of the NP area) is the most primary forest types (BDNB, 2008). In addition, the pure bamboo forest, bamboo and tree mixed forest and grasslands are virtually kept in tact, creating a diversity of vegetation in the park. In BDNB, there are various valleys formulated by high mountains, harbouring high diversity of plants. The valley created by Gia Rich and Hon Giao mountain ranges is a remarkable example, where there is a concentration of coniferous trees such as Po Mu (*Fokienia hodginsii*); Krempf's pine (*Pinus krempfii*), Dalat Pine (*Pinus dalatensis*); Feather Pine (*Darcrycarpus impricatus*), etc. The status of these vegetation types is summarised in Table 3 below.

Table 2. Climate data at Da Lat Meteorological station (1964–1998)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Max temperature (°C)	30	31	31.5	31.2	30.6	30	29.2	29.3	29.7	30	29.2	29.4	31.5
Mean temperature (°C)	22.3	24	25	25.2	24.5	23.4	22.8	22.5	22.8	22.5	21.7	21.4	23.2
Daily mean temperature (°C)	15.8	16.7	17.8	18.9	19.3	19	18.6	18.5	18.4	18.1	17.3	16.2	17.9
Average min temperature (°C)	11.3	11.7	12.6	14.4	16	16.3	16	16.1	15.8	15.1	14.3	12.8	14.3
Min temperature (°C)	−0.1	−0.6	4.2	4	10	10.9	10.4	10.6	10	8.1	4.4	2.6	−0.6
Average precipitation (mm)	11	24	62	170	191	213	229	214	282	239	97	36	1,739
Average rainy days	2	2	5	11	18	20	23	22	23	19	10	5	161
Average relative humidity (%)	82	78	77	84	87	88	90	91	90	89	85	84	85
Mean monthly sunshine hours	214	220.3	206.8	196.7	176.1	158.2	128.3	130	102.4	144.7	168.6	190.2	2,036.30

Table 3. Land coverage status of BDNB

No.	Land coverage status	Total area (ha)	Percentage (%)
1	Evergreen broad-leaf forest	20,937.32	32.36
2	Broad-leaf and coniferous forest	14,340.78	22.16
3	Coniferous forest	19,645.16	30.36
4	Bamboo and tree mixed forest	1,610.57	2.49
5	Bamboo (*Bambusa procera*) forest	197.82	0.31
6	Plantation	1,505.30	2.33
7	Bare land	5,940.95	9.18
8	Agricultural land	525.10	0.81
	Total	**64,703.00**	**100.00**

1.5 FLORA AND FAUNA

LBBR, whose core zone is BDNB, is a biodiversity center and a hotspot of biodiversity conservation in Vietnam. This zone has a very rich biodiversity, including many endangered species listed in Vietnam RedData Book (2007) and IUCN Red List (2010). There are seven different habitat types distributed in five geographical landscapes. Since the full range of biodiversity in BDNB and the whole LBBR is still unknown, future works on biodiversity will be required using tropical biological indicators.

It has been reported that BDNB had more than 1,900 terrestrial vascular plants of around 820 genera and 179 families of 4 phyla with 8 species of endemic plants. There were 67 species of high conservation value listed as critically endangered (CR), endangered (EN) and vulnerable (VU) in the Vietnam RedData Book (2007) and 12 in the IUCN Red List (2010).

There were 820 animal species of 507 genera, 123 families and 6 classes with 3 endemic species, 45 species listed in the Vietnam RedData Book (2007) and 60 species listed in the IUCN Red List (2010).

Table 4 summarises the species richness and threatened species in LBBR.

Table 4. Number of species known in LBBR

Group of organisms	No. of Species	No. of Genera	No. of Families	No. of Endemic Species	Vietnam Red Data Book			IUCN Red List		
					Total	CR	EN	Total	CR	EN
Vascular Plants	1,940	825	180	8	64	2	32	34	2	3
Mushrooms	66	24	-	0	0	0	0	0	0	0
Animals	820	507	123	14	45	3	16	60	0	8
Mammals	*89*	*64*	*24*	*3*	*18*	*1*	*7*	*18*	*0*	*5*
Bird	*274*	*194*	*54*	*2*	*12*	*0*	*3*	*10*	*0*	*2*
Reptile	*46*	*38*	*11*	*2*	*12*	*2*	*6*	*4*	*0*	*1*
Amphibian	*46*	*27*	*7*	*4*	*3*	*0*	*0*	*28*	*0*	*0*
Fish	*30*	*19*	*7*	*3*	*0*	*0*	*0*	*0*	*0*	*0*
Insect	*335*	*165*	*20*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Total	2,826	1,356	303	22	109	5	48	94	2	11

Notes: CR: Critically endangered; EN: Endangered.

This Biosphere Reserve is considered as a model of local sustainable development in a harmonious combination between biodiversity conservation and preservation of cultural identity of peoples, between economic development and environmental protection, between rational use of natural resources and improvement of life quality, and between education and scientific research.

1.6 MANAGEMENT

In the Management Board for LBBR, Director of BDNB is the Deputy Head of the Standing Board. Buffer and transition areas are under the management of local authorities and households according to the policies on land and forest land allocation of the government (called shortly as land allocated for forest protection). Concerning the buffer area management, the National Park keeps a memorandum of conservation cooperation between the National Park and the Management Board for Da Nhim Upstream Forests (protection forests as stipulated by the government). The Management Board of the National Park is responsible for forest protection in the core area. All management policies ought to be in line with Law on Forest Protection and Development (2004), Law on Biodiversity (2008) and Law on Environmental Protection (2014) as well as other related decrees or regulations at a national level.

The Management Board of BDNB, presently, plays a key role in the management of the Biosphere Reserve. The Management Board also involves the participation of representatives from district authorities and tourism companies in the area.

1.7 SOCIAL AND ECONOMICAL STATUS

The population of the Biosphere Reserve was 571,772 people (2011) (Table 5). The population was mainly distributed in the city of Da Lat (211,696 people), accounting for nearly 40%. The second largest population was found in Duc Trong District (170,485 people), representing 32%, followed by Don Duong District (96,322 people), Dam Rong District (42,141 people), Lam Ha District (30,400 people) and Lac Duong District (20,728 people). The highest population density was in Da Lat City with 536 people/km^2, 3.4 times greater than the average of the entire region. The population density in Lac Duong District was the lowest, just 16 people/km^2. The reason for having a low population density is that more than 87% of the Lac Duong District's area is forest. The population density in the districts of Don Duong, Lam Ha and Duc Trong was relatively close to each other at about 150-200 people/km^2. The population density of Dam Rong District was 49.1 persons/km^2.

Table 5. Population in LBBR in 2005 – 2011

No.	***Administrative units***	***Population (head)***		
		2005	**2008**	**2011**
1	Da Lat city	191,281	200,164	211,696
2	Lac Duong district	16,245	18,492	20,728
3	Lam Ha district	23,458	27,125	30,400
4	Don Duong district	90,027	93,476	96,322
5	Duc Trong district	154,708	163,931	170,485
6	Dam Rong district	29,701	39,507	42,141

Regarding the ethnic structure of Lam Dong province in general and of the Biosphere Reserve the Kinh group is the majority; the remaining fraction consists of K'Ho group and other ethnic minorities, namely Tay, Nung, Cham, etc. In the period 2008 - 2011, the population increased by

20,443 people (an average of 6,814 people/year). The population growth rate in the recent years in the local area of the BR has been 1.013%/year. During this period, the total population growth was recorded the highest in Da Lat City with 8,532 people, accounting for 36%. The next ranked was Duc Trong District with 6,554 people, accounting for about 28%. These are two areas with the highest rates of urbanisation in the region.

2 THE PROJECT AND THE COMPONENT

Japan International Cooperation Agency (JICA) agreed with the Government of Vietnam on the implementation of a technical cooperation project named "Sustainable Natural Resource Management Project (SNRMP)" to enhance the capacity for sustainable natural resource management in Vietnam in July 2015. JICA has begun to implement the project since January 2016.

SNRMP consists of four (4) components, including:

Component 1: Policy support;
Component 2: Sustainable Forest Management and REDD^{+};
Component 3: Biodiversity conservation;
Component 4: Knowledge sharing.

The Project is executed by the Joint Venture of Nippon Koei Co., Ltd. (NK), Kokusai Kogyo Co., Ltd., and Japan Forest Technology Association which made a contract with JICA in December 2015, and NK is mainly responsible for operation and management of the Component 3, Biodiversity Conservation Component, of the Project.

Component 3 is implemented in LBBR. As stated in the project document, the main objective of Component 3 is to establish an integrated and collaborative ecosystem management system for sustainable conservation and management of LBBR. Specifically, the component aims to: i) establish an institutional framework necessary for management and operations of LBBR; ii) upgrade/improve the collaborative management agreement with the benefit sharing mechanisms as a tool for conservation of forest ecosystems in the core and buffer zones of LBBR; and iii) use the results of forest and biodiversity monitoring for the management of the core and buffer zones of LBBR.

This report is prepared as a final technical report for a survey contracted between NK and the Southern Institute of Ecology (SIE). The main objective of the survey is to develop a biodiversity monitoring system through collecting baseline data and information in the core and buffer zoon areas of BDNB, which consists of the most essential properties of LBBR. Specifically, the survey aims to:

- assess species richness, their ecological niches, and relationships in some selected groups of flora and fauna in the target area;
- propose a system (including methodologies) for biodiversity monitoring; and
- develop a set of biodiversity indicators and indexes, which reflects the dynamic balance and/or state of ecosystems concerned, and overall environmental quality of the target area.

As biodiversity can be appraised at three levels – genetic diversity, species diversity and ecosystem diversity, this study deals with the ecosystem and species diversity levels.

The survey focused on the core and buffer zones of LBBR. Six ecosystems were surveyed, including:

1. Evergreen broad-leaf forest (EF);
2. Broad-leaved and coniferous mixed forest (MF);
3. Coniferous forest (CF);
4. Bamboo and tree mixed forest of (MB);
5. Bamboo (*Bambusa procera*) forest (BF), and
6. Water bodies (AQ).

II. STUDY CONTENTS AND METHODS

The knowledge about biodiversity in BDNB, which was considered to hold the most biodiversity of the core and buffer zones of LBBR, has been much improved recently, thanks to a numbers inventories and findings, such as Nguyễn & Kuznetsov (2011), Middleton *et al.* (2014), Lưu *et al.* (2015), Vũ *et al.* (2015), etc. The most updated checklists of biodiversity of the park were reported by the present Southern Institute of Ecology - SIE (Lưu & Lê, 2009 and Lưu & Diệp, 2012), which included sound records of more than 1,000 species and were used in preparing the application of LBBR to UNESCO. Recently a project to develop a 25-ha forest dynamic plot in BDNB has been conducted by SIE has recorded in detail more than 1,000 species of plants, animals and macrofungi. The last three studies that recorded species with vouchered specimens, geographic information and/or photos have provided significant sound data that can be used to make a reliable database following standards established by the Global Biodiversity Information Facility (GBIF; www.gbif.org). They also mentioned challenges in confirming data in many of the other unpublished reports on biodiversity of the park, which did not show sound evidence of existing species. Therefore, they recommended implementing a new biodiversity databasing program based on systematic and competent inventories for the whole park. Such a database would be helpful for purposes of conservation, development and management.

In addition, there is still a big gap of understanding of changes in forest and other natural ecosystems and associated populations of different species, especially those endangered. These unknown changes are getting severer in the context of climate change from which Vietnam is one of the countries suffering the most.

Given this context and to address the objectives of the project, this survey is to build a biodiversity database at ecosystem and species levels based on selected available sources of data and new field surveys and develop a long-term biodiversity monitoring system with conventional indicators and those locally specific and derived from the fieldwork.

The participation of local staffs/villagers is crucial in implementing the surveys continuously and effectively and in building their capacity in the survey skills, data analysis and management. They will get acquainted with classic and modern research techniques and tools to be appropriately combined in the survey so that they will be able to develop future monitoring activities with minimum inputs from outsider experts.

From this approach, the following contents and activities have been carried out within this survey.

1 VEGETATION MAPPING

The objectives of this task are to provide:

- Maps of land cover/ forest type of 1990, 2000 and 2010, and their change over these periods to 2014;
- Detailed forest maps for 20-30 ha derived from high spatial resolution (0.5m): 1/10,000.

The mapping team included:
- Pham Bach Viet, team leader;
- Luu Hong Truong, team member;

- Nguyen Quoc Dat, team member;
- Dang Minh Tri, team member;
- Pham Huu Nhan, team member;
- Tran Van Bang, team member.

The following works were carried out:

1.1 INTERPRETATION OF SATELLITE IMAGES

Using the 2014 vegetation map provided by the BDNB, the following works were implemented:

- Remote sensing work: Satellite images are processed with the following steps: preprocessing to convert digital number into radiance and reflectance (top of atmosphere) and to correct noise of atmosphere (cloud, haze); mosaicking images and georectifying images after base projection WGS 84, UTM zone 49 (entire LBBR is within zone 49); classification of forest types following the FAO's Land Cover Classification System (LCCS); making training data and samples based on ground truth data from field works.
- The LCCS (Version 3) includes five components (*Antonio Di Gregorio, U. Leonardi, land cover classification system – software version 3, FAO-UN, Rome 2016*) which are vegetation, vegetation characteristics, abiotic surface, abiotic surface characteristics and land cover class characteristics, details as the follows:
  - i) Vegetation with different growth form: woody: trees, shrubs; herbaceous: graminae forbs.
  - ii) Vegetation characteristics: floristic aspect (single or group of plant species), allometric measurements, age, natural or seminatural vegetation, cultivated and managed vegetation.
  - iii) Abiotic surfaces: artificial surface (built-up surface, non-built-up surface), natural surface (rocks surface, soil sand deposit surface), water body and associated surface.
  - iv) Abiotic surface characteristics: artificial surface, natural surface, water and associated surfaces (aquaculture, artificiality, water salinity, water chemistry).
  - v) Land cover characteristics: climate, land form, geographic aspects, topographic aspect, surface characteristics (consolidated, unconsolidated surfaces).

    The system considers mainly vegetated and abiotic surface, distributing over horizontal and vertical structure patterns. Depended on available data and information sources, a land cover type can be completely described with the above five components or with only two to three components.

    The new LCCS version 3 is more flexible than previous version because it can be applied on various fields of agriculture, forestry, aquaculture, land use, urban, etc. for scientific research or management purposes.

- GIS work: interpretation and classification results were converted into GIS format to correct errors of misclassification. Calculation of area for each land cover type and change analysis for periods of land cover (1990, 2000 and 2010).

- Data source:

  - Map: topographic old maps at 1/50,000 for the target area, forest maps in the past.

- Satellite images: SPOT 1990, 2000, 2010 (10-20 m spatial resolution) for 1/25,000 maps. Times and dates of images depends on available images with cloud free. These images will be used for historical status of land cover and forest identification.
  Landsat TM imagery (30 m spatial resolution) was also utilised in order to take advantage of its spectral channels comparing to SPOT in identifying land cover. These Landsat images were freely acquired from the USGS via internet (https://earthexplorer.usgs.gov/).

- For better interpretation, using very high spatial resolution for key sample: Pleiades (0.5): 1/3/2014 and 2/3/2014 (22 – 25 USD/sqkm). These very high spatial resolution images will assist to make key samples for interpretation and classification for the 1/10,000 map.

- Imagery of Google Earth application with high details covering the Bidoup-Nui Ba was used as a reference source for image interpretation and identifying changes. High detail images are available on Google Earth, which are very high spatial resolution acquiring since 2006 to 2017.

Table 6. Information of satellite images used

Source of image	Acquired Date (dd/mm/yy)	Spatial resolution (m)	Notes	Date for analysis
SPOT (1-4) SPOT 5	21/01/1988 090/6/1986 28/01/2000 29/03/2000 25/04/2010	10-20 5-10	2 dates for mosaicking	1990 2000 2010
Landsat 5 TM Landsat 7 ETM Landsat 8	1991, 2001 2010 2017	30 15-30	Free images, obtain from USGS via internet	1990 2000 2010 2017
Pleiades	04/02/2014, 01/03/2014, 02/03/2014.	0.5-2	4 sub areas	

1.2 FIELD SURVEYS

Field surveys are significant to ensure the accuracy of vegetation processed from the satellite images. The following field surveys were conducted:

- Surveying each vegetation type to identify forest types, species dominant and forest strata. However, in this study such data are available from building biodiversity databases below.

- Collection of key samples for interpretation and for validation: fast description of forest/ land cover status, coverage, and main species. Data gathered from the databasing work were used as significant source of forest structure and biodiversity.

- Identifying 1) forest gaps that were made by storms, lightening, landslides, or natural decay of old trees and by logging; 2) any types of regeneration of young stands; 3) special species groups (endangered, endemic or dominant plants), e.g. *Fokienia hodginsii* and *Pinus krempfii*; 4) wet environment, e.g. streams, ponds, swamps, etc.; 5) sunny and dry environment; 6) forest fire affected areas; etc., where represent different ecological niches.

For mapping, there were more than 450 GPS waypoints (Figure 2) for 1/25,000 mapping including points with description and only for marks. There were 60 GPS waypoints for detailed mapping at 1/10,000 within an area of approximately 30 ha, which is located in the southern slope of the Bidoup peak and at altitudes ranging about 1,800 to 2,000 m.

At each GPS waypoint, an area of a forest stands of approximately 2,500 to 7,000 sqm (radial distance of approximate 20-50 m from a main GPS waypoint) was surveyed (Figure 4).

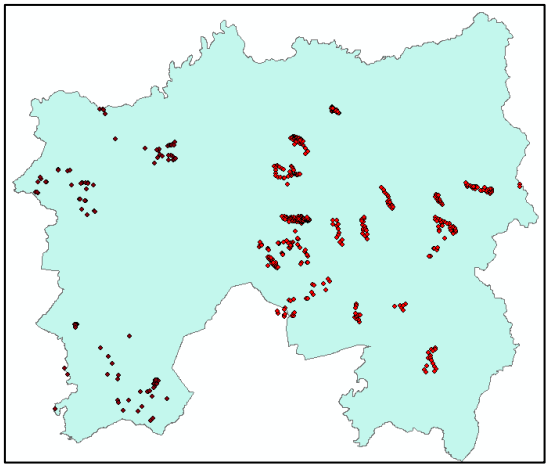


Figure 2. GPS waypoints of field surveys

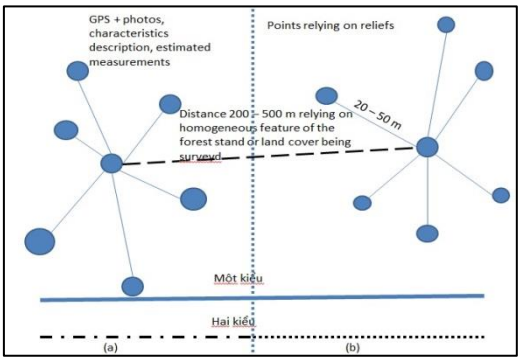


Figure 3. GPS waypoints at a forest stand

The results were expected as follows:

- Vegetation map of 1:25,000 for the core and buffer zones of LBBR of 107,175 ha, plus about 1,500 ha that BDNB was planning to transfer to a bank for 1990, 2000 and 2010. Their changes in periods between 1990 and 2010 plus 2014 were reported.

- A detailed map of 1:10,000 for 20-30 ha selected within the evergreen broad-leaf forest, broad-leaved and coniferous mixed forest, and coniferous forest.

The area of each land cover/ land use type and their changes are crucial in determining the trend of landuse changes in the past and serve as a baseline for future monitoring. These data are especially important for the buffer zone where landuse is intended to change.

1.3 DATA ANALYSIS AND MAPPING

Forest mapping

Landsat images were used and analysed along with SPOT images because the Landsat image has better spectral quality than that of SPOT. Spectral bands of blue, green, red, near infrared and short-waved infrared (B, G, R, IR, SWIR/spatial resolution of 30m) of Landsat were fused with Panchromatic band (15 m) to enhanced spatial information (only for Landsat 7 ETM+ and Landsat 8). Image interpretation was based on differences of objects (*i.e.* land cover types) on different spectra responses, and data from field survey were used to validate and to correct draft draft classification.

Classification results from satellite images at the raster format were converted to the vector GIS format to edit and correct errors from misclassification.

The requirement of the project was to build the historical maps of 1990, 2000 and 2010 from satellite images for monitoring changes since the past. Because field surveys were done at the present time (2017), satellite images at this present time should be used too. The interpretation of the 2017 satellite image was then applied “backwards”. This means that the interpretation has been done for the present and then induced for the older satellite images.

Forest Canopy Density (FCD)

FCD is obtained by calculation of Vegetation index, Bare soil index, and Shadow index (Rikimaru *et al.*, 2002). This analysis indicates forest quality in relation to forest strata. The Landsat images were utilised to compute these indices to yield FCD.

2 DEVELOPMENT OF BIODIVERSITY DATABASE OF LBBR

The task of this activity was to develop a biodiversity database of taxonomic groups in LBBR for both key terrestrial and aquatic ecosystems. The following are the expected outputs:

- Database of vascular plants (including ferns);
- Database of mammals;
- Database of birds;
- Database of reptiles and amphibians;
- Database of insects (butterflies and termites);
- Database of fishes.

Besides these key taxonomic groups of the five terrestrial ecosystems (vegetation types), the species diversity of fishes and reptiles – amphibians were also databased for the aquatic ecosystems. All are summarised as follows:

Forest/land type	Vascular plants	Mammals	Birds	Reptiles	Amphibians	Fishes	Insects
Evergreen broad-leaved forest	x	x	x	x	x		x
Broad-leaved and coniferous mixed forest	x	x	x	x	x		x
Coniferous forest	x	x	x	x	x		x
Bamboo and tree mixed forest	x	x	x	x	x		x
Bamboo forest	x	x	x	x	x		x
Water bodies				x	x	x	

The following describe steps and methods to realise the above databasing tasks.

2.1 COLLECTION AND ANALYSIS OF EXISTING INFORMATION ON BIODIVERSITY

To clarify the biodiversity in LBBR at species level, it is important to collect and assess all available sources of biodiversity information on LBBR including published papers, unpublished reports and accessible international sources of biodiversity such as GBIF, TROPICOS and other herbaria's catalogues. All were assessed and analysed for quality before selected for databasing. Many of unpublished reports may not provide adequate information fields as requested for a standard expected database. The missing data are foreseen and accepted as blank. Most of adequate data would be provided from former surveys of SIE which gathered information following the data format required by GBIF. Published papers also provide a good source of information.

The flora and fauna of LBBR has been known from different published and unpublished reports (see References for details). Actually, most of the gathered information was about the core zone, *i.e.* BDNB. These have been analysed and digitised for the database. They are listed in the references.

2.2 SUPPLEMENTAL FIELD SURVEYS OF BIODIVERSITY

To develop a reliable database of LBBR, the database available in the former activities must be supplemented by additional surveys which were expected to provide significant data load and can be used a baseline data for future monitoring (Figure 4). Appendix 1 shows some photo illustrating the field work.

In general, all recorded flowering, sporing and/or fruiting vascular plants (including ferns and lycophytes) are sampled for vouchered specimens which help identification of species and can be re-checked if any questions arise. Recorded small mammals, reptiles, amphibians, fishes and insects are sampled where possible but all must have associated data required for the database with defined fields (see the databasing part below for details). Photos are expected to serve as evidence of record. Each species of plants must have at least 5 high-quality photos indicating its main characteristics. Each species of animals should have at least one photo although three photos are expected as a standard. All records must have coordinates using GPS.

Figure 4. The survey team at a rest

2.2.1 Sampling design

The sampling design of the survey had to meet the two requirements:

- Providing the information for the database of biodiversity;
- Providing fundamental data for recommending indicators for the biodiversity monitoring system, which is explained below.

Designs of activities and methods for surveys generally followed the guidance by DWC (2008): Biodiversity Baseline Survey: Field Manual. Revised version. Consultancy Services Report, Infotechs IDEAS in association with GREENTECH Consultants. Although this guidance was originally designed for Sri Lanka, it is reasonable to apply the recommended methods with slight modifications to adapt to the present study. In addition, as stated by the authors of the methods, by integrating surveys of plants and animals, this protocol provides a basis for examining potential relationships between plant and animal species (amphibian, reptile or small mammal) and assemblages, and, we believe, for future monitoring in LBBR as requested by the TOR. In fact, a similar approach of 100 m x 5 m plots was applied successfully to inventories of plants in tropical forests in Cambodia and Vietnam lead by Japanese scientists (e.g. Yahara *et al.*, 2013).

Total 80 plots (100 m x 5 m each) have been set up with nylon cord for the five vegetation types; this is, 16 plots have been established in 4 groups for each vegetation type. Half of the plots were in the core zone and the other half in the buffer zone. Each group of 4 plots were aligned in a transect of 1 km length so that one plot was located at least 150 m apart from the next. Each transect is at least 500 m away from the other. All plots were geo-located, using a GPS (Global Positioning System), and permanently marked for purposes of possible future monitoring, using paint and/or a thick nylon cord tied loosely around a branch of vegetation.

Table 7 is the summarised information on the 80 plots. In each transect the 4 plots are coded as P1, P2, P3 and P4 suffices after their respective transect codes.

Each survey site was planned to survey three times a year, one in the rainy season, one in the dry season and another in the transmitting months. The first field survey was conducted in late July and August 2016, the second in December 2016 and January 2017 and the last in May and June 2017. Each site took average four days of field trip, including 2 days of surveys within the plots and 2 days of travelling (walking in the forest) and surveys outside the plots.

To prepare the field work, a workshop was organised at the office of the project in Da Lat, where the team leader presented about and make clear about the study contents, methods and timing. Discussions and feedbacks from the audience, which include Nippon Koei team, SNRMP magangement board and team members from BDNB, were gathered to improve the efficience of the field surveys. The final survey sites have been concluded upon agreement by the participants. The team, which was supervised by Prof. Masazuka Kashio (Figure 5) from NK.

Although most convenient survey areas should be selected to reduce costs, the surveys are prioritised on areas (forest sections) that have not been inventoried. The selection of these sites wase made based on the team's working experience of LBBR, consultation of staffs of BDNB, LBBR Management Board and other research groups who have worked in the survey area. This way also held for the aquatic bodies.

In the first two days of the first field trip, we tried to locate the transects using the available 2014 vegetation map provided by the BDNB which was said to be the most updated one for the region. Because of the complex topography, this work took lot of time. While the evergreen broad-leaf and coniferous forests were recognised in the field, it was impossible to find out any piece of mixed forest of broad-leaf and coniferous trees (or broad-leaf and coniferous mixed forest) although the team searched a large forest area. Where was indicated as this vegetation type in the map turned out to be the pine forest. Finally, after discussion with Prof. Masakazu Kashio, it was decided to set up plots for this vegetation type (also called as broad-leaved and coniferous mixed forest – MF) located in the transitional forest which was along the boundary of the evergreen broad-leaf forest and coniferous forest. This is actually an important position for ecological studies of forest succession as the boundary between the evergreen broad-leaf forest and coniferous forests is known to be determined and shifted by fire as an ecological factor. At the Dung Jar Rieng forest section, we had six transects in the core zone, each two for every of these three vegetation types. Additional similar six transects were set up for the buffer zone. Altogether there are twelve transects in the Dung Jar Rieng forest section. The other eight transects were set up for the *Bambusa procera* forest (or bamboo forest) and bamboo and tree mixed forest in core and buffer zones which were in the Da Long forest section. Finally, total 80 plots for 5 vegetation types were set up as planned in the TOR (Figure 6, Figure 7, Figure 8, Figure 9, and Figure 10).

In the field surveys, species of the same taxonomic groups, i.e. vascular plants, mammals, birds, reptiles, amphibians, fishes and insects (mainly butterflies and termites), were recorded using uniform methods in the five major vegetation types. This is also to help determine possible association among species and sites.

For aquatic surveys, four water courses in the sub-basin of the Srepok River were chosen, namely Liêng H'Nhung (S1); Tum Tâm (S2); Plây Cuốt (S3) and Lố Lao (S4) (Figure 11, Figure 12). We replicated sampling of the head, middle and lower reaches of each watercourse.

Table 7 is the summarised information on the 20 transects. Each transect has four plots of 5 x 100 m which are coded as P1, P2, P3 and P4 suffices after their respective transect codes.

The following described the methods used in the field.

2.2.2 Surveys of vascular plants

- Quantitative: All vascular plant species were recorded on a sub-plot basis (10 m x 5 m) within every plot (100 m x 5 m). For trees of ≥ 4 m in height, the number and DBH (Diameter at Breast Height) of individuals was also recorded; this was done for the first field trip. Successive trips were for identifying recorded species based on collected additional specimens with reproductive organs. Therefore, all species existing in the plot have been recorded and identified, preferably to at least the genus level. The species diversity and several ecological indices of vegetation types were estimated.

- Qualitative: The presence of additional species encountered along a transect, between plots, is recorded separately. This activity was extended outside the plots, i.e. to where possible, to include other additional species encountered to enrich the database.

- Voucher specimens: Specimens of unidentifiable, previously unrecorded or otherwise notable species were collected, photographed as appropriate, curated and subsequently lodged at SGN herbarium. The photos are part of the database. For accurate identification, collection in general was paid specially to flowering/fruiting plants. On average, 4 duplicates are collected for one species. Specimens were collected and processed following the protocol by Royal Botanic Garden, Kew (Bridson & Forman, 1999).

- Identification: followed key literature including An illustrated flora of Vietnam, Vietnam Forest Trees and neighbor floras such as Flora of China, Flora Malesiana, Flora of Thailand, Flore Générale de l'Indochine, and Flore du Cambodge, du Laos et du Viêtnam. The plant and family names followed the Plantlist.

- The plant surveying team included:
  - Luu Hong Truong, SIE, team leader;
  - Nguyen Quoc Dat, SIE, team member;
  - Dang Minh Tri, SIE, team member;
  - Nguyen Hieu Cuong, SIE, team member;
  - Pham Huu Nhan, BDNB, team member;
  - Nguyen Ich Le Phuoc Thanh, BDNB, team member;
  - Truong Quang Cuong, BDNB, team member.

In the first field trip, the plant survey team tried to make as much survey of flora as possible. It was important to priorise inventorying the srubs and herbaceous plants as they may be damaged or disappeared in the next field trips because of drier climate and possible human impacts including fire. This was considered significant for the forest types (with deciduous plants) other than the evergreen broad-leaf forest.

2.2.3 Field surveys of mammals

- Quantitative: Small mammals were sampled using 20 Sherman's or Elliott's traps, set 10 m apart within alternate plots of a transect for two consecutive nights (40 trap nights). Traps were baited with roasted coconut/other foods and checked and reset early each morning. Camera traps were set up along the transect for catching any terrestrial mammals; the number of camera traps, which were provided by the project, BDNB and SIE, were five per transect (10 camera nights). Bats were trapped using mist nets (12 m by 2.5 m) set at ground level and canopy height in close proximity to a transect for two nights.

C

Figure 5. Prof. Masakazu Kashio (NK) and a team leader, Mr. Huynh Quang Thien, in the field

Figure 6. Establishing a transect

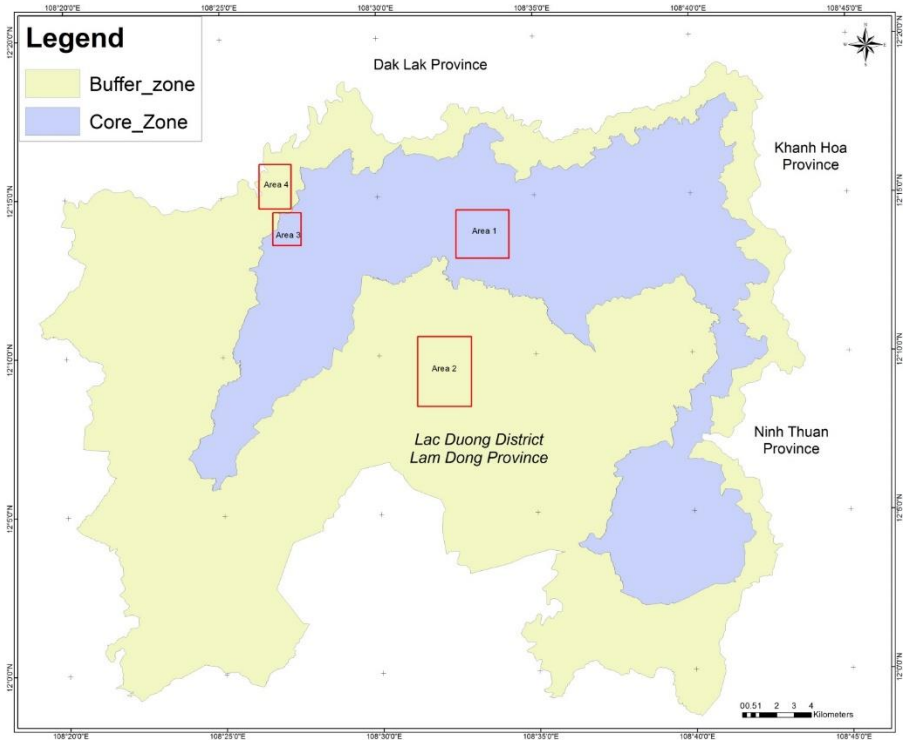


Figure 7. Location of surveyed areas in LBBR

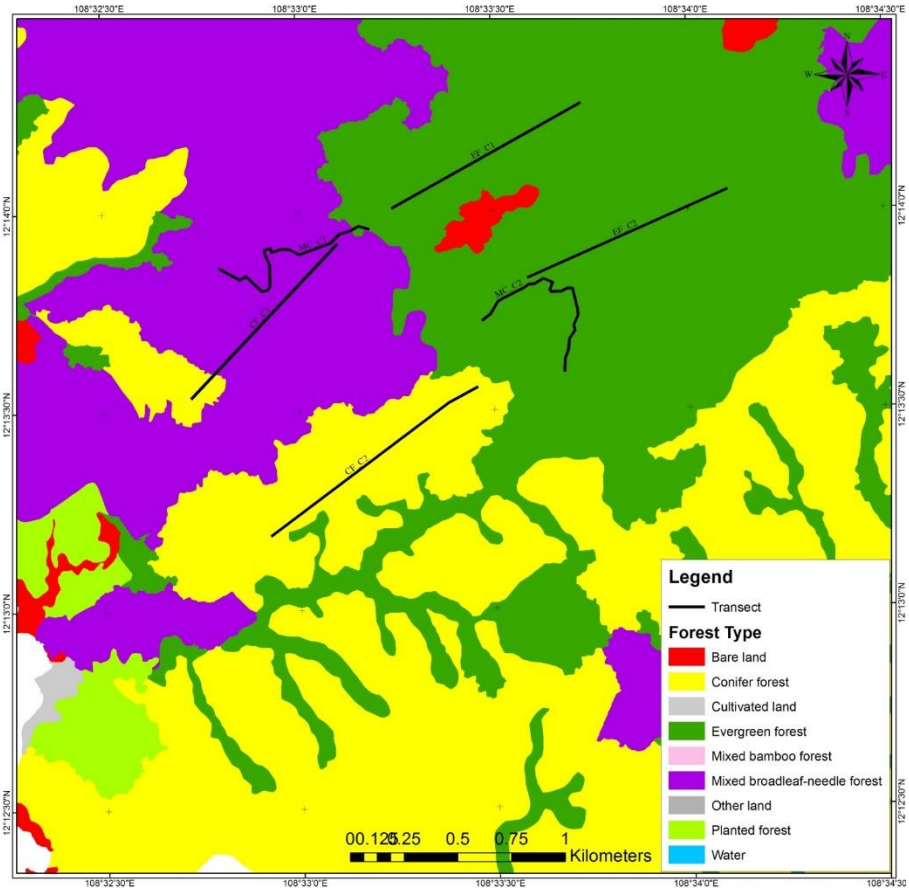


Figure 8. Location of transects in the core zone at Dung Jar Rieng forest section

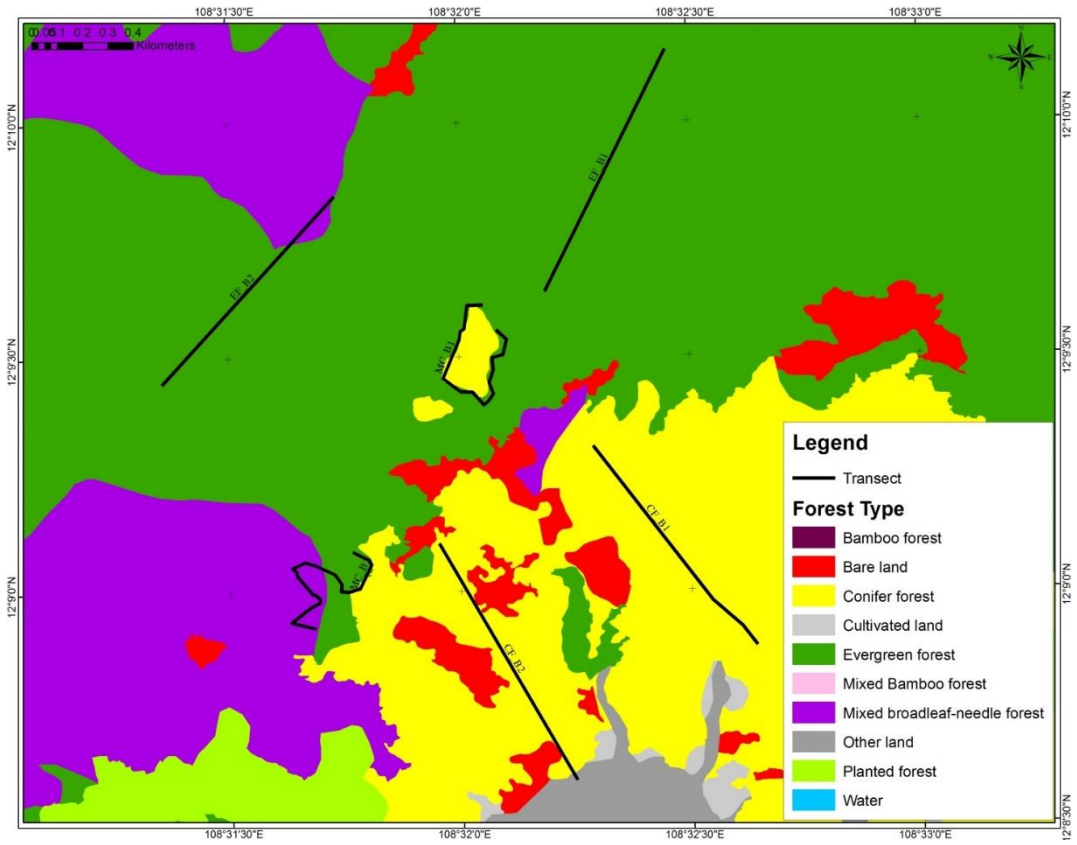


Figure 9. Location of transects in the buffer zone at Dung Jar Rieng forest section

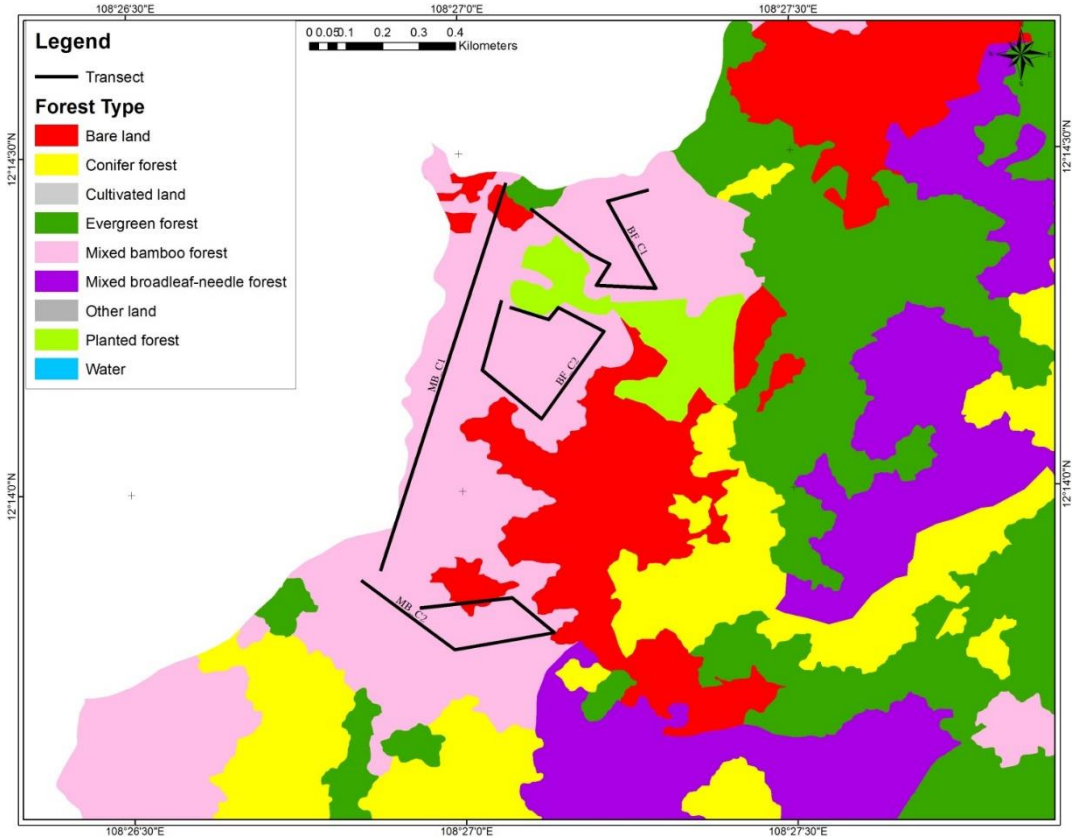


Figure 10. Location of transects in the core zone at Da Long forest section.

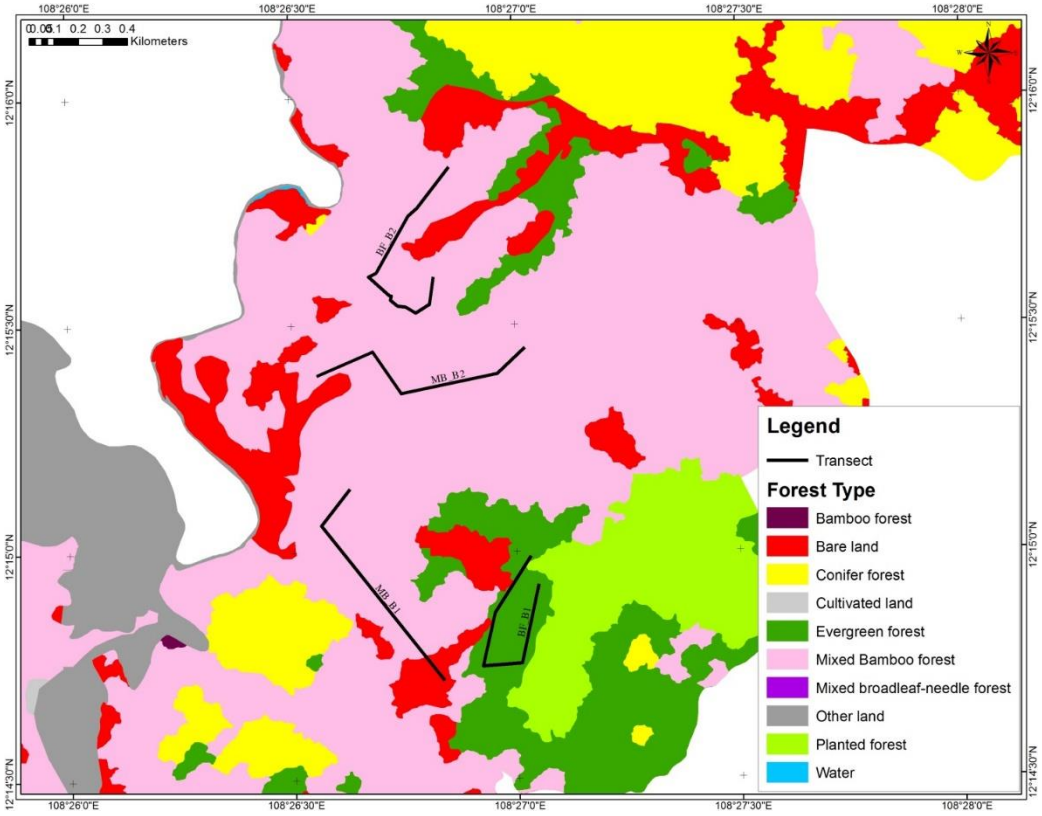


Figure 11. Location of transects in the buffer zone at Da Long forest section

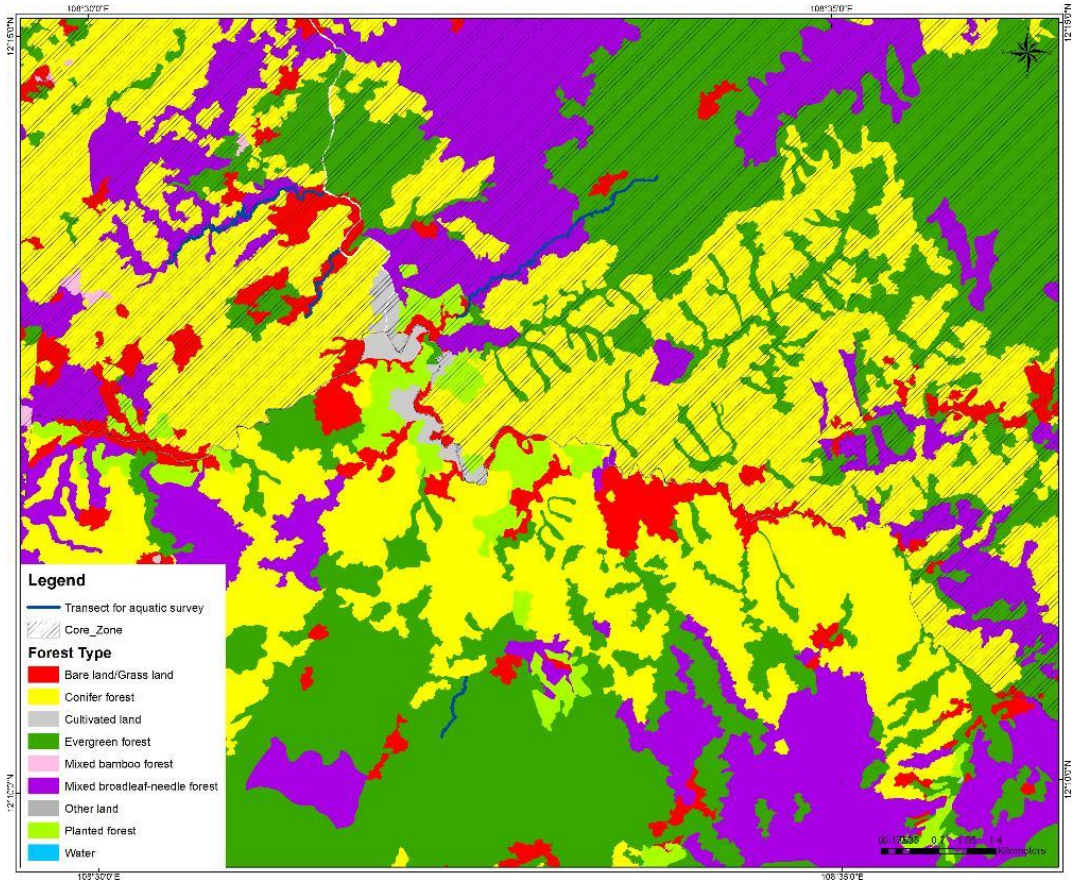


Figure 12. Location of the survey streams

Table 7. Transects set up for the survey

Transect code	Forest type	Zone	Forest section	Beginning (lon,lat)		End (lon,lat)		Subplots
				X	Y	X	Y	
EF_C1	Evergreen broad-leaf forest	Core Zone	Dung Jar Rieng	108.55394	12.233481	108.562073	12.237827	EF_C1_P1 (P2, P3, P4)
EF_C2	Evergreen broad-leaf forest	Core Zone	Dung Jar Rieng	108.568298	12.234148	108.5597	12.23051	EF_C2_P1 (P2, P3, P4)
EF_B1	Evergreen broad-leaf forest	Buffer Zone	Dung Jar Rieng	108.54081	12.169204	108.536354	12.160631	EF_B1_P1 (P2, P3, P4)
EF_B2	Evergreen broad-leaf forest	Buffer Zone	Dung Jar Rieng	108.528786	12.164092	108.522469	12.157437	EF_B2_P1 (P2, P3, P4)
CF_C1	Coniferous forest	Core Zone	Dung Jar Rieng	108.551628	12.232039	108.545296	12.225584	CF_C1_P1 (P2, P3, P4)
CF_C2	Coniferous forest	Core Zone	Dung Jar Rieng	108.557556	12.22597	108.548637	12.219785	CF_C2_P1 (P2, P3, P4)
CF_B1	Coniferous forest	Buffer Zone	Dung Jar Rieng	108.543922	12.147997	108.53804	12.155126	CF_B1_P1 (P2, P3, P4)
CF_B2	Coniferous forest	Buffer Zone	Dung Jar Rieng	108.532433	12.151714	108.537338	12.14325	CF_B2_P1 (P2, P3, P4)
MC_C1	Broad-leaf and coniferous mixed forest	Core Zone	Dung Jar Rieng	108.546532	12.231044	108.553001	12.232616	MC_C1_P1 (P2, P3, P4)
MC_C2	Broad-leaf and coniferous mixed forest	Core Zone	Dung Jar Rieng	108.561256	12.226539	108.557739	12.228721	MC_C2_P1 (P2, P3, P4)
MC_B1	Broad-leaf and coniferous mixed forest	Buffer Zone	Dung Jar Rieng	108.534126	12.160173	108.534576	12.159288	MC_B1_P1 (P2, P3, P4)
MC_B2	Broad-leaf and coniferous mixed forest	Buffer Zone	Dung Jar Rieng	108.527962	12.148727	108.529305	12.151432	MC_B2_P1 (P2, P3, P4)
BF_C1	Bamboo forest	Core Zone	Da Long	108.451706	12.240301	108.454697	12.240725	BF_C1_P1 (P2, P3, P4)
BF_C2	Bamboo forest	Core Zone	Da Long	108.450958	12.238049	108.451157	12.237872	BF_C2_P1 (P2, P3, P4)
BF_B1	Bamboo forest	Buffer Zone	Da Long	108.450714	12.248797	108.450447	12.249831	BF_B1_P1 (P2, P3, P4)
BF_B2	Bamboo forest	Buffer Zone	Da Long	108.44754	12.264123	108.446915	12.260099	BF_B2_P1 (P2, P3, P4)
MB_C1	Bamboo and tree mixed forest	Core Zone	Da Long	108.451103	12.240949	108.447823	12.231392	MB_C1_P1 (P2, P3, P4)
MB_C2	Bamboo and tree mixed forest	Core Zone	Da Long	108.447334	12.231164	108.448799	12.23046	MB_C2_P1 (P2, P3, P4)
MB_B1	Bamboo and tree mixed forest	Buffer Zone	Da Long	108.447159	12.245284	108.44371	12.252338	MB_B1_P1 (P2, P3, P4)
MB_B2	Bamboo and tree mixed forest	Buffer Zone	Da Long	108.442528	12.256497	108.450295	12.257475	MB_B2_P1 (P2, P3, P4)

- Direct observations were made along transects, where possible recording perpendicular distance from the center line to the location of a sighting. Arboreal species were recorded whenever observed.

- Qualitative: The presence of additional species encountered elsewhere within the vegetation type was recorded separately. They were also recorded during the 2-day travel among the survey sites in each survey time. Voucher specimens and tissue: Captured specimens of small mammals, including bats were measured, in accordance with international standards, photographed, curated and subsequently lodged at SIE.

- Identification: Main references that used for mammal identification were Preliminary Identification Manual for Mammals of South Vietnam (Van Peenen *et al.* 1969), A Photographic Guide to Mammals of South-East Asia (Francis 2008), An Identification Guide to the Rodents of Vietnam (Lunde & Nguyen Truong Son 2005), Bats of Vietnam and adjacent territories: An identification manual (Borissenko & Kruskop 2003).

- The mammal surveying team included:
  - Le Khac Quyet, SIE, team leader
  - Le Van Dung, SIE, team member
  - Bui Duc Tien, SIE, team member
  - Tran Van Bang, SIE, team member

2.2.4 Field surveys of birds

- Quantitative: Variable Circular Plots (VCPs) were established at the beginning and end of each plot within a transect to record birds from direct observation or indirectly from their songs over a period of 10 minutes in duration, once early morning and once in the evening. The distance from the observer was recorded, based on three radial zones (0-10 m radius, >10-20 m radius and > 20 m radius). The VCP was divided into quarters, each of which is recorded for 2½ minutes. Any bird seen or heard outside the quarter being monitored was recorded as outside. The survey in the VCPs took place for 2 days and was repeated for each trip.

- Mist nets (6, 9 and 12 m in length and 2.6 m or 3 m in height) were used to sample cryptic species that tend to be under-represented in VCPs. Each transect was surveyed for 1 day in each trip.

- Qualitative: The presence of additional species encountered elsewhere within the vegetation was recorded separately. They were also recorded during the 2 days of travel among the survey sites in each survey time.

- We do not collect bird specimens. All netted birds were photographed. We also tried to take photographs of sighted birds. Bird species identification was based on field guide books including Birds of Vietnam (Nguyen Cu *et al.* 2000), A Field Guide to the Birds of South-East Asia (Robson 2010), and Introduction to birds of Vietnam (Le Manh Hung 2012).

- The bird surveying team included:
  - Hoang Minh Duc, SIE, team leader
  - Le Duy, SIE, team member
  - Bui Duc Tien, SIE, team member

- Le Khac Quyet, SIE, team member
- Le Van Dung, SIE, team member

2.2.5 Field surveys of reptiles and amphibians

- Quantitative: Amphibians and reptiles (herpetofauna) were sampled by applying visual encounter survey (VES; Heyer *et al.* 1994) within alternate plant plots within transect or throughout transect. The data from this method are analysed for site occupancy for each species of amphibian and reptile. For each plot or transect, the survey is conducted for 4 hours during suitable time for survey amphibian and reptile (mainly in nighttime).

- Qualitative: The presence of additional species encountered along a transect, between plots, or elsewhere within the protected area is recorded separately. Visual Encounter Surveys (Heyer *et al.*, 1994) are carried out mainly at night, with a similar amount of time spent searching each habitat over the survey period. Species are also recorded during the 2-day travel among the survey sites in each survey time.

- Voucher specimens: Specimens of unidentifiable, previously unrecorded or otherwise notable species were collected, measured in accordance with international standards, photographed, curated and subsequently lodged at SIE.

- Reptilians and Amphibians were identified by using main publications: Les Batraciens de L'Indochine (Bourret 1939, 1941, 1942), About identification of amphibians and reptiles in Vietnam I, II & III (Đào 1977, 1979, 1981), A field guide to the Snakes of South Vietnam (Campden-Main 1970), Herpetofauna of Vietnam (Nguyễn *et al.* 2009), etc.

- Reptiles and amphibians were surveyed for the five vegetation types. For aquatic bodies, three transects, with a distance of 100m each, along streams and their banks, were established for sampling amphibians and reptiles, at night between 18.00 and 24.00 pm. All frogs and reptiles were directly taxonomically identified and returned in the field except for the unclear specimens which were further examined in the lab. Number of species and individuals of each species were counted for community data.

- The herpetological surveying team included:
  - Tran Thi Anh Dao, SIE, team leader
  - Tran Van Bang, team member;
  - Dang Hong Sang, team member;
  - Dang Thi Tuyet, team member;
  - Nguyen Phat Tai, team member.

2.2.6 Field surveys of freshwater fishes

For aquatic bodies, while reptiles and amphibians were surveyed using conventional methods, fishes were recorded as follows:

- Quantitative: Replicate sampling of the head, mid- and lower reaches of at least four rivers, streams or swamps within the chosen basin was undertaken for fish and various measures of water quality. Fish were sampled using tools among sweep, throw, gill and seine nets, rod and line, and by snorkeling for a standard period of time, or until it was apparent that additional species were unlikely to be recorded from the sampling station.

- Water quality was assessed for pH, conductivity, dissolved oxygen, total dissolved solids, turbidity and temperature at sampling stations.

- Qualitative: Local professional fishermen were employed to use throw nets in deeper water bodies and tanks. Endeavors were made to sample diurnally (daytime and at night). The presence of species reliably reported by fisherman was also recorded, separately from field data.

- Voucher specimens and tissue: Specimens of fishes were measured, in accordance with taxonomically conventional standards, photographed, and a selection of them preserved for subsequent identification and curation. They were subsequently lodged at SIE.

- Fishes were identified using determination keys of following main documents: Fishes of the Cambodian Mekong (Rainboth 1996); Fishes of Laos (Kottelat 2001); Freshwater fishes of Northern Vietnam (Kottelat 2001). Classification system followed Nelson (2006) and Eschemeyer *et al.* (2017).

- The fish surveying team included:
  - Huynh Quang Thien, SIE, team leader;
  - Nguyen Thanh Trung, SIE, team member.

2.2.7 Field surveys of insects

- Quantitative: The insect survey targeted butterflies and termites using hand collecting, malaise traps and fruit traps to collect species. Butterflies will be sampled and recorded using hand nets along the transect by continuously walking back and forth during survey time (9:00 to 12:00 in the morning and 14:00 to 17:00 in the afternoon). Along the transect, butterfly samples were counted or collected by a predetermined sampling path. The presence of all organisms was counted within a fixed distance (i.e., 1 m, 5 m) on either side of 1-km travel along the transect. Fruit trap will be used for sampling high and fast flying species or under canopy butterflies. Three butterfly traps with over ripped bananas mixed with sugar water were hung along each transect and visited when the fieldworker pass the trap during transect sampling. The distance between 2 traps is at least 20 meters. Both species name and number of individuals caught during the 2 days/nights are recorded.

- Quadrat sampling method was applied to study termite, modified from Constantino (1992) and Palin *et al.* (2011). All termite species in 3 sub-plots ware sampled randomly in each sample period. Searching focused on the most common termite microhabitats, such as litter layer, base of tree and inside dead wood. Workers and soldiers are sampled and stored in 80% ethanol. Number of termite species and number of mounds in the sub-plots were recorded. Their feeding type was also recorded (decayed or un-decayed dead wood, soil, etc.).

- Qualitative: The presence of additional species encountered along a transect, between quadrats, or elsewhere within the protected area was recorded separately. They were also recorded during the 2 days of walking.

- Voucher specimens: Insect specimens are subsequently lodged at SIE.

- Identification was done using various references for the Vietnamese and regional target faunas, such as Butterflies of the Oriental Region (D'Abrera 1982-1986), Butterflies of Vietnam (an illustrated checklist) (Monastyrskii & Devyatkin 2003), A Checklist of Butterflies in Indo-China: Chiefly from Thailand, Laos & Vietnam (Inayoshi & Saito 2014), Termite (Isoptera) fauna of Vietnam (Nguyen *et al.* 2004), etc.

- The insect surveying team included:
  - Do Van Cuong, SIE, team leader
  - To Van Quang, SIE, team member

Table 8 summarises the surveys for each group of biodiversity and respective sampling methods:

Table 8: Survey methods for the target groups of biodiversity.

Taxonomic group	Survey/Sampling Methods	Target taxa	Remarks
Vascular plants	100m x 5m quadrats: located at 150m intervals along 1km transect. Surveys extended outside the transects for enriched database	All vascular taxa	The method is applied in all the vegetation sites. Each vegetation type has 2 sites of total 4 transects.
Mammals	Direct observations: along 1 km transects, where possible recording perpendicular distance from transect to mammal sighted or spoor.	All mammal taxa except some mammals like some bats, small rodents and nocturnal mammals	The method is applied in all the vegetation sites. Each vegetation type has 2 sites of total 4 transects.
	Night spotting: from 7:00 pm – 10:00 pm, along 1 km transects, where possible recording perpendicular distance from transect to mammal sighted or spoor.	All nocturnal mammal taxa	ditto
	Sherman traps: located at 10 m intervals within 2 quadrats (100 m x 5	Small mammals	The method is applied in all vegetation sites.

Taxonomic group	Survey/Sampling Methods	Target taxa	Remarks
	m) for 4 nights.		
	Camera traps: located 05 cameras along to the transect for 2 nights	Terrestrial mammal	ditto
	Bat survey mist nets: 2 or 4 nets (at canopy and ground levels) manned by 2 persons for ≥3 hours at 6.30-11 pm in close proximity to transect.	All bat taxa	The method is applied in all the vegetation sites.
Birds	Variable Circular Plots: 8 VCPs (radius = 0-10m, 11-20m and >20m) aligned at each end of 4 quadrats (100m x 5m): birds recorded for 10 minutes within each VCP, once at dawn and once at dusk.		The method is applied in all the vegetation sites. Each vegetation type has 2 sites of total 4 transects.
	Direct observations: record birds along 1 km transects between quadrats.	All bird taxa	The method is applied in all the survey sites.
	Photography	All bird taxa if appropriate	ditto
	Mist nets: 2 nets (at canopy and ground levels) manned by 2 persons during daytime (6 am – 6 pm) at appropriate location adjacent to transect.		The method is applied in all vegetation sites.
Amphibians	Visual Encounter survey (VES):	All amphibian and	The method is applied in all the

Taxonomic group	Survey/Sampling Methods	Target taxa	Remarks
and reptiles	about 30 minutes survey in each quadrat.	reptile taxa	survey sites. Each vegetation type has 2 sites of total 4 transects with 8 quadrats.
	Visual encounter survey: within transect of 100 m x for 1 hour survey.	All amphibian and reptile taxa	For aquatic bodies, 4 sites are to be surveyed. Each site (stream/river/swamp) is surveyed at head, mid- and lower reaches within LBBR.
	Opportunistic diurnal and nocturnal searches	All amphibian and reptile taxa	ditto
Fishes	Water quality: pH, conductivity, dissolved oxygen, total dissolved solids, turbidity, temperature recorded at head, mid- and lower reaches of rivers.	n/a	The method is applied in all aquatic sites. Total 4 sites are selected ofr survey. Each site (stream/river/swamp) is surveyed at head, mid- and lower reaches within LBBR.
	In-stream fish sampling using nets	All fish taxa	The method is applied in all the survey sites
	Snorkeling and visual observations	All taxa if appropriate	ditto
Insects	Hand net along the transect, and traps for butterflies Quadrat sampling method for termites	ditto	Foci: butterflies and termites. The method is applied in all the vegetation sites. Each vegetation type has 2 sites of total 4 transects.
	Opportunistic encounters	All concerned taxa	ditto

It is noted that sampling sites (i.e. transects, quadrats and plots) are permanently marked on the ground (except the aquatic bodies) and, using GPS coordinates, on maps. All records of specimens

and observations of species will be georeferenced and given a unique identifier. They are recorded on standard field data forms and transferred to the defined database using the same metadata (Darwin code) recommended by GBIF.

2.3 BIODIVERSITY INFORMATION MANAGEMENT SYSTEM

The biodiversity database built for LBBR should be able to share with and receive data from other major international and national platforms of biodiversity. One of the key requirements is that its data format must be built in accordance with the Darwin Core, which is the common format for GBIF and other tools for managing biodiversity database at national and herbarium levels, including the JICA-supported Vietnam National Biodiversity Database Portal.

In this project, the BRAHMS software (Oxford University) is recommended for management of biodiversity database at LBBR as it (1) is built using Darwin Core, and thus compatible with the major platforms including GBIF and the Vietnam National Biodiversity Database Portal, and thus convenient for wider sharing, (2) operates well on personal computers that are cheap and available at LBBR, (3) free but well supported by the developer, and (4) is known by a staff of BDNB who used to get trained at SIE about the software. Although the BRAHMS is originally designed for plant herbarium management, but its usefulness has been extended in latest versions and adapted to successfully manage biodiversity databases in several protected areas and provincial departments of natural resources and environment in Vietnam. The actual use of the software indicates it is very powerful in not only managing biodiversity databases but also analysing data and producing reports on many aspects of biodiversity including distribution of recorded taxa, statistics of taxa, checklists of any taxa groups with full description, showing photos for each taxon, etc. Its capacity of linking to many GIS softwares including Google applications, ArcGIS, QGIS, etc. makes it one of the most powerful free softwares for management of biodiversity database. Using BRAHMS allows the project having a simple system that can share data with others easily.

Based on all the above activities, all records and/or specimens of plants and animals will be input into BRAHMS including at least the following standard data fields:

- Kingdom
- Family
- Genus
- Species
- Author 1
- Subspecies 1
- Author 2
- Subspecies 2
- Author 3
- Local name
- Collector/recorder
- Specimen code 1
- Country: Vietnam
- Province: Lam Dong
- District
- Commune (if applicable)
- Longitude
- Latitude
- Day of record

- Month of record
- Year of record
- Determined by
- Day of determination
- Month of determination
- Year of determination
- Botanical description
- Exotic species
- Local knowledge (if applicable)
- IUCN Redlist ranking
- Vietnam Redlist ranking
- Photo file number (as many as possible)

More fields can be added depending on the species charactertistics, e.g. “Life form”, “Habitat”, “Niche”, “Feed”, “Nesting”, and “Breeding”.

The databasing was assigned to each survey team as they knew their taxonomic group best. Indigenous knowledge on useful species and their ecology, which were recorded presently within a project funded by MOST to SIE, will be used to fulfill the database in the future. Such data will not only enrich the database to be built but also be helpful for any sustainable measures of resource management and development. The results were also expected to be used to generate some community-based indicators in the future monitoring program to be designed at the end of this study.

3 DEVELOPMENT OF BIODIVERSITY MONITORING PROGRAM

3.1 APPROACH

Biodiversity monitoring may be set to monitor for: (1) changes in ecological status and integrity; (2) fundamental understanding of the ecosystem processes, (3) prediction on changes and trends, and provision of warning for unfavourable one, and (4) management action (Lee *et al.*, 2005). All these pruposes may be set for this project although the first purpose seems to be the primary. The ecosystems and biodiversity of the concerned five vegetation types and aquatic bodies in LBBR were recommened as the target to develop a monitoring program.

In this project, it was designed that the consultant team will research to suggest a biodiversity monitoring with indicators representing the status of LBBR ecosystems. Therefore, a number of potential indicators must be suggested for discussion and agreement in the present workshop, in order to develop a suitable monitoring system with sets of selected indicators and ther survey methodologies which enable long-term implementation.

Although several efforts have been made in BDNB to develop permanent sites for long-term monitoring of the local ecosystem, they mainly include a large plot of 25 ha in a tropical evergreen broad-leaved forest mixed with conifers established near the Giang Ly Forest Station. Another smaller plot of 50 m x 50 m has been established nearby. In addition, a first database of biodiversity of the park was made within a Vietnam Conservation Fund-funded project in 2009. Besides, a program to monitor the gibbon has been developed by WWF. No systematic program has been developed for monitoring all key ecosystems and their biodiversity in LBBR.

Therefore, it is necessary to determine a totally new monitoring system for LBBR with selected concrete and quantified indicators.

According to United States National Academy of Sciences (2000), good indicators should have three key features:

- They quantify information so that its significance is more apparent;
- They simplify information about complex phenomena;
- They are a cost-effective alternative to monitoring many individual processes, species, etc.

According to Kapos *et al.* UNEP-WCMC, 2001), indicators should be:

- scientifically valid;
- based on easily available data;
- responsive to change;
- easily understandable;
- relevant to focal issues and users' needs;
- subject to target or threshold setting.

Potential indicators are determined based on research. They can be species or non-species. In this project, several chemical/physical characteristics of the ecosystems were measured to reflect the basic natural conditions of the ecosystems, including those of rainfall, soil, air, water, etc. Biodiversity indicators are those universally used for ecosystems, such as diversity indices (Simpson's, Shannon's, species richness, area of vegetation types). In addition, indicator species were determined using expert experience, Importance Value Index (Curtis & MacIntosh, 1950) and an analysis of the relationship between their occurrence or abundance values from a set of sites and the classification of the same sites into site groups (De Cáceres *et al.*, 2009, 2010, 2012). Species indicators include individual species or combinations of indicator species; the latter is an extension of the former, which was proved, be useful to develop multispecies ecological or environmental indicators. The combination of indicator species in this report indicated the group of indicators that can represent the habitat and provide strong relevant relationship of species with habitat type. Therefore, the indicator consisting of the two or more species jointly may have higher positive predictive value compared with the indicators of two species considered independently.

3.2 DATA COLLECTION AND ANALYSIS

While the species richness and area of the vegetation types were made available from the activities Vegetation mapping and Development of biodiversity database, the indices of species diversity and indicator species must be concluded from further analyses of the data collected from the plots.

As conventional, the **species richness, Simpson's index and Shannon's index** were calculated using universal softwares MS Excel and Primer 5.0.

Indicator species were determined using analyses of traditional indicator value and association with habitat or point biserial correlation (De Cáceres & Legendre, 2009; De Cáceres *et al.*, 2010 & 2012). Indicator Value (*IndVal*) index of a species in a site group (or vegetation type) G is calculated as the product of A and B, wherein A is the specificity or positive predictive value of species S as indicator of the site group and B is fidelity or sensitivity of the species as indicator of the target site group (Murtaugh 1996; Dufrêne & Legendre 1997; De Cáceres & Legendre 2009; De Cáceres *et al.*, 2010 & 2012). A = P(G|S) is the probability that the surveyed site belongs to the

target site group G given the fact that species S has been found. B = P(S|G) is the probability that the species could be found in newly surveyed sites of the same site group.

Both A and B can be calculated from the presence–absence or abundance data as follows:

- Positive predictive value for presence–absence data:

$$A_{pa}^{g} = \frac{n_n / N_p}{\sum_{k=1}^{K} n_k / N_k}$$

- Positive predictive value for abundance data

$$A_{ind}^{g} = \frac{a_p / N_p}{\sum_{k=1}^{K} a_k / N_k}$$

- Sensitivity

$$B = \frac{n_p}{N_p}$$

Where:

N_p: number of sites that belong to the target site group; n: number of occurrences of the indicator across all sites; n_p: number of occurrences of the indicator within sites that belong to the target site group; N_k: number of sites that belong to the site group k; n_k: number of occurrences of the indicator within sites that belong to the site group k; a_p: sum of the abundance values of the indicator within the target site group; a: sum of the abundance values of the indicator over all sites.

After calculating the *IndVal* value for all site groups, which are groups of plots in the same vegetation types in this project, the site group is looked for which the species is maximally associated. For this, the maximum *IndVal* value across site groups was tested for statistical significance using a permutation test (with the null null hypothesis that there is no association in this site group), one first needs to reject the, a procedure that involves comparing an observed test statistic with a distribution obtained by randomly reordering (i.e., permuting) the data. The P value of the permutation test of positive (negative) species preference is the proportion of permutations that yielded the same or higher (lower) association values than that observed for the unpermuted data.

For plants, Importance Value Index (IVI) following standard phytosociological methods by Curtis & McIntosh (1950) was additionally calculated for all trees to determine **species of highest ecological importance**, which were then selected as indicator species.

The data analyses were conducted in the R using *indicspecies* and *BiodiversityR* packages (ver. 1.7.1) (De Cáceres & Legendre, 2009 & 2012).

We applied this approach in all individual habitat types (vegetation types and aquatic bodies) to find their specific indicator species.

As the niche approach was also considered for this project, we tried to develop niche analyses using the same methods. Niches are often considered in terms of occupation of habitats, sources of foods, preferences to environment conditions, etc. However, despite of trying to note niche characteristics

in the field, we did not have adequate information on ecology of most of the recorded species due to short time of survey and unavailibity of ecological data. Therefore, the niche-specific species recommended for monitoring were proposed based mainly on the expert's observations and experience.

Many indicators can be drawn from the gathered-data analyses (we called them as **data-based indicator species**) and if all selected for monitoring, they may not be practical (especially for plants). Therefore, only indicators with highest statistical significance (all indicators with $p < .005$; for trees $P < 0.01$) calculated from the abundance data were selected to propose as monitoring indicator species, which are candidates for discussion in the workshop so that shortlisted indicator species will be assigned for a biodiversity monitoring system being developed.

Selection of relevant indicators and related measures play a crucial role on ensuring the success of a biodiversity monitoring program to be built and implemented. However, due to the limited surveyed areas, other potential indicating species may not have been recorded during the surveys. As a supplementation, we also employ the expert knowledge to suggest additional indicator species (***expert-based indicator species***), which refer to those not mentioned above (for example: exotic/invasive, herbaceous and endangered species). They are also the subject for the workshop discussion and agreement.

All of those findings were presented in a consultation workshop and succeeding scientific one organised in April and August 2017, respectively. All proposed monitoring indicators and program were discussed about and adjusted for a competent and feasible future monitoring program which is presented below.

4 CAPACITY BUILDING

One of the targets of this project was to build the capacity of the local staffs of LBBR and BDNB using the on-the-job-training approach. This has been conducted successfully by SIE in former protected areas, for example Bu Gia Map NP in Binh Phuoc Province. In this approach, staffs of LBBR were invited to join all technical meetings and field trips. Techinal staff of LBBR will be further trained to properly use the database built from this project.

III. RESULTS

1 VEGETATION MAPPING

1.1 RESULTING MAPS

Based on LCCS, land cover/ forest types of the LBBR are identified for the core and buffer zone as the follows.

A. Natural/ Semi natural vegetation
   Forests
      Evergreen Broadleaves
      - Evergreen broad-leaved forest, conifer at emergent strata
      - Evergreen broad-leaved forest, *Fagaceae* dominance
      - Evergreen mixed broad-leaved – conifer forest

      Evergreen Conifers
      - Evergreen open conifer forest, Pinus Kesiya dominance
      - Evergreen conifer forest, broad-leaved understorey

   Others
      - Grass, shrubs
      - Shrubs (trees and bamboos)
      - Mixed cultivated – grass, shrubs
      - Cultivated (various crops)

B. Abiotic
      - Water surface for aquaculture
      - Water surface for reservoir
      - Buil-up

This classification system was analyzed and identified based on field survey of land cover types coinciding to the pre-identified ecosystems for biodiversity survey (Evergreen broad-leaf forest, Broad-leaved and coniferous mixed forest, Coniferous forest, Bamboo and tree mixed forest, Bamboo and Water bodies). Besides land cover types corresponding to ecosystems, the classification system is of grass-shrubs and land cover types with human factors as cultivation, aquaculture and built-up. These were identified within survey in 2017. The type of bamboos is not obviously detected and recognized on satellite images because of using satellite images with medium spatial resolution for the past periods (1990, 2000, 2010), so that this type is not presented on resutl maps, corresponding to ecosystem of bamboo.

Figure 13 to Figure 17 show the resulting vegetation maps in LBBR since 1990. In general, forest changes in BDNB are not much in the core zone, and changes in the buffer zone are mainly due to developing cultivated land (Table 9). The water surfaces for aquaculture and built-up are difficult to detect for 1990, 2000 and 2010. However, these two types can be better identified at new satellite images in 2017.

It notices that BDNB forests became a special use forest in 1993, and then a national park in 2004. In 2015, the Lang Biang area was declared as a Biosphere Reserve, including BDNB. The Forest status in 1990, 2000, 2010 and 2017 are mapped based on satellite image interpretation and our recent field surveys. On Table 10, the land cover type of built-up and water surface for aquaculture are not able to idenetify because these were not detected obviously. This is also in case of both the Mixed cultivated – grass – shrubs and Shrubs.

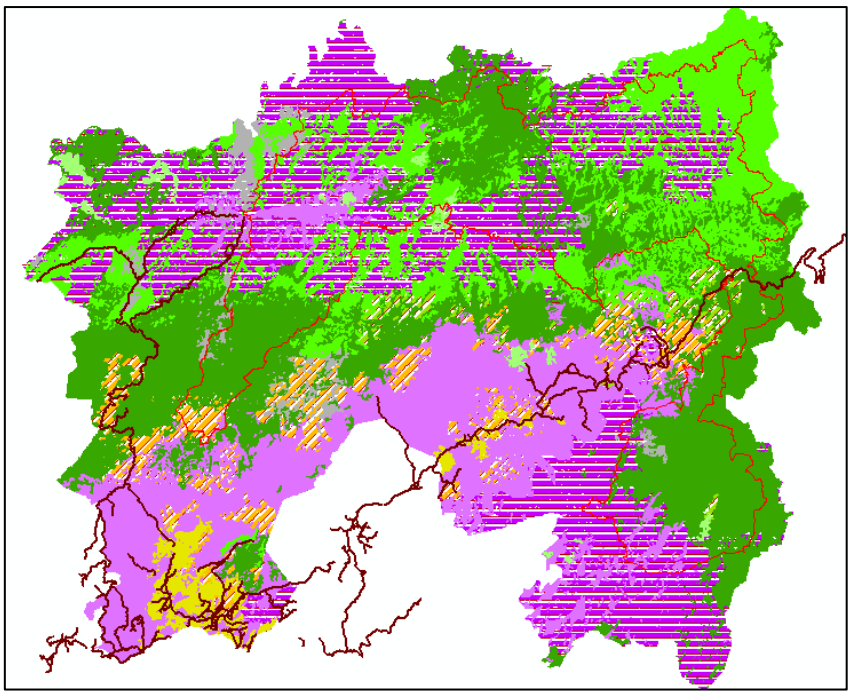


Figure 13. Forest status of 1990, core and buffer zones

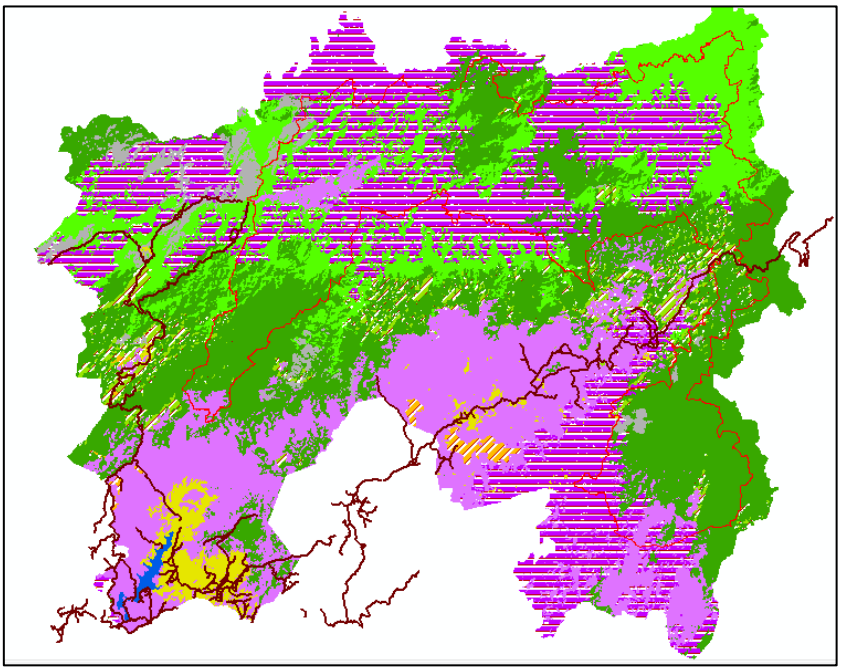


Figure 14. Forest status of 2000, core and buffer zones

Since 1990 to 2017, broad-leaved forests have expanded from 33,550 ha up to 37,500 ha whilst conifer forest has reduced its area about 3,600 ha and cultivated land increased up to 5,700 ha in 2017 compared to 2,100 ha in 1990.

In the west site of the buffer zone at elevations of 800 – 1000 m, the forests were almost evergreen although in some small patches, semi-evergreen forests could exist with occurrence of *Dipterocarpus obtusifolius*.

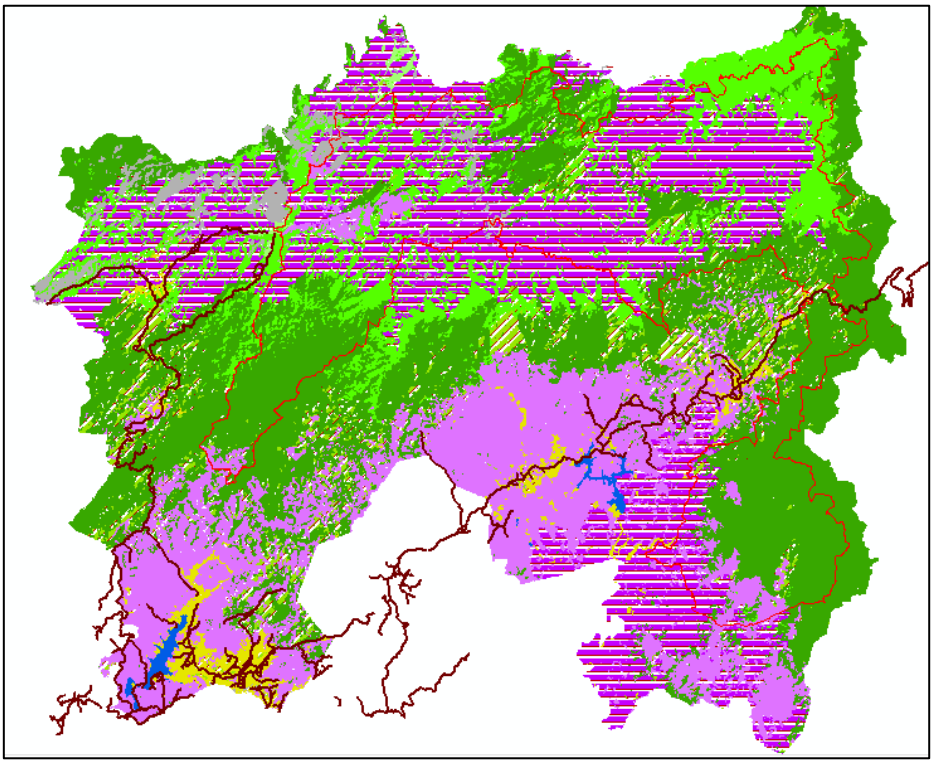


Figure 15. Forest status of 2010, core and buffer zones

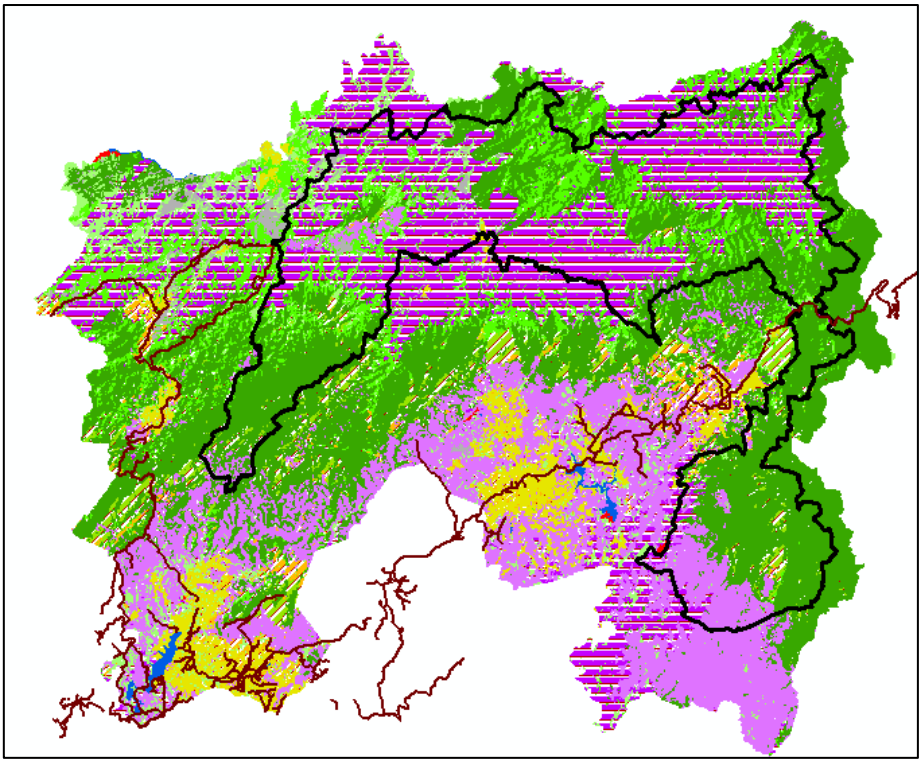


Figure 16. Forest status of 2017, core and buffer zones

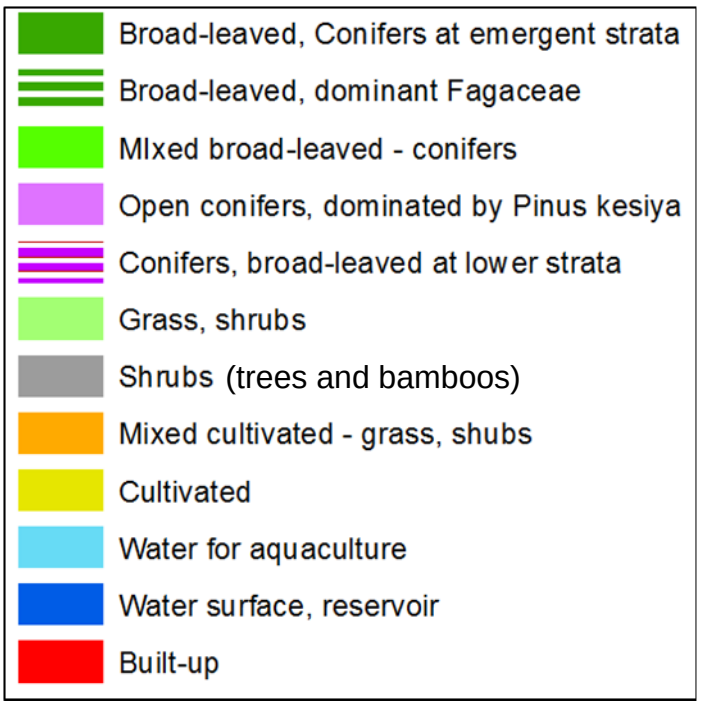


Figure 17. Map legend

Table 9. Vegetation change from 1990 to 2010 of the core and buffer zone (area – in ha)

Land cover / Forest types (Core and Buffer zones)	1990	2000	2010	2017
1. Evergreen broad-leaved forest, with emergent of conifer	32400.6	33200.2	36435.0	34607.2
2. Evergreen broad-leaved forest, Fagaceae dominant	1150.1	3606.6	5790.9	2936.0
3. Evergreen mixed broad-leaved – conifer forest	18080.1	16232.0	12412.8	12358.9
4. Evergreen open conifer forest, Pinus Kesiya dominant	20439.2	21582.4	20469.8	19219.5
5. Evergreen conifer forest, broad-leaved understorey	26033.2	27411.4	27002.0	23563.4
6. Grass, shrubs	906.2		232.1	5370.0
7. Shrubs (trees and bamboos)	2102.5	2775.6	2359.6	1566.8
8. Mixed cultivated – grass, shrubs	5005.2	592.5		2376.1
9. Cultivated (various crops)	2140.4	2581.2	3073.2	5775.2
10. Water surface for aquaculture				2.1
11. Water surface for reservoir		275.6	482.1	385.2
12. Built-up				97.2
Total	*108257.5*	*108257.5*	*108257.5*	*108257.5*

The core zone covers 32.2 percent of the total area of core and buffer zone with area of nearly 35,000 hectares. Out of which, only about 40 percent broad-leaved forest covers in the area and the rest composes of conifer forest, mixed broad-leaved - conifer and other land cover types. In the core zone, conifer forest has increased area, mostly from forest plantation of *Pinus*.

At evergreeen broad-leaved forest, the average tree height of main canopy is about 15-20 m. The emergent layer is above 20-25 m, which includes coniferous trees of *Podocarpaceae, Pinus Krempfii*, *Pinus dalatensis*…. Forest stands with dominant of *Pinus* have an average tree height of 12-15 m to 20 m (Figure 18).

Table 10. Vegetation change from 1990 to 2010 of the core zone (area – in ha)

Land cover / Forest types (Core zone)	1990	2000	2010	2017
Evergreen broadleaf forest, with emergent of conifer	13477.9	13313.7	12534.2	13024.7
Evergreen broadleaves forest, *Fagaceae* dominant	203.7	530.3	1178.8	597.3
Evergreen mixed broadleaves – conifer forest	8880.3	7297.2	6084.6	5727.3
Evergreen open conifer forest, *Pinus Kesiya* dominant	1646.4	1556.0	1684.5	2205.5
Evergreen conifer forest, broadleaves understorey	9790.7	11770.0	12890.0	11947.4
Grass, shrubs	195.9	0.0	12.1	838.3
Shrubs (trees and bamboos)	346.1	397.2	462.3	381.3
Mixed cultivated – grass, shrubs	323.6			86.2
Cultivated (various crops)		0.3	18.4	53.2
Water surface for aquaculture				0.0
Water surface for reservoir				
Built-up				3.6
Total	*34864.7*	*34864.7*	*34864.7*	*34864.7*

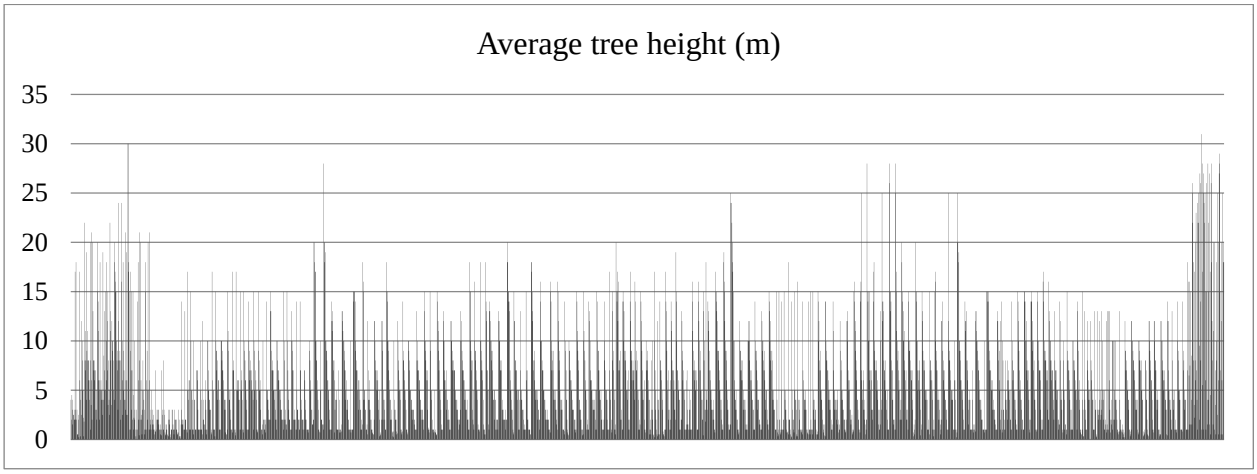


Figure 18. Stratification of forest stands with different average tree heigh at GPS waypoints

Stratification of forest refers to the vertical layering within a forest stand that also implies to forest health. The more layer of a forest stand, the healthier forest. The forest canopy density (FCD) was calculated from Landsat satellite images and presented in Table 11. Here are the classes of density:

- 0 : without forests (water surface, built-up, cultivated, grasses-shrubs)
- 1 : open forest (almost one forest layer with or without shrubs
- 2 : forest with 2 strata, canopy layer and understorey layer
- 3 : dense forest with more than two strata (emergent layer, canopy layer and understorey)

The resulting maps for 1991, 2001, and 2010 are shown in Figure 19. Noting that the FCD of two forests can stand with equal cover rate and different numbers of tree storeys, in which one with more tree layers has higher FCD. This means that where forests with more layers will have higher FCD with the same cover rate, and natural forests with tree layers will have higher FCD than monocultural planted forests.

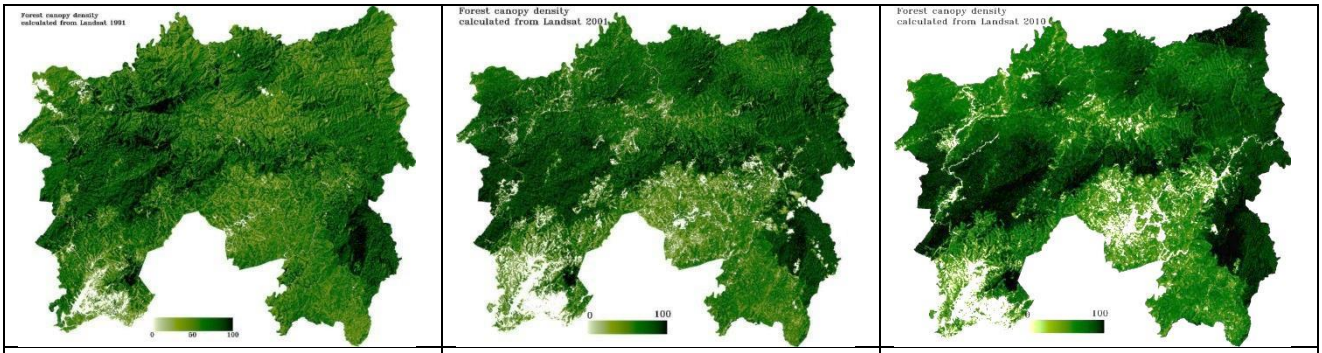
Table 11. Forest Canopy Density in different levels (percentage)

1991		
FCD		Area (km2)
0	0	3.443
1	1 - 40	14.972
2	41 - 65	793.736
3	over 65	271.138
		1083
Core zone		
FCD		Area (km2)
0	0	0.000
1	1 - 40	0.000
2	41 - 65	239.576
3	over 65	109.658
		349

2001		
FCD		Area (km2)
0	0	22.032
1	1 - 40	82.450
2	41 - 58	742.488
3	over 58	236.270
		1083
Core zone		
FCD		Area (km2)
0	0	1.301
1	1 - 40	6.920
2	41 - 58	243.768
3	over 58	97.229
		349

2010		
FCD		Area (km2)
0	0	33.815
1	1 - 40	166.340
2	41 - 60	680.442
3	over 60	204.629
		1085
Core zone		
FCD		Area (km2)
0	0	0.442
1	1 - 40	16.746
2	41 - 60	252.473
3	over 60	80.224
		349

The highest FCD is found mainly for dense evergreen broad-leaved forests with coniferous trees in the emergent layer. The under canopy layer is dominated by broad-leaved trees. *Pinus krempfii*, *Pinus dalatensis* and *Podocapaceae* can be found at this type of forest.



FCD 1991	FCD 2001	FCD 2010

Figure 19. Forest Canopy Density of LBBR in 1991, 2001, and 2010.

(*Notes: Forest canopy density is calculated from Landsat images in 1991, 2001, and 2010. White color - Zero is minimum value, indicating without forest or open forest with only a tree layer; Dark green color (value 100) is maximum value, indicating dense forest with 2 or 3 tree layers*)

Lower FCDs are found for the coniferous forests dominated by Pinus kesiya (CF) and the mixed broad-leaved and coniferous forests (MF). The lowest FCD is found for areas with grasses and shrubs. All artificial surfaces including built-up area, cultivated land (annuals or perennials), and water surface such as aquaculture ponds and resevoirs have FCD ranging from 0 to less than 10. The FCD analysis indicates that low FCDs are distributed mainly in the buffer zone where the land is covered with pine stands and cultivation.

In general, changes in BDNB are seen positive as well negative. Broad-leaved forests increase in area (Table 9). Coniferous and mixed broad-leaved and coniferous forests reduce in area.

Detailed changes have been identified in the core and buffer zones based on Google Earth. There are about 54 sites (Table 12 and Figure 20) showing changes in terms of forest coverage, i.e. loss or gain forested area.

Table 12. Sites of forest cover changes from 2006 to 2017

Changes in buffer zone			
Identified year	Base year	Change	Number of surveyed sites
2011	2006	Loss	2
2014	2009	Loss	6
2014	2010	Loss	2
2014	2011	Loss	1
2014	2012	Loss	3
2017	2014	Loss	11
2017	2014	Gain	1
2017	2015	Loss	1
2017	2016	Loss	7
		Total	**34**

Changes in core zone			
Identified year	Base year	Change	Number of surveyed sites
2013	2006	Loss	1
2014	2006	Loss	8
2014	2006	Gain	3
2016	2014	Loss	1
2017	2016	Loss	7
		Total	**20**

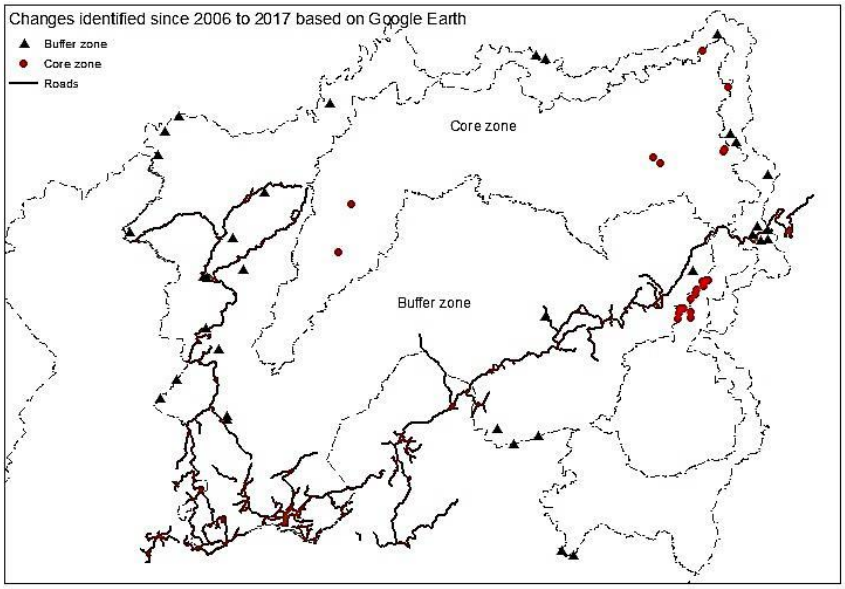


Figure 20. Changing sites in forest coverage since 2006 till 2017

1.2 DISCUSSION

Forest loss is due to conversion of forested land to water surface - resevoir, cultivation, road construction or logging. Forest gain is mainly due to reforestation and natural forerest recovery. In the buffer zone, there are 33 sites, and in the core zone there are 17 sites detected as loss of forests (Table 12), which include new loss or increase in area at various sizes. Changes at the core zone almost occur at the border or nearby (Figure 19). High potential impact is in the south and west of the area, and along the road.

In terms of conservation and management, these forest areas are under high pressure of potential negative impact regarding to its shape of the national park as a narrow part near the Bidoup mountain, a road crossing the forest and socio-economic development. Particlularly, new aquaculture ponds have been developed in recent years because of its suitable environment (low temperature, near the fresh water source, flat relief). Cultivation expands in area; in many sites it is named as high technology agriculture development with various crops planted in green houses. These developed sites are without tall trees and almost bare in vegetation; this makes changes of surface water regime (more surface run-off) and increase of day-night variation in temperature.

2 DEVELOPMENT OF BIODIVERSITY DATABASE OF LBBR

2.1 Plant diversity database

2.1.1 Diversity of plants

Based on the plot system records, the diversity indices for trees have been calculated for each habitat (Table 13)

Table 13. Diversity indices estimated from the plot system.

Diversity indices		Species richness	Simpson's index D	Shannon's index H'
EF	total	99	0.97	3.91
	core zone	57	0.96	3.51
	buffer zone	66	0.94	3.49
CF	total	28	0.81	2.37
	core zone	24	0.88	2.48
	buffer zone	14	0.56	1.47
MF	total	67	0.89	3.22
	core zone	42	0.94	3.25
	buffer zone	41	0.81	2.58
BF	total	37	0.32	1.01
	core zone	27	0.34	1.03
	buffer zone	12	0.29	0.75
MB	total	46	0.60	1.87
	core zone	19	0.38	1.12
	buffer zone	31	0.70	1.99

Notes: MB: Mixed forest of trees and bamboo; BF: Bambusa procera forest; MF: Broad-leaved and coniferous mixed forest; EF: Evergreen broad-leaf forest; CF: Coniferous forest.

The difference of tree diversity between the core and buffer zones is found significantly. The highest difference is found in the evergreen forest type (EF) and the lowest is found in the coniferous forest type (CF).

2.1.2 Database of plants

Based on the available reports until 2016 provided by BDNB, we have refined the plant checklist of 1,932 species by reducing synonyms and unclear scientific names (i.e. those unable to be confirmed by any accepted databases) and thus come to a refined checklist that includes only 1,830 species.

Our field surveys within this project have noted around 745 morphologically different species with 984 records. Many of these cannot be identified to the species rank due to unavailability of their reproductive organs when we collected them, and they are saved for further inventory. Combining the refined checklist and our new identified plants within this suvey, the database of higher plants in LBBR has been made, including 1966 species, 966 genera and 188 families. Our field trips within this suvey recorded 136 species as new to the local flora.

Noticeably, there are several taxa that may be finds new to science (for example, see Figure 21) and we hope to describe them as new species as scientific results from this project.

Figure 21.* Aristolochia *sp. nov., a new beautiful flowering plant found within the survey.

It is noticeable that during 2014-20116 there have been at least 13 plant species from LBBR described as new to science. This makes this biosphere reserve as one of the most attractive hotspots of diversity in the country and as such it reflects that we are still far from fully understanding the local biodiversity. Therefore, before this knowledge is available, it is important to preserve LBBR intact and develop biodiversity inventory/database projects as soon as possible.

To the present knowlegde, the 10 most plant species-diversity families and 10 most plant species-diversity genera are listed in Table 14 and Table 15.

Table 14. Ten most plant species-diversity families in LBBR.

Family	Number of known species
Orchidaceae	271
Leguminosae	110
Compositae	92
Rubiaceae	74
Poaceae	69
Cyperaceae	52
Polypodiaceae	52
Fagaceae	42
Moraceae	42
Ericaceae	41

Table 15. Ten most plant species-diversity genera in LBBR.

Genus	Number of known species
Dendrobium	46
Ficus	37
Bulbophyllum	25
Ardisia	21
Asplenium	20
Lithocarpus	20
Symplocos	19
Carex	18
Rubus	18
Blumea	16
Lasianthus	16

2.1.3 Discussion

Although the built database includes around 1966 plant species and all our new records have full data sets as required, many have no detailed data as should they be. Many have been included as they were mentioned in previously reported checklists. It is difficult to confirm their existence in the reserve as they do not have information on respestive specimens, coordinates, photos, etc. This problem holds for the other groups of biodiversity presented below and can only be improved by further surveys with well designed methods. A full database of species diversity of LBBR can be reached if further inventories are conducted systematically and can be gradually filled in by monitoring activities.

Nevertheless, this indicates existing gaps of the built database that need further surveys to fill in, and this should be an urgent task for future activities.

2.2 Mammal diversity database

2.2.1 Diversity of mammals

Our field surveys within this project have recorded 38 mammal species of 14 families and seven orders within quadrats (see Table 16) and additional eight (8) species recorded opportunistically during the survey period.

Based on the mammal records along the transects, the diversity indices for mammal fauna have been calculated for each habitat (Table 17). The record accumulation is shown in Figure 22.

By this project, there are the first baseline surveys of mammals carried out in the Dung Jar Rieng and Da Long areas that used live trapping and mist-netting techniques to record the diversity of nocturnal mammals and bats. In addition, the presence of mammals in survey areas was recorded by direct observations or indirect evidence from footprints, vocalisations, fresh droppings and other signs. A total of 20 transects (100 m x 5 m) was surveyed. A total of 20 Sherman traps with 1,200 trapping nights and 10 camera-traps with 480 trapping nights were set to recorded for mammals in the transects. Mist nets (60 hours of mist netting; 300 net emeter hours) to capture bats were laid at appropriate locations within quadrats and at other locations, such as dry streambeds, along roads and other potential fly routes. A total of was carried out to records the bats. Opportunistic encounters with mammals elsewhere within survey areas were recorded. No mammal voucher specimen was collected.

Key points are as follows:

- Survey areas in Dung Jar Rieng and Da Long support a rich indigenous mammal fauna. This is reflected in the presence of five bats, five primates, five carnovores, nine rodents, and three ungulates.

- Seven species are nationally threatened and eight are threatened at the global level .

- The most commonly recorded species were *Tamiops maritimus* and *Niviventer langbianis*. Other large mammals were rare.

- The various habitat types support different assemblages of species. Evergreen broad-leaf forest is the richest habitat.

- All survey areas have been under disturbance of human activities by poaching, collection of non-timber forestry products, and forest firing.

2.2.2 Database of mammals

In comparison to available checklist of 89 mammals recorded in BDNB (Lưu & Lê, 2010), these baseline surveys recorded additional four bats: *Cynopterus* cf. *brachyotis*, *Megaerops niphanae*, *Macroglossus sobrinus* and *Megaderma* cf. *spasma* and four rodents: *Rattus andamanensis*, *R. nitidusi*, *Vandeleuria oleracea* and *Bandicota savilei*. Thus, up to date, there are 98 mammal species of 29 families, ten orders recorded in LBBR.

Table 16. List of mammals recorded in the surveyed areas

No.	Species	Common name	EF		CF		MF		BF		MB		Out of Transects		Conservation	
			CZ	BZ	CZ	BZ	CZ	BZ	CZ	BZ	CZ	BZ	CZ	BZ	VN	IUCN
	I. Scandentia															
	1. Pupaiidae															
1.	*Tupaia benlangeri*	Northern treeshrew	Tr	Tr			Tr	Tr			T	T	O			
	II. Chiroptera															
	2. Pteropodidae															
2.	*Cynopterus* cf. *brachyotis*	Lesser short-nosed fruit ba												Tr		
3.	*Cynopterus sphinx*	Greater short-nosed fruit bat												Tr		
4.	*Megaerops niphanae*	Ratanaworabhan's Fruit Bat												Tr		
5.	*Eonycteris spelaea*	Cave nectar bat												Tr		
6.	*Macroglossus sobrinus*	Long-tongued fruit bat												Tr		
	3. Megadermatidae															
7.	*Megaderma* cf. *spasma*	Lesser false vampire bat												Tr		
	III. Primates															
	4. Cercopithecidae															
8.	*Pygathrix nigripes*	Black-shaked douc	O		O										EN	EN
9.	*Macaca leonia*	Pig-tailed macaque		O											VU	VU
10.	*Macaca arctoides*	Stump0tailed mcacque	T		T		O								VU	VU
11.	*Macaca fascisularis*	Long-tailed macaque												O		
	5. Hylobatidae															
12.	*Nomascus gabriella*	Southern yellow-cheeked gibbon	H										O		EN	EN
	IV. Carnivora															
	6. Mustelidae															
13.	*Martes flavigula*	Yellow-thorated marten														

No.	Species	Common name	EF		CF		MF		BF		MB		Out of Transects		Conservation	
			CZ	BZ	CZ	BZ	CZ	BZ	CZ	BZ	CZ	BZ	CZ	BZ	VN	IUCN
14.	*Melogale moschata*	Small-toothed ferret-badger		O				T								
	7. Viverridae															
15.	*Viverra zibetha*	Large Indian civet	O												VU	NT
16.	*Chrotogale owstoni*	Owston's palm civet	T				T								VU	EN
17.	*Paguma larvata*	Masked palm civet	O	T			T	T					O			
18.	*Paradoxurus hermaphroditus*	Asian palm civet	O							O			O			
19.	*Prionailurus bengalensis*	Leopard cat														
	V. Artiodactyla												O			
	8. Suidae															
20.	*Sus scrofa*	Wild boar	T				T		T	T		T				
	9. Tragulidae															
21.	*Tragulus kanchil*	Lesser mouse deer									T	T				
	10. Cervidae															
22.	*Muntiacus vaginalis*	Red muntjac	O		O		T									
23.	*Muntiacus vuquangensis*	Large-altered muntjac														
24.	*Rusa unicolar*	Sambar									T					
	VI. Rodentia															
	11. Sciuridae															
25.	*Ratufa bicolor*	Black grant squirrel	O				O									
26.	*Callosciurus erythraeus*	Pallas' squirrel														
27.	*Tamiops maritimus*	Eastern striped squirrel	O	O	O		O	O								
28.	*Dremomys rufigenis*	Asian red-cheeked squirrel										O				
29.	*Menetes berdmorei*	Berdmore's ground squirrel			O						O					
30.	*Petaurista philippensis*	Red-giant flying squirrel														
	12. Muridae														VU	NT

No.	Species	Common name	EF		CF		MF		BF		MB		Out of Transects		Conservation	
			CZ	BZ	CZ	BZ	CZ	BZ	CZ	BZ	CZ	BZ	CZ	BZ	VN	IUCN
31.	*Mus pahari*	Gairdner's shrewmouse	Tr	Tr												
32.	*Rattus andamanensis*	Sikkim rat				Tr										VU
33.	*Rattus nitidus*	Himalayan field rat	Tr													
34.	*Niviventer langbianis*	Lang Bian white-bellied rat	Tr	Tr							Tr	Tr				
35.	*Vandeleuria oleracea*	Asiatic long-tailed climbing mouse	Tr	Tr									O			
36.	*Bandicota savilei*	Savile's bandicoot rat			Tr	Tr						Tr	Tr			
	13. Spalacidae															
37.	*Rhizomys pruinosus*	Hoary bamboo rat							T	T						
	14. Hystricidae															
38.	*Hystrix brachyura*	Malayan porcupine	T		T		T									

Table 17. Mammal diversity indices estimated from the survey areas

Sites		#Individuals	Species Diversity	Simpson's index (D)	Shannon's index (H')
Bamboo Forest (BF)	*Buffer*	13	7	0.90	1.84
	Core	9	5	0.89	1.58
	Total	**22**	**8**	**0.87**	**1.89**
Conifeous forest (CF)	*Buffer*	5	3	0.80	1.05
	Core	11	6	0.91	1.86
	Total	**16**	**8**	**0.93**	**2.12**
Evergreen Forest (EF)	*Buffer*	20	11	0.89	21.50
	Core	115	23	0.75	2.10
	Total	**135**	**26**	**0.81**	**2.35**
Bamboo and tree mixed forest (MB)	*Buffer*	7	4	0.81	1.28
	Core	3	3	1.00	1.10
	Total	**10**	**6**	**0.89**	**1.70**
Broad-leaved and conifeous forest (MF)	*Buffer*	10	6	0.91	1.75
	Core	25	10	0.91	2.24
	Total	**35**	**13**	**0.93**	**2.46**

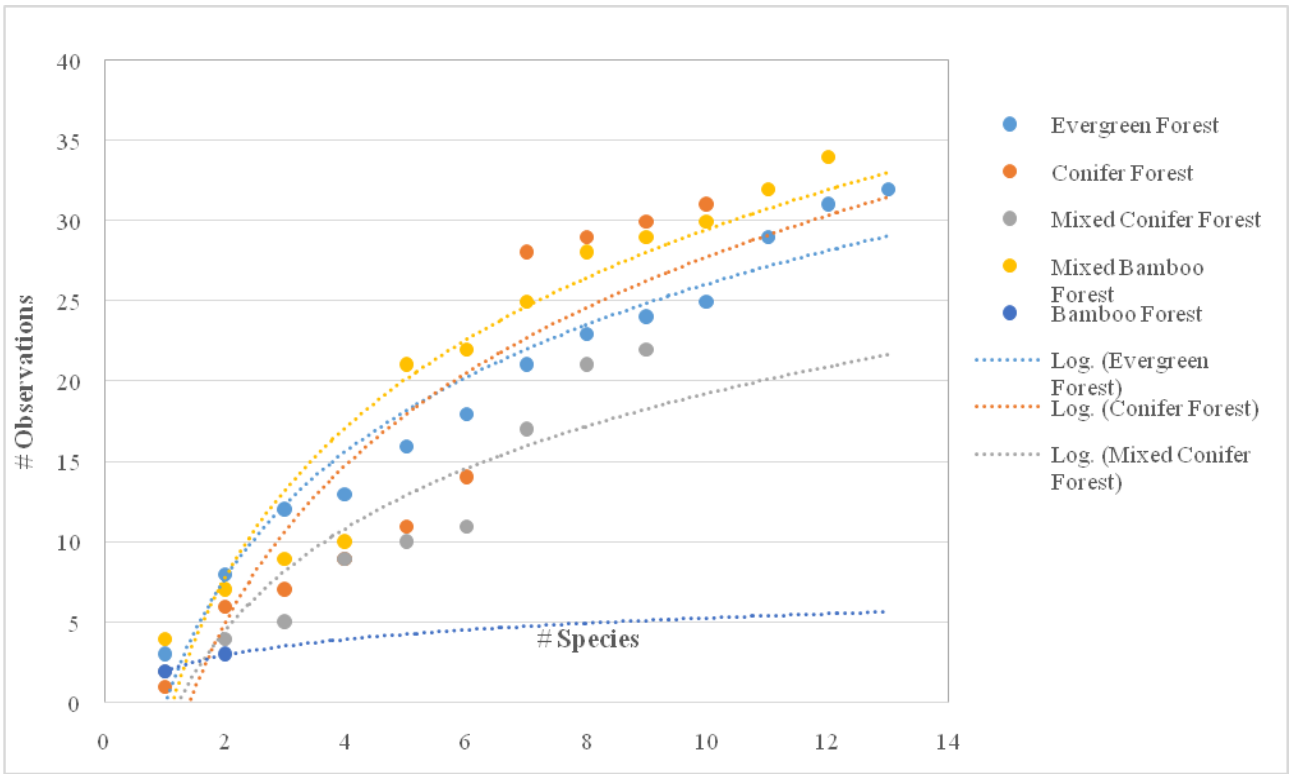


Figure 22. Species accumulation curves for the mammal dataset

2.2.3 Discussion

LBBR is recognised having high biodiversity with many endangered species including mammals (UNESCO, 2015). However, only some field surveys of mammals in LBBR had not been carried out intensively, for example Krutskov and Morozov (2002), IEBR (2003), Nguyen Duy Chinh *et al.* (2006), Mahood *et al.* (2009) and Lưu & Lê (2010). These were rapid or short-term surveys. Therefore, there are not records of all mammal species in LBBR.

Although in low frequency, illegal hunting and trapping are main threats to survival of mammals in LBBR. During the field surveys, we had encountered a few mantraps and evidence of old trapping activities. In particular, we encountered some local people in surveyed areas in BDNB who were going to fishing or other unknown purposes.

In LBBR, controlled and uncontrolled forest fires are also threats to wildlife, especially small mammals and other ground dwelling aninals. It could be seen that forest fires are also impact natural forest regeneration in surveyed areas.

2.3 Bird diversity database

2.3.1 Diversity of birds

Bird species recorded within and outside transects varied by locations and survey times. The first survey carried out in the wet season and recorded total of 95 bird species, including 80 species in transects and 78 species out of transects. Of these, seven species are endemic to Lang Biang Plateau and Indochina region and listed in the Redlist of Threatened Species of IUCN (2016).

The second survey implemented in the start of dry season and recorded 81 species belong to 34 families, of which 56 species were found in transects and 77 species were found outside of transects. There were four species listed in the Redlist of Threatened Species of IUCN (2016) including Crested Argus *Rheinartia ocellate*, Black-hooded laughingthrush *Garrulax millet*, Collared laughingthrush *Trochalopteron yersini* and Short-tailed scimitar babbler *Rimator danjoui*. Comparison to species composition of the first survey, the second survey added 25 species to the avifauna in the study site but did not record 29 species recorded in the first survey.

The third survey carried out in the dry season and recorded 74 species of 31 families including 64 species in transects and 63 species outside transects. Only two important species to conservation was recorded, Black-hooded laughingthrush *Garrulax milleti* (NT) and Vietnamese cutia *Cutia legalleni* (NT). This survey added seven more species to the list of birds recorded in the survey areas but did not find 53 species recorded in the first two surveys.

Among 127 species recorded during our study, 99 species were in transect and 105 were outside transects. There were 83 species found both inside and outside transect while number of species recorded only inside transect and only outside transect were 19 and 25 species, respectively.

The evergreen forest and coniferous forest support the highest levels of bird diversity in comparison to other habitat types. The number of species and species important to conservation in each habitat are indicated in Table 18.

In detail, the number of bird species recorded in transect and outside transects in five habitats of core zone and buffer zone of the Lang Biang BR is shown in Table 19.

Table 18. Number of species and important species by habitats

Habitat	# species	Important species
Evergreen forest (EF)	88	07
Coniferous forest (CF)	57	01
Mixed forest of broadleaf and coniferous species (MF)	45	03
Bamboo forest (BF)	38	0
Mixed forest of broadleaf and bamboo (MB)	48	0

Table 19: Bird species recorded in core zone and buffer zone by habitats.

Habitat	Core zone				Buffer zone			
	In transect 1	In transect 2	In two transects	Outside transects	In transect 1	In transect 2	In two transects	Outside transects
Evergreen forest	21	31	44	58	21	15	28	48
Coniferous forest	25	16	32	27	19	21	26	30
Mixed forest of broadleaf and coniferous species	9	12	15	28	17	9	18	27
Mixed forest of broadleaf and bamboo	5	13	14	15	8	13	16	24
Bamboo forest	9	15	20	5	19	18	27	11

2.3.2 Database of birds

The Lang Biang Plateau, including BDNB is considered as an Endemic Bird Area of the world. Since the discovery of Da Lat Town by Dr. Alexandre Yersin in 1897, French naturalists and explorers had carried out many studies in this plateau and contributed to our knowledge of biodiversity in the region. Archival study shows that historical studies of the avifauna of the Lang Biang Plateau is dated back 100 years ago when most scientists focused on collecting bird specimens and distribution and species composition. Robinson and Kloss (1919) provided initial data on the avifauna of this area, including description of some new birds such as *Cutia legalleni* and *Garrulax miletti*. Following surveys conducted between 1920s and 1930s by Delacour and Jabouille had provided a list of birds of the Lang Biang Plateau. In 1938, a Swedish ornithologist, Bertil Björkegren also conducted a collection of bird specimens in which described a new species *Crocias langbianis* in this area. Since the early 1940s, due to the impacts of political and war turbulences, studies on avifauna in particular and animals in general in the Lang Biang Plateau were suspended till the end of 1980s. In 1989, these studies were brough back with a long survey conducted by Craig Robson et al from Sep. 1980 to Mar. 1990. The study recorded 111 bird species in Lang Biang Mountain and Cong Troi forest section. From 1993 to 1994, Birdlife International conducted a survey of endemic bird species in the Lang Biang Plateau that also recorded 64 species in Bidoup Mountain, Gia Rich Mountain, Nui Ba Mountain and Cong Troi forest section. In 2003,

the Institute of Ecology and Biological Resources carried out a bird survey in Bidoup Mountain and recorded 160 species. In 2002 and 2009, Vietnam-Russian Tropical Center presented a bird checklist of 135 species in Giang Ly and Bidoup forest section. Mahood *et al.* (2009) also recorded several internationally important species in the region including Crested Argus (*Rheinardia ocellata*), grey-crowned crocias (*Crocias langbianis*), Black-hooded Laughingthrush (*Garrulax milleti*), Orange-breasted Laughingthrush (*Garrulax annamensis*), Vietnamese Greenfinch (*Carduelis monguilotti*), Yellow-billed Nuthatch (*Sitta solangiae*) and Short-tailed scimitar babble (*Jabouilleia danjoui*).

Most recently, the results of a bird survey conducted from November 2009 to March 2012 by the Center for Biodiversity and Development (CBD = presently SIE) at several forest compartments in Bidoup-NuiBa, including Hon Giao, Cong Troi, Lang Biang Mountain, 60, 76, 77, 85 and 86 recorded 106 species belonging to 41 families (Phung Ba Thinh *et al.* 2012). The authors also compiled a list of 268 species that occured in the region. As a component of the project "Establish the plot of 25 hectare to study of ecological progression at Bidoup - Nui Ba National Park" an extensive study on birds in 2014 showed 70 bird species within this plot. In addition, the study also classified species composition based on ecological niches. Furthermore, the Global Biodiversity Information Facility (GBIF) also stored hundreds of records of 301 bird species at Bidoup - Nui Ba National Park over the last 100 years.

In summary, a total of 386 species belonging to 65 family was recorded in the Lang Biang Plateau. Based on this study and literature review, an updated checklist of bird species in this area is provided, including 394 bird species belonging to 67 families. There are 23 species listed in the Redlist of Threatened Species of IUCN (2016) and 20 species in Vietnam RedData Book 2007 from Near Threatened (NT) to Endangered (EN) (see Bird Brhams database). A database of birds in the Lang Biang Pateau is developed with 1,838 records of 394 species. It shows that the avifauna in the Lang Biang Plateau is highly diverse in species composition as well as in important species to conservation. It also provides reliable evidence that the Lang Biang Plateau is one of the *centres of bird diversity of Vietnam.*

2.3.3 Discussion

The Lang Biang Plateau supports a very high diversity of birds, one of the most bird richness in Vietnam with 394 bird species belonging to 67 families recorded. This study has recorded eight new species to the region while many species recorded in the past have not been reconfirmed (*e.g.* Vulture). This means that the checklist provided in this bird database is the most comprehensive one and all species of the region probably have been recorded (except migratory birds).

Species composition varies between habitats and by seasons in each habitat. While the detectability of most species is high, the change in species composition in habitats and by seasons would be related to food availability of each habitat by seasons and bird behaviors.

For better monitoring of bird diversity/abundance in relation with their habitats, species or group of species that are restricted to a specific habitat are recommeneded as bird indicators. The evergreen forest and coniferous forest support high diversity of birds (high H index) and play an important role to some bird species since they are confined to these forest types.

2.4 Reptile and amphibian diversity database

2.4.1 Diversity of reptiles and amphibians

A total of 210 observations in streams and 296 observations in terrestrial forests was performed. Details of the observations encountered within and outside the surveys sites/subplots along the streams and transects are shown in Table 20. In total, we have recorded 25 species of amphibians and 21 species of reptiles which inhabit the survey sites (Table 21). Their common species is reflected with Sorensn's index in Table 22.

Table 20. Number of herptological observations performed during the survey (07/2016-2017)

Location	S	BF-B	BF-C	CF-B	CF-C	EF-B	EF-C	MB-B	MB-C	MF-B	MF-C
inside	137	18	5	13	1	51	33	20	15	46	19
outside	63	6	0	8	1	27	22	5	4	0	2

Table 21. Checklist of recorded amphibian and reptile species in LBBR (07/2016-2017)

	Class	Order	Family	Name
1.	Amphibia	Anura	Megophryidae	*Brachytarsophry intermedia* (Smith, 1921)
2.	Amphibia	Anura	Bufonidae	*Duttaphrynus melanostictus* (Schneider, 1799)
3.	Amphibia	Anura	Rhacophoridae	*Feihyla palpebralis* (Smith, 1924)
4.	Amphibia	Anura	Dicroglossidae	*Fejervarya limnocharis* (Gravenhorst, 1829)
5.	Amphibia	Anura	Ranidae	*Hylarana milleti* (Smith, 1921)
6.	Amphibia	Anura	Ranidae	*Hylarana montivaga* (Smith, 1921)
7.	Amphibia	Anura	Ranidae	*Sylvirana nigrovittata* (Blyth, 1856)
8.	Amphibia	Apoda	Ichthyophiidae	*Ichthyophi bannanicus* Yang, 1984
9.	Amphibia	Anura	Bufonidae	*Ingerophrynus galeatus* (Günther, 1864)
10.	Amphibia	Anura	Megophryidae	*Leptobrachium pullum* (Smith, 1921)
11.	Amphibia	Anura	Dicroglossidae	*Limnonectes poilani* (Bourret, 1942)
12.	Amphibia	Anura	Microhylidae	*Microhyla berdmorei* (Blyth, 1856)
13.	Amphibia	Anura	Microhylidae	*Microhyla fissipes* (Boulenger, 1884)
14.	Amphibia	Anura	Microhylidae	*Microhyla heymonsi* Vogt, 1911
15.	Amphibia	Anura	Microhylidae	*Microhyla micryletta* Dunois, 1987
16.	Amphibia	Anura	Microhylidae	*Microhyla* sp.
17.	Amphibia	Anura	Ranidae	*Odorrana graminea* (Boulenger, 1900)
18.	Amphibia	Anura	Megophryidae	*Ophryophryne gerti* Ohler, 2003
19.	Amphibia	Anura	Megophryidae	*Ophryophryne hansi* Ohler, 2003
20.	Amphibia	Anura	Megophryidae	*Ophryophryne* sp.
21.	Amphibia	Anura	Rhacophorus	*Polypedates megacephalus* Hallowell, 1861
22.	Amphibia	Anura	Rhacophorus	*Raorchestes gryllus* (Smith, 1924)
23.	Amphibia	Anura	Rhacophorus	*Theloderma corticale* (Boulenger, 1903)
24.	Amphibia	Anura	Rhacophorus	*Theloderma palliatum* Rowley, Le, Hoang, Dau & Cao, 2011
25.	Amphibia	Anura	Megophryidae	*Xenophrys major* (Boulenger, 1908)
26.	Reptile	Squamata	Agamidae	*Acanthosaura lepidogaster* (Cuvier, 1829)
27.	Reptile	Squamata	Colubridae	*Amphiesma* sp.

	Class	Order	Family	Name
28.	Reptile	Squamata	Agamidae	*Bronchocela smaragdina* (Günther, 1864)
29.	Reptile	Squamata	Elapdae	*Bungarus* cf. *candidus* (Linnaeus, 1758)
30.	Reptile	Squamata	Agamidae	*Calotes* sp.
31.	Reptile	Squamata	Gekkonidae	*Cyrtodactylus bidoupimontis* Nazarov, Poyarkov, Orlov, Phung, Nguyen, Hoang & Ziegler, 2012
32.	Reptile	Squamata	Gekkonidae	*Cyrtodactylus* sp.
33.	Reptile	Squamata	Scincidae	*Eutropis* sp. (Hallowell, 1857)
34.	Reptile	Squamata	Scincidae	*Eutropis longicaudata* (Hallowell, 1857)
35.	Reptile	Squamata	Colubridae	*Lycodon subcinctus* Boie, 1827
36.	Reptile	Squamata	Colubridae	*Pareas hamptoni* (Boulenger, 1905)
37.	Reptile	Squamata	Colubridae	*Pareas* sp.
38.	Reptile	Squamata	Agamidae	*Physignathus cocincinus* Cuvier, 1829
39.	Reptile	Squamata	Colubridae	*Rhandophis* sp.
40.	Reptile	Squamata	Scincidae	*Scincella* sp.
41.	Reptile	Squamata	Scincidae	*Sphenomorphus maculatus* (Blyth, 1853)
42.	Reptile	Squamata	Scincidae	*Sphenomorphus* sp.
43.	Reptile	Squamata	Lacertidae	*Takydromus sexlineatus* Daudin, 1802
44.	Reptile	Squamata	Viperidae	*Trimeresurus albolabris* Gray, 1842
45.	Reptile	Squamata	Viperidae	*Trimeresurus vogeli* (David, Vidal & Pauwels, 2001)
46.	Reptile	Squamata	Scincidae	*Tropidophorus* sp.

Table 22. The similarity index between forest types and sites

	BF.B	BF.C	CF.B	CF.C	EF.B	EF.C	MB.B	MB.C	MF.B	MF.C
BF.B										
BF.C	33.33									
CF.B	26.67	18.18								
CF.C	47.06	30.77	50.00							
EF.B	42.11	13.33	22.22	30.00						
EF.C	28.57	35.29	20.00	27.27	41.67					
MB.B	52.63	26.67	11.11	50.00	36.36	25.00				
MB.C	37.50	33.33	13.33	23.53	31.58	28.57	42.11			
MF.B	28.57	-	40.00	36.36	58.33	38.46	33.33	38.10		
MF.C	26.67	18.18	28.57	50.00	33.33	30.00	44.44	66.67	40.00	

2.4.2 Database of reptiles and amphibians

The database of the reptile and amphibians for LBBR was built with 358 records and specimens.

A total of 137 individuals of amphibians and reptiles were recorded within the survey stream subplots (see the details in Table 23) during 3 surveys.

Table 23. Number of species and individuals recorded in stream transects (07/2016-06/2017)

	Total (n=9)		Survey 1 (n=3)		Survey 2 (n=3)		Survey 3 (n=3)	
Stream	Number of species	Number of individuals	Number of species	Number of individuals	Number of species	Number of individuals	Number of species	Number of individuals
S1	10	69	7	18	2	22	6	29
S2	5	24	3	4	1	3	5	17
S3	4	29	3	17	3	11	1	1
S4	5	15	3	10	1	1	4	4

A total of 221 individuals of amphibians and reptiles were recorded in the survey subplots within the terrestrial transects (see the details in Table 24) during 3 surveys in the year 2016-2017.

Table 24. Number of species and individuals recorded in terrestrial transects (07/2016-06/2017)

	Total (n=24)				Survey 1 (n=8)				Survey 2 (n=8)				Survey 3 (n=8)			
Forest	Core Zone		Buffer Zone		Core Zone		Buffer Zone		Core Zone		Buffer Zone		Core Zone		Buffer Zone	
	Spe.	Ind.	Spe.	Ind.	Spe.	Ind.	Spe.	Ind.	Spe.	Ind.	Spe.	Ind.	Spe.	Ind.	Spe.	Ind.
EF	13	33	11	51	6	15	7	15	7	11	8	21	13	7	11	15
CF	1	1	7	13	0	0	5	7	1	1	2	2	1	0	7	4
MF	7	19	13	46	2	5	8	24	4	5	4	12	7	9	13	10
BF	4	5	8	18	4	4	6	11	1	1	0	0	4	0	8	7
MB	8	15	11	20	5	9	10	15	0	0	1	1	8	6	11	4

Note: Evergreen Forest (EF); Conifeous forest (CF); Mixed Conifer_broadleaf Forest (MF); Bamboo Forest (BF); Mixed Bamboo_broadleaf Forest (MB); Number of species (Spe.); Number of individuals (Ind.)

2.4.3 Discussion

The species accumulation curve for the herpetofauna dataset (Figure 23) indicates that almost the common species of amphibians and reptiles have been found within the survey.

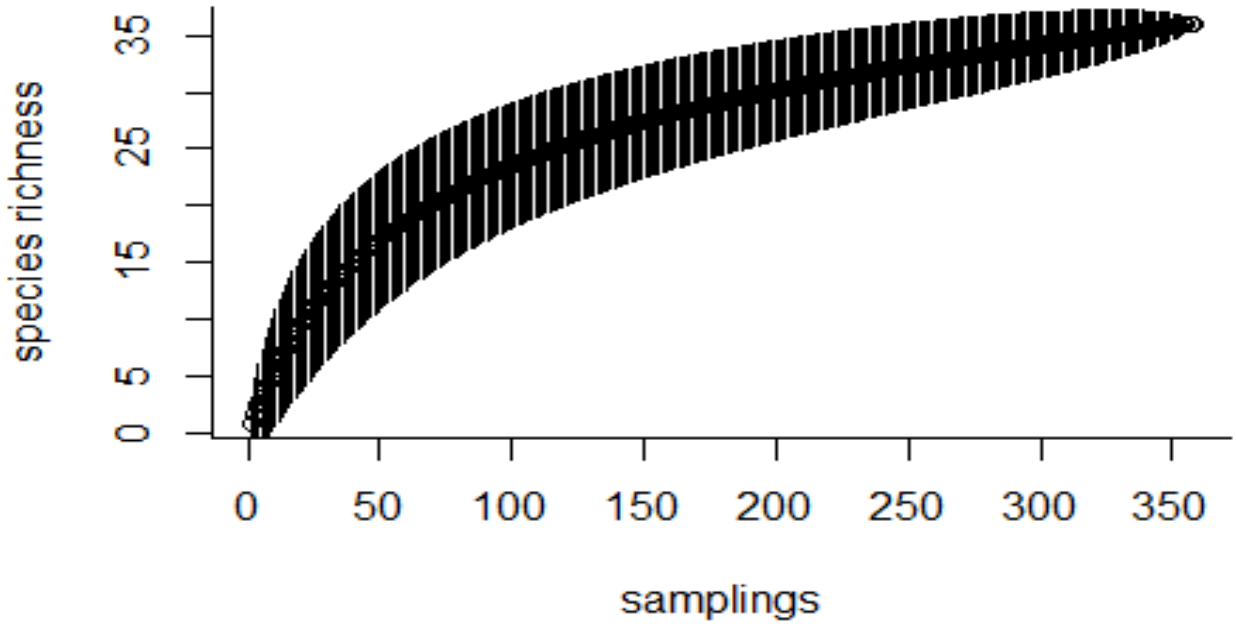


Figure 23. Species accumulation curve for the herpetofauna dataset

The amphibians and reptiles seem to prefer inhabiting in the broad-leaf forest (evergreen forest, broad-leaved and coniferous mixed forest, and Bamboo and tree mixed forests). The number of species and individuals of amphibians and reptiles found in these forest types always higher than those in the conifeous forest and bamboo forest (Table 24).

The results from this study show that the herpetofauna communities in buffer zone, where the impact of human is high, is characteristic with the dominance of common species such as *Microhyla berdmorei*, *Fejervarya limnocharis*, *Ingerophrynus melanostictus*, *Calotes versicolor*. In the other hand, the herpetofauna in core zone is characterised with the abundance of rare species such as *Acanthosaura lepidogaster*, *Brachytasorphrys intermedia*, and *Trimeresurus vogeli*. The exception for the different between herpetofauna diversity in core zone and buffer zone is at evergreen forest. During the survey, some species that require the specialised habitat and niches such as *Feihyla palbebralis*, *Rhacophorus vampyrus*, and *Rhacophorus calcaneus*. The appearance of these species in the forest match with the specialised characteristic of forest such ash high elevation, require pond for breeding.

2.5 Fish diversity database

2.5.1 Diversity of fishes

In four selected streams, there were ten species of eight genera and five families recorded during the survey. Besides the systematic survey, the opportunistic observations recorded 06 species and provided 01 species adding to the fish composition of the survey area. The detail distribution of 10 fishes is presented in Table 26 for each stream.

Table 25. List of fishes recorded in surveyed sites

No.	Family	Species	S1	S2	S3	S4	O
1	Balitoridae	*Annamia normani*		+	+		+
2	Balitoridae	*Schistura* cf. *sokolovi*	+	+	+		+
3	Nemacheilidae	*Nemacheilus* sp.				+	
4	Balitoridae	*Schistura* sp.	+	+	+		
5	Gastromyzontidae	*Ungen* sp.		+	+	+	
6	Channidae	*Channa gachua*	+	+	+		
7	Cyprinidae	*Neolissochilus stracheyi*	+	+	+		+
8	Cyprinidae	*Onychostoma krongnoensis*	+	+	+		+
9	Cyprinidae	*Poropuntitus laoensis*	+	+	+		+
10	Gyrinocheilidae	*Gyrinocheilus anymonieri*					+
Total			6	8	8	2	6

The result shows that the stream S2 and S3 have the largest number of species (08 species); the less number of fish species is in the stream S4 (02 species) while the remaining streams; S1 has 06 species. None of these fish is presently determined being threatened according to IUCN Redlist (2017) or Vietnam Red Data Book (2007). There are three species of loach being processed for formal description.

The most abundant family is Balitoridae and Cyprinidae; the most common species is *Poropuntius laoensis*. During our surveyed, none of exotic fishes has been recorded in the chosen streams of Krong Kno River.

2.5.2 Database of fishes

Gathering the data from this survey and literature review, a database of fish has been created, comprising 142 records of 53 species (5 orders and 10 families). In which, 04 species are considered as threatened according to the 2017 IUCN Red List.

2.5.3 Discussion

An analysis of fish assemblages shows the reparation among the stream S4 and others (Figure 24). This can be explained not only by the difference of fish composition but also the distance to each stream themself. As can be seen from the figure the stream S4 habits 01 unique species and share 01 more species with other stream, this fish assemblage is separated from the remaining three streams which house similar species.

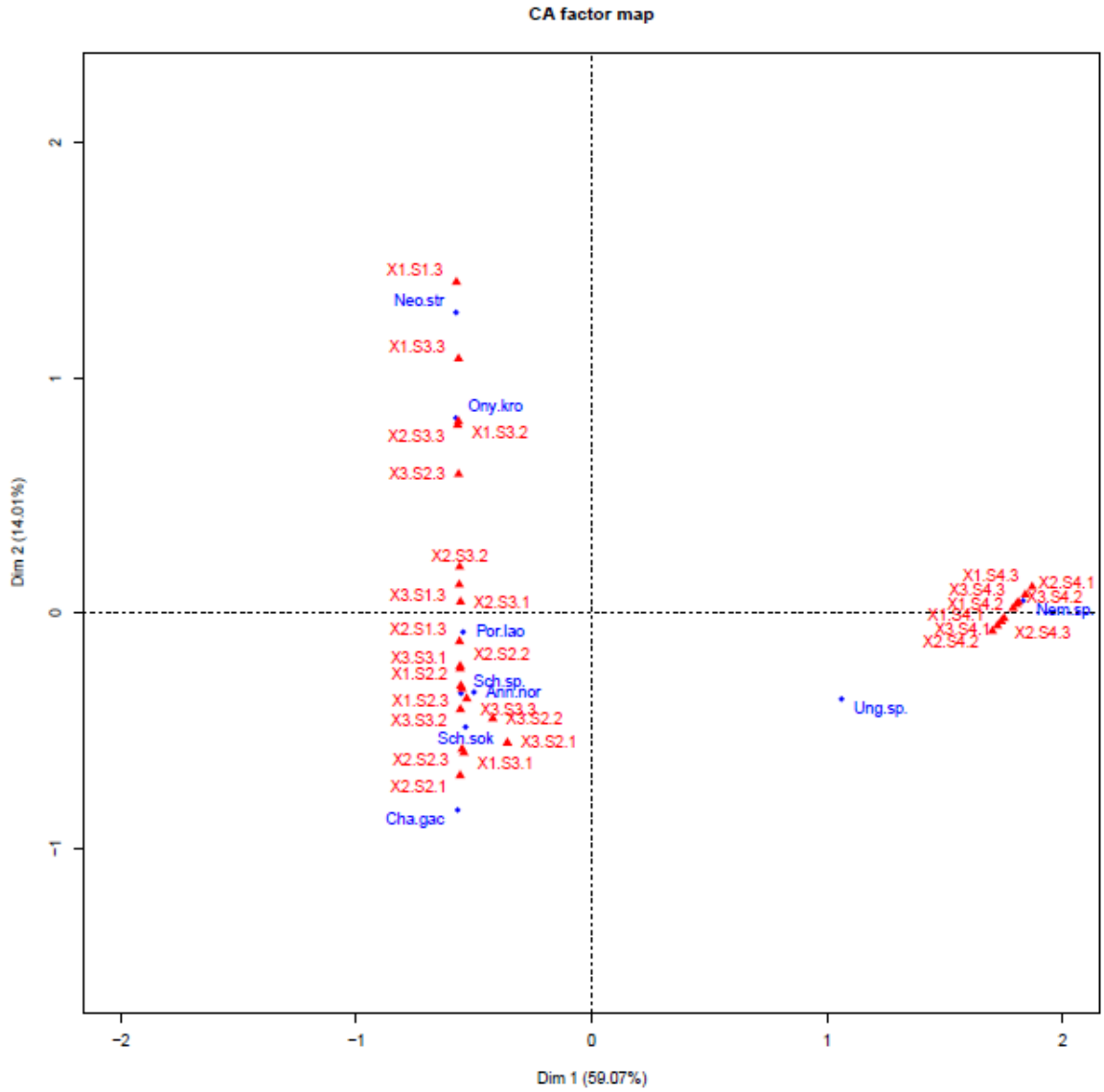


Figure 24. Canonical correlation analysis for fish communities

2.6 Insect database

2.6.1 Diversity of insects

Our field surveys in this project recorded 54 species, including 46 butterflies (36 genera, 9 families) and 8 termites (7 genera, 2 families) (Table 26). Besides, we had also surveyed outsides the transects, recording at least 20 species adding to the insect composition of the study area. Therefore, the full checklist of insects species for the study site includs species that oudsite the transects.

None of threatened insect was recorded in transets or plots, but outside is different, such as: 5 species endemic to the Da Lat Plateau: *Coeliccia suoitia, Coeliccia mattii, Anisopleura bipugio, Rhinocypha seducta* belonging to the stream in EF of core zone; 2 species of nationally threatened insects (Vietnam RedData Book (2007) and included in Appendix II of CITES: *Troides aeacus, Troides helena* along the stream border buffer and core zone in Da Long. Noticed that at least 3 taxa of the Odonata order may be may be finds new to science and we hope to describe them as new species as scientific results from this project.

Table 26. List of insect species recorded in the surveyed areas

No.	Order	Family	Species
1	Isoptera	Rhinotermitidae	*Reticulitermes flaviceps*
2	Isoptera	Rhinotermitidae	*Schedorhinotermes medioobscurus*
3	Isoptera	Termitidae	*Discuspiditermes nemorosus*
3	Isoptera	Termitidae	*Globitermes sulphureus*
4	Isoptera	Termitidae	*Nasutitermitinae sp1*
5	Isoptera	Termitidae	*Nasutitermitinae sp2*
6	Isoptera	Termitidae	*Odontotermes proformosanus*
7	Isoptera	Termitidae	*Pericapritermes latignathus*
8	Lepidoptera	Amathusiidae	*Faunis bicoloratus*
9	Lepidoptera	Amathusiidae	*Faunis eumeus*
10	Lepidoptera	Amathusiidae	*Thaumantis diores*
11	Lepidoptera	Danaidae	*Parantica sp.*
12	Lepidoptera	Hesperiidae	*Notocrypta sp.*
13	Lepidoptera	Lycaenidae	*Arhopala sp.*
14	Lepidoptera	Lycaenidae	*Caleta roxus*
15	Lepidoptera	Lycaenidae	*Drupadia ravindra*
16	Lepidoptera	Lycaenidae	*Heliophorus ila*
17	Lepidoptera	Lycaenidae	*Jamides celeno*
18	Lepidoptera	Lycaenidae	*Lycaenid*
19	Lepidoptera	Nymphalidae	*Ariadne merione*
20	Lepidoptera	Nymphalidae	*Athyma perius*
21	Lepidoptera	Nymphalidae	*Charaxes bernardus*
22	Lepidoptera	Nymphalidae	*Chersonesia risa*
23	Lepidoptera	Nymphalidae	*Euthalia narayana*
24	Lepidoptera	Nymphalidae	*Kallima inachus*
25	Lepidoptera	Nymphalidae	*Kaniska canace*

No.	Order	Family	Species
26	Lepidoptera	Nymphalidae	*Lexias pardalis*
27	Lepidoptera	Nymphalidae	*Neptis hylas*
28	Lepidoptera	Nymphalidae	*Parthenos sylvia*
29	Lepidoptera	Nymphalidae	*Polyura athamas*
30	Lepidoptera	Nymphalidae	*Symbrenthia lilaea*
31	Lepidoptera	Nymphalidae	*Tanaecia lepidea*
32	Lepidoptera	Papilionidae	*Atrophaneura varuna*
33	Lepidoptera	Papilionidae	*Papilio helenus*
34	Lepidoptera	Papilionidae	*Papilio paris*
35	Lepidoptera	Pieridae	*Catopsilia pomona*
36	Lepidoptera	Pieridae	*Delias agostina*
37	Lepidoptera	Pieridae	*Eurema blanda*
38	Lepidoptera	Pieridae	*Eurema hecabe*
39	Lepidoptera	Riodinidae	*Abisara burnii*
40	Lepidoptera	Satyridae	*Ethope diademoides*
41	Lepidoptera	Satyridae	*Lethe confusa*
42	Lepidoptera	Satyridae	*Lethe verma*
43	Lepidoptera	Satyridae	*Melanitis phedima*
44	Lepidoptera	Satyridae	*Mycalesis anaxias*
45	Lepidoptera	Satyridae	*Mycalesis annamitica*
46	Lepidoptera	Satyridae	*Mycalesis francisca*
47	Lepidoptera	Satyridae	*Mycalesis mnasicles*
48	Lepidoptera	Satyridae	*Mycalesis sangaica*
49	Lepidoptera	Satyridae	*Mycalesis sp.*
50	Lepidoptera	Satyridae	*Mycalesis zonata*
51	Lepidoptera	Satyridae	*Neopa bhadra*
52	Lepidoptera	Satyridae	*Ragadia crisilda*
53	Lepidoptera	Satyridae	*Ypthima sp.*

2.6.2 Database of insects

More than 800 records of at least 74 species (3 orders and 15 families) retrieved from prevous records and within this survey have been input to the database of insects, including 2 nationally threatened species, 5 endemic species and 3 undescribed species.

2.6.3 Discussion

BF and MB have the highest number of butterflies; the lowest is found in EF. In general, the species richness is higher in the core zone than in the buffer zone; but this does not hold for MF, because its core zone with denser plants is not a good habitat for butterflies.

3 SUGGESTED BIODIVERSITY MONITORING PROGRAM

A number of monitoring indicators can be drawn from the results from analyzing the data collected from the field and from the experts' opinions. However, to choose suitable indicators depends on the target of a monitoring program for LBBR, personnel resource and costs of time and budget. Here we list a number of non-species and species indicators that were prepared for open discussion in the August 2017 workshop. A final chosen system of monitoring indicators and related programs for the case of LBBR has been drawn from the workshop and these is further integrated to be a biodiversity monitoring framework as presented below. A manual for biodiversity monitoring programs in LBBR was be prepared separately upon the project's requirements.

3.1 NON-SPECIES INDICATORS

3.1.1 Environment conditions

Within this survey, we inventoried potential environmental indicators at 80 subplots within 20 transects during the trip. Environmental data of the subplots is shown in Table 27 and Table 28.

Table 27. Environmental air parameters within subplots along transects (07/2016-06/2017)

Transect	**Subplot**	**Temperature** (°C)			**Huminity** (%)		
		1	2	3	1	2	3
BF-B1	1	26.00	23.15	25.20	80.85	77.45	78.60
BF-B1	2	23.95	24.10	25.10	88.70	76.20	80.80
BF-B1	3	24.30	24.50	25.90	87.40	77.75	81.30
BF-B1	4	26.10	22.75	24.60	86.05	79.60	73.95
BF-B2	1	22.80	-	26.25	82.35	-	86.55
BF-B2	2	23.00	-	26.60	81.25	-	81.90
BF-B2	3	22.45	-	25.80	81.85	-	82.25
BF-B2	4	23.15	-	24.90	82.70	-	82.60
BF-C1	1	23.35	-	23.44	86.05	-	98.25
BF-C1	2	21.70	-	24.22	90.20	-	100.00
BF-C1	3	21.25	-	24.50	94.90	-	99.10
BF-C1	4	22.45	-	24.44	95.35	-	99.55
BF-C2	1	23.15	25.10	25.94	88.10	74.80	84.35
BF-C2	2	23.10	22.60	26.75	83.00	78.85	86.15
BF-C2	3	23.75	22.55	26.03	76.65	76.15	87.65
BF-C2	4	24.65	24.15	24.64	78.30	77.65	91.75
CF-B1	1	19.05	18.45	-	82.15	84.85	-
CF-B1	2	19.40	18.30	-	92.80	87.60	-
CF-B1	3	19.25	16.40	-	89.80	92.75	-
CF-B1	4	21.50	15.70	-	86.10	93.70	-
CF-B2	1	19.65	20.00	20.47	87.90	86.00	100.00
CF-B2	2	17.45	19.50	19.36	81.50	85.00	100.00
CF-B2	3	20.40	20.45	19.75	87.70	80.65	100.00
CF-B2	4	19.30	18.75	19.75	85.85	89.45	100.00

Transect	**Subplot**	**Temperature** (°C)			**Huminity** (%)		
		1	2	3	1	2	3
CF-C1	1	22.60	57.75	21.81	83.55	90.90	100.00
CF-C1	2	22.45	58.15	21.22	83.90	90.25	100.00
CF-C1	3	21.65	58.70	20.47	87.70	88.55	100.00
CF-C1	4	20.75	60.60	21.11	89.10	85.70	100.00
CF-C2	1	22.35	18.90	22.17	85.80	88.10	94.70
CF-C2	2	22.80	18.60	20.64	80.45	86.45	94.95
CF-C2	3	23.05	17.20	21.78	77.25	80.45	92.05
CF-C2	4	22.00	17.50	21.56	86.30	82.60	96.15
EF-B1	1	18.55	19.15	20.19	80.75	94.50	98.55
EF-B1	2	18.20	20.30	21.36	81.25	88.80	91.65
EF-B1	3	19.10	19.85	19.78	80.70	94.40	98.65
EF-B1	4	18.85	20.25	21.17	81.10	88.40	96.65
EF-B2	1	17.85	16.70	21.50	86.55	87.55	97.50
EF-B2	2	17.25	17.60	21.50	88.45	94.40	97.50
EF-B2	3	16.90	95.20	21.50	92.45	94.40	97.50
EF-B2	4	17.65	17.65	21.50	86.80	96.90	97.50
EF-C1	1	18.45	14.45	21.19	75.00	92.55	92.45
EF-C1	2	18.95	14.50	22.50	82.45	95.50	91.15
EF-C1	3	20.25	14.35	22.42	87.10	95.20	90.80
EF-C1	4	18.75	15.50	21.83	86.80	96.40	93.25
EF-C2	1	18.75	16.90	-	90.35	87.55	-
EF-C2	2	18.80	16.40	-	90.40	90.20	-
EF-C2	3	18.75	16.70	-	91.05	88.25	-
EF-C2	4	18.75	16.55	-	90.40	88.55	-
MB-B1	1	24.80	22.85	25.00	91.75	79.60	85.20
MB-B1	2	24.35	22.75	24.90	92.30	79.60	83.35
MB-B1	3	24.45	24.05	25.90	93.45	79.60	82.50
MB-B1	4	23.25	24.05	25.25	87.80	78.20	81.90
MB-B2	1	24.90	23.15	-	79.75	77.45	-
MB-B2	2	25.75	24.10	-	78.60	76.20	-
MB-B2	3	24.60	24.50	-	88.85	77.75	-
MB-B2	4	24.55	22.75	-	88.15	79.60	-
MB-C1	1	23.35	20.95	24.72	85.45	80.50	95.80
MB-C1	2	22.70	22.35	23.31	88.40	81.30	99.80
MB-C1	3	23.25	21.30	22.94	88.85	81.30	97.15
MB-C1	4	22.45	20.85	22.92	89.70	79.95	97.60
MB-C2	1	26.45	-	76.20	85.55	-	94.80
MB-C2	2	26.25	-	75.00	85.05	-	98.90
MB-C2	3	26.45	-	-	87.10	-	-
MB-C2	4	26.10	-	-	86.45	-	-
MF-B1	1	19.70	20.80	-	91.20	87.35	-
MF-B1	2	20.60	20.60	-	91.20	81.15	-
MF-B1	3	19.10	19.90	-	87.85	87.95	-
MF-B1	4	21.10	19.95	-	85.65	85.80	-

Transect	**Subplot**	**Temperature** (ºC)			**Huminity** (%)		
		1	2	3	1	2	3
MF-B2	1	18.65	18.90	44.03	82.00	90.75	100.00
MF-B2	2	18.60	20.50	45.04	80.50	87.40	98.30
MF-B2	3	18.70	20.45	44.39	81.55	88.90	100.00
MF-B2	4	19.85	19.90	44.29	81.05	83.75	100.00
MF-C1	1	18.65	16.80	-	82.00	88.35	-
MF-C1	2	18.60	16.05	-	80.50	86.50	-
MF-C1	3	18.70	17.05	-	81.55	88.05	-
MF-C1	4	19.85	16.90	-	81.10	82.10	-
MF-C2	1	21.50	16.75	19.94	76.80	88.00	100.00
MF-C2	2	20.00	16.05	20.03	75.80	85.00	100.00
MF-C2	3	19.45	17.00	20.78	74.55	88.50	99.90
MF-C2	4	20.90	17.50	20.92	71.30	81.80	100.00

Table 28. Environmental parameters (in the soil) at locations within subplots along transects (07/2016-06/2017)

Transect	sub plot	Temp (ºC)			Hum (%)			pH			Litter Depth(cm)		
		1	2	3	1	2	3	1	2	3	1	2	3
BF-B1	1	22.95	21.90	25.25	83.45	80.00	79.70	6.05	6.30	6.80	1.0	0.0	1.0
BF-B1	2	22.55	21.75	25.00	86.30	65.00	81.25	5.80	6.15	6.00	1.0	0.5	1.0
BF-B1	3	23.50	22.20	25.65	83.30	75.00	81.90	6.00	6.30	5.70	1.0	0.0	1.5
BF-B1	4	23.95	22.75	0.00	84.15	84.80	74.15	6.35	6.10	6.35	1.0	0.0	1.0
BF-B2	1	23.25	-	24.85	86.05	-	87.65	6.20	-	6.10	1.0	-	0.5
BF-B2	2	23.85	-	25.45	86.90	-	81.80	6.25	-	6.15	1.0	-	0.0
BF-B2	3	24.10	-	25.10	85.75	-	82.60	6.40	-	6.20	1.5	-	1.5
BF-B2	4	24.10	-	25.10	85.00	-	84.00	6.20	-	6.30	2.5	-	1.0
BF-C1	1	23.95	20.95	25.20	88.70	-	98.80	6.10	6.40	6.30	1.0	1.5	1.0
BF-C1	2	23.25	21.10	25.00	93.30	-	100	6.35	6.00	6.20	1.0	1.5	1.5
BF-C1	3	22.75	21.15	24.90	94.55	-	99.25	6.10	6.50	6.20	1.0	1.5	1.0
BF-C1	4	23.05	22.15	24.85	95.45	-	99.30	6.25	6.30	6.10	1.0	0.5	1.0
BF-C2	1	23.85	22.05	25.95	87.85	76.75	91.40	6.20	6.30	6.50	1.0	0.0	1.0
BF-C2	2	23.50	21.75	25.55	84.15	79.55	92.95	6.20	6.20	6.40	1.0	0.0	2.0
BF-C2	3	23.50	21.80	24.45	76.90	76.45	89.60	6.25	6.20	6.45	1.0	0.0	1.5
BF-C2	4	23.15	22.60	24.55	80.20	77.25	94.95	6.10	6.60	6.15	1.0	0.0	1.5
CF-B1	1	21.80	17.95	20.65	82.15	83.65	20.00	6.80	6.80	6.70	1.0	0.0	1.0
CF-B1	2	21.20	17.75	20.55	90.60	86.95	20.00	6.60	6.50	6.75	0.0	0.0	0.0
CF-B1	3	21.75	17.75	20.35	82.75	86.95	15.00	6.55	6.70	6.70	0.0	0.0	0.0
CF-B1	4	20.80	17.45	19.85	83.00	93.55	40.00	6.60	6.50	6.15	0.0	0.0	0.0
CF-B2	1	20.25	19.15	20.15	85.10	83.90	100	6.45	6.40	6.55	0.0	0.0	1.5
CF-B2	2	20.35	19.30	20.25	81.60	84.65	100	6.65	6.80	6.60	0.0	0.0	1.0
CF-B2	3	21.00	19.80	20.00	82.35	79.70	100	6.65	6.85	6.55	0.0	0.0	3.0
CF-B2	4	20.65	19.90	20.45	83.40	79.65	100	6.70	6.95	6.60	0.0	0.0	2.5
CF-C1	1	22.50	17.50	22.90	82.10	90.40	100	6.90	6.15	5.25	0.5	0.0	0.5
CF-C1	2	22.25	17.65	22.90	83.95	89.10	100	6.70	6.10	6.40	0.0	0.0	0.0

Transect	sub plot	Temp (°C)			Hum (%)			pH			Litter Depth(cm)		
		1	2	3	1	2	3	1	2	3	1	2	3
CF-C1	3	21.75	18.50	23.00	86.90	87.60	100	6.90	5.75	6.20	0.0	0.0	0.0
CF-C1	4	21.00	18.15	22.25	83.95	86.40	100	7.00	6.20	6.25	0.0	0.0	0.0
CF-C2	1	22.30	20.30	23.05	78.15	87.80	95.35	6.10	6.10	5.70	1.0	1.5	4.5
CF-C2	2	21.85	19.95	22.85	78.90	85.65	95.90	6.15	6.20	5.65	1.0	1.5	2.5
CF-C2	3	21.55	19.20	22.25	78.30	81.95	95.00	6.15	6.35	5.90	1.5	2.0	1.5
CF-C2	4	21.30	19.15	22.35	81.30	82.65	94.45	6.20	6.50	6.05	1.0	4.0	1.0
EF-B1	1	18.35	17.90	17.35	-	94.80	98.25	6.15	5.85	6.25	1.5	2.0	2.5
EF-B1	2	18.50	17.95	17.80	-	90.00	92.80	5.90	6.25	5.90	2.0	0.5	2.5
EF-B1	3	18.75	18.20	17.85	-	91.30	98.45	5.90	4.95	6.30	2.0	0.5	1.5
EF-B1	4	19.10	18.30	18.20	-	88.80	97.25	6.20	5.90	6.10	1.5	0.0	2.5
EF-B2	1	17.05	16.85	18.10	86.55	86.15	50.00	6.30	6.60	6.30	1.0	1.5	1.0
EF-B2	2	17.50	16.85	18.25	87.95	93.00	40.00	6.05	6.55	6.15	1.0	0.5	1.0
EF-B2	3	17.85	16.60	18.20	88.50	90.60	20.00	5.75	5.75	6.20	2.5	2.0	2.5
EF-B2	4	17.90	17.10	19.25	88.05	93.05	45.00	5.65	5.55	6.00	1.5	1.0	1.5
EF-C1	1	20.55	15.95	21.05	78.30	91.05	95.90	6.90	5.95	6.30	1.0	0.0	2.5
EF-C1	2	19.95	15.90	20.75	77.30	94.05	93.65	6.85	5.90	5.85	0.5	0.0	1.0
EF-C1	3	19.75	16.30	21.15	86.00	91.45	91.40	7.00	6.15	6.25	0.0	0.0	1.5
EF-C1	4	19.75	16.35	21.50	83.30	91.25	94.20	6.80	6.00	6.25	1.5	0.0	1.5
EF-C2	1	19.70	17.05	21.05	86.50	85.80	67.50	6.70	6.20	6.30	0.5	0.5	0.5
EF-C2	2	19.30	17.00	20.55	89.00	88.40	65.00	6.75	6.15	5.55	0.0	1.0	0.0
EF-C2	3	19.70	16.85	20.75	89.65	87.15	57.50	6.85	6.25	6.10	1.5	1.0	1.5
EF-C2	4	18.55	16.85	20.15	85.70	83.30	-	6.70	5.60	5.90	1.0	0.0	1.0
MB-B1	1	24.35	21.95	24.80	89.60	85.00	85.05	6.10	6.10	6.20	1.0	0.0	1.0
MB-B1	2	23.45	21.65	24.95	89.25	70.00	73.80	6.20	6.15	6.00	1.0	0.0	1.0
MB-B1	3	22.95	22.05	25.65	90.35	80.00	82.50	5.95	5.95	5.90	1.0	0.0	1.0
MB-B1	4	23.70	22.20	24.80	87.80	80.00	81.40	6.05	5.85	5.70	1.0	0.0	1.0
MB-B2	1	24.55	21.90	-	86.15	80.00	-	5.90	6.00	-	1.0	0.5	1.0
MB-B2	2	24.35	21.75	-	82.35	78.00	-	6.20	6.15	-	1.0	0.5	1.0
MB-B2	3	24.00	22.20	-	82.65	75.00	-	6.10	6.30	-	1.0	0.0	1.0
MB-B2	4	24.35	22.75	-	81.95	84.80	-	6.30	6.10	-	1.0	0.0	1.0
MB-C1	1	23.45	21.65	24.85	88.30	80.80	99.35	5.80	6.10	5.80	1.0	0.0	1.0
MB-C1	2	23.65	21.85	24.30	86.80	81.90	100	6.30	6.20	6.10	1.0	0.0	1.0
MB-C1	3	23.30	21.75	24.10	87.80	82.50	99.40	6.15	5.85	6.25	1.0	0.0	1.0
MB-C1	4	23.00	21.55	23.85	86.55	82.15	98.40	6.20	5.55	6.40	1.0	1.5	2.5
MB-C2	1	23.10	21.20	24.65	87.95	-	95.90	5.95	5.50	6.30	2.5	1.0	1.0
MB-C2	2	23.15	21.40	24.90	86.95	-	100	6.20	5.60	6.35	2.0	1.5	1.0
MB-C2	3	22.90	21.65	-	88.40	-	-	6.85	6.50	-	1.5	0.5	-
MB-C2	4	24.35	22.40	-	84.90	-	-	6.35	6.50	-	1.0	1.0	-
MF-B1	1	20.70	18.20	19.05	86.90	86.90	37.50	6.05	6.55	6.65	1.0	0.0	1.0
MF-B1	2	21.00	18.75	17.95	88.80	82.35	55.00	6.35	6.40	6.15	1.5	2.5	1.5
MF-B1	3	20.45	18.35	18.05	81.65	87.95	55.00	6.40	6.30	6.70	1.0	0.0	1.0
MF-B1	4	20.50	18.30	18.35	83.05	84.95	22.50	6.10	6.50	6.85	1.0	0.0	1.0
MF-B2	1	18.90	18.45	19.65	79.65	82.65	100	6.25	6.10	6.80	2.0	0.0	3.0
MF-B2	2	18.75	18.85	20.10	77.65	85.30	96.95	5.95	5.50	6.70	1.5	0.5	1.5

Transect	sub plot	Temp (°C)			Hum (%)			pH			Litter Depth(cm)		
		1	2	3	1	2	3	1	2	3	1	2	3
MF-B2	3	19.05	18.60	19.85	78.70	87.95	100	5.90	6.40	6.25	3.0	1.0	5.0
MF-B2	4	19.35	18.85	19.85	75.10	82.15	100	6.55	6.45	6.80	1.5	0.0	2.0
MF-C1	1	18.90	18.10	21.25	79.65	88.75	67.50	6.25	5.90	5.80	2.0	1.0	2.0
MF-C1	2	18.75	17.35	21.55	77.65	84.80	70.00	5.95	6.25	6.00	1.5	1.0	1.5
MF-C1	3	19.05	17.45	21.10	78.70	86.55	67.50	5.90	5.90	6.10	3.0	1.5	3.0
MF-C1	4	19.35	17.75	21.65	75.10	82.80	40.00	6.55	6.00	6.35	1.5	1.5	1.5
MF-C2	1	6.65	18.20	20.45	70.85	92.35	100	19.10	5.90	6.70	3.5	2.0	1.0
MF-C2	2	6.35	17.40	19.95	72.20	89.40	99.45	19.50	6.40	6.75	2.0	1.5	1.0
MF-C2	3	6.50	17.40	21.00	81.65	87.55	100	19.35	6.15	6.70	2.0	1.5	1.0
MF-C2	4	6.20	17.75	20.5	82.45	80.00	100	19.55	6.20	6.60	2.0	1.0	1.0

A total of four small streams were surveyed during the trip. For each stream, we conducted the survey at 3 sites (upper stream, middle stream, and lower stream). All the amphibian and reptile occurrences within the sites were recorded, including data of taxonomic, microhabitat and activities. Occurrences of individuals at locations between the survey sites (mark by number 0) were also recorded for species richness. Environmental data of survey sites along the streams, at the herpetological survey time, is shown in Table 29.

3.1.2 Vegetation indicators

The indicators of monitoring vegetation should be the coverage of vegetation types and their dominant plants that can be computed directly from the mapping and field activities. Changes in the landuse are measured as the absolute or relative amounts.

3.1.3 Diversity indices

3.1.3.1 Diversity indices of plants

The diversity indices of plants include the conventional ones for habitats: the species richness (number of species per ha or per vegetation type, which can be referred from a better database), the Simpson's diversity index and Shannon's diversity index. Those have been presented in the survey results of plants. For individual indicator species, their IVI, indicator value and association index should be used.

3.1.3.2 Diversity indices of mammals

The diversity indices of mammals include the conventional ones: the species richness, the Simpson's diversity index (D) and Shannon's diversity index (H') (see the next section for birds). Results from the present survey are presented in Table 17. For individual indicator species, their distribution based on field records and encounter rate are important.

3.1.3.3 Diversity indices of birds

In general, species composition or species richness do not fully reflect the diversity of birds. Other ecological indices were used to assess the avifauna of the study area including Shannon's

diversity index H', the encounter rate and Sorensen's Similarity index. These indices are important to biodiversity monitoring program.

Table 29. Environmental parameters at sites along the survey streams in Bidoup Nui Ba (07/2016-06/2017)

Transect	Air						Water																	
	Temp (°C)			Hum (%)			Width (m)			Depth (m)			Temp (°C)			pH			TDS (ppm)			EC (µs)		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
S1.1	23.30	20.80	22.00	75.30	68.20	82.70	1.50	1.50	1.50	0.20	0.20	0.50	22.10	17.30	19.10	7.64	7.30	7.35	-	12.00	19.00	-	25.00	38.00
S1.2	19.20	19.20	22.00	80.10	81.50	79.70	1.50	1.50	1.20	0.20	0.20	0.20	19.10	17.20	19.60	7.00	7.74	7.66	18.00	21.00	28.00	3.60	41.00	57.00
S1.3	21.60	22.30	24.95	81.20	86.50	78.20	1.50	1.50	2.50	0.10	0.50	0.45	20.60	19.60	22.25	7.76	8.05	7.88	51.00	40.00	53.00	101.00	79.00	106.00
S2.1	22.70	20.70	22.10	73.10	100	-	1.50	1.00	2.25	0.10	0.10	0.10	21.00	19.50	21.50	7.59	7.70	8.10	50.00	37.00	54.00	100	75.00	107.00
S2.2	22.30	20.80	22.95	80.60	100	0.00	0.80	0.80	3.00	0.15	0.10	0.10	21.10	20.40	21.50	7.50	7.63	8.13	54.00	42.00	54.00	109.00	74.00	108.00
S2.3	21.30	21.10	21.70	83.10	100	0.00	1.50	1.50	3.00	0.50	0.10	0.08	21.40	20.00	21.70	7.45	7.63	7.75	55.00	39.00	55.00	110.00	77.00	109.00
S3.1	25.00	20.10	-	88.00	100	-	3.00	2.00	-	0.20	0.20	-	21.20	19.60	-	7.57	7.67	-	27.00	23.00	-	57.00	46.00	-
S3.2	22.30	22.40	22.70	80.60	100	88.35	0.80	1.00	6.50	0.10	0.80	0.23	21.10	19.70	21.55	7.50	7.81	8.21	54.00	26.00	32.00	109.00	51.00	65.00
S3.3	23.30	19.30	22.70	75.30	100	88.00	3.00	2.00	5.00	2.00	0.10	0.86	22.10	19.80	21.95	7.64	7.67	8.12	36.00	29.00	33.00	72.00	60.00	65.00
S4.1	18.90	20.10	21.70	83.90	79.50	83.20	2.00	2.00	3.00	0.10	0.20	0.40	18.40	17.20	18.70	6.54	7.16	7.46	4.00	3.00	8.00	8.00	5.00	4.00
S4.2	19.30	20.10	23.70	68.60	79.50	78.00	2.00	1.00	1.00	0.10	0.80	0.20	18.80	17.80	18.60	6.37	6.68	7.46	6.00	3.00	6.00	13.00	7.00	13.00
S4.3	23.60	20.10	20.40	71.00	79.65	89.40	2.00	2.00	2.50	0.10	0.10	0.10	19.20	17.80	19.10	6.77	6.89	6.81	8.00	4.00	8.00	16.00	9.00	16.00
S0-0	22.20	-	-	78.80	-	-	-	-	-	-	-	-	20.20	-	-	7.99	-	-	74.00	-	-	15.00	-	-
S1-0	22.70	-	-	70.20	-	-	-	-	-	-	-	-	19.10	-	-	6.84	-	-	7.00	-	-	16.00	-	-

Note: S1-1: upper stream 1; S1-2: middle stream 1; S1-3: lower stream 1; S2-1: upper stream 2; S2-2: middle stream 2; S2-3: lower stream 2; S3-1: upper stream 3; S3-2: middle stream 3; S3-3: lower stream 3; S1-0: location of stream 1 which was used for diversity survey only; S0-0: stream 5 which was used for species richness survey only.

1. Diversity Index

Diversity indices provide important information about rarity and commonness of species in a community. In this study, the Shannon's diversity index (H') and Simson's index (D) are used. These indices account for both abundance and evenness of the species present in a certain habitat.

Table 30. Diversity indices of birds by habitat and survey times

Vegetation		Simpson's index D	Shannon's index H'
EF	total	0.95	3.29
	core zone	0.95	3.21
	buffer zone	0.92	2.74
CF	total	0.95	3.28
	core zone	0.94	3.04
	buffer zone	0.93	2.86
MF	total	0.92	2.82
	core zone	0.87	2.30
	buffer zone	0.93	2.87
BF	total	0.92	2.92
	core zone	0.90	2.60
	buffer zone	0.94	3.04
MB	total	0.85	2.42
	core zone	0.76	1.86
	buffer zone	0.89	2.44

It can be seen from Table 30 that Shannon's diversity index varied among the habitats and survey areas, and the Evergreen forest and Conifeous forest have higher values. In fact, these habitats are also more diverse in term of number of species.

2. Sorensen's Similarity index

In total of 127 species found in five habitats, several common species occur in all habitat while some species are adapted to certain environmental features and so found in only one habitat. To assess the similarity of bird composition between habitats, the SSI is used, habitat that has lower SSI with others seems to be unique and needed more attention of management.

Table 31. Sorensen's index in different habitat types in LBBR

Habitat type	MB (48)	BF (38)	MF (45)	EF (88)	CF (57)
MB (48)	1	0.53	0.34	0.40	0.42
BF (38)	-	1	0.51	0.35	0.46
MF (45)	-	-	1	0.59	0.63
EF (88)	-	-	-	1	0.52
CF (57)	-	-	-	-	1

Notes: MB: Mixed forest of trees and bamboo; BF: Bambusa procera forest; MF: Mixed forest of broad-leaved and coniferous forest; EF: Evergreen broad-leaved forest; CF: Coniferous forest.

Table 31 shows that there is only high similarity of bird species composition between Bamboo forest and Mixed forest of tree and bamboo (S=0.63) and between Evergreen forest and Mixed forest of tree and bamboo (S=0.59) while the bird communities in most habitat types are

different in species composition, demonstrated by S<0.5. The low S values illustrate that most bird species in LBBR use a unique of habitat types. Number of bird recorded in evergreen forest and conifeous forest were quite high (88 species and 57 species) but many of them found only in these habitats, 26 and 32 species, respectively. There were nine species that occur in all five habitats including three species of bulbul.

3. Encounter rate

The encounter rate shows the abundance of a certain species in habitat. In this study, the encounter rate is used to assess number of individuals of a species in transect only. Given the fact that each transect was surveyed in four legs per survey time in each area, the encounter rate is calculated by total number of individuals of each recorded species over a distance of 8-km. The encounter rates of 99 species recorded in the surveyed transects are shown in Figure 25.

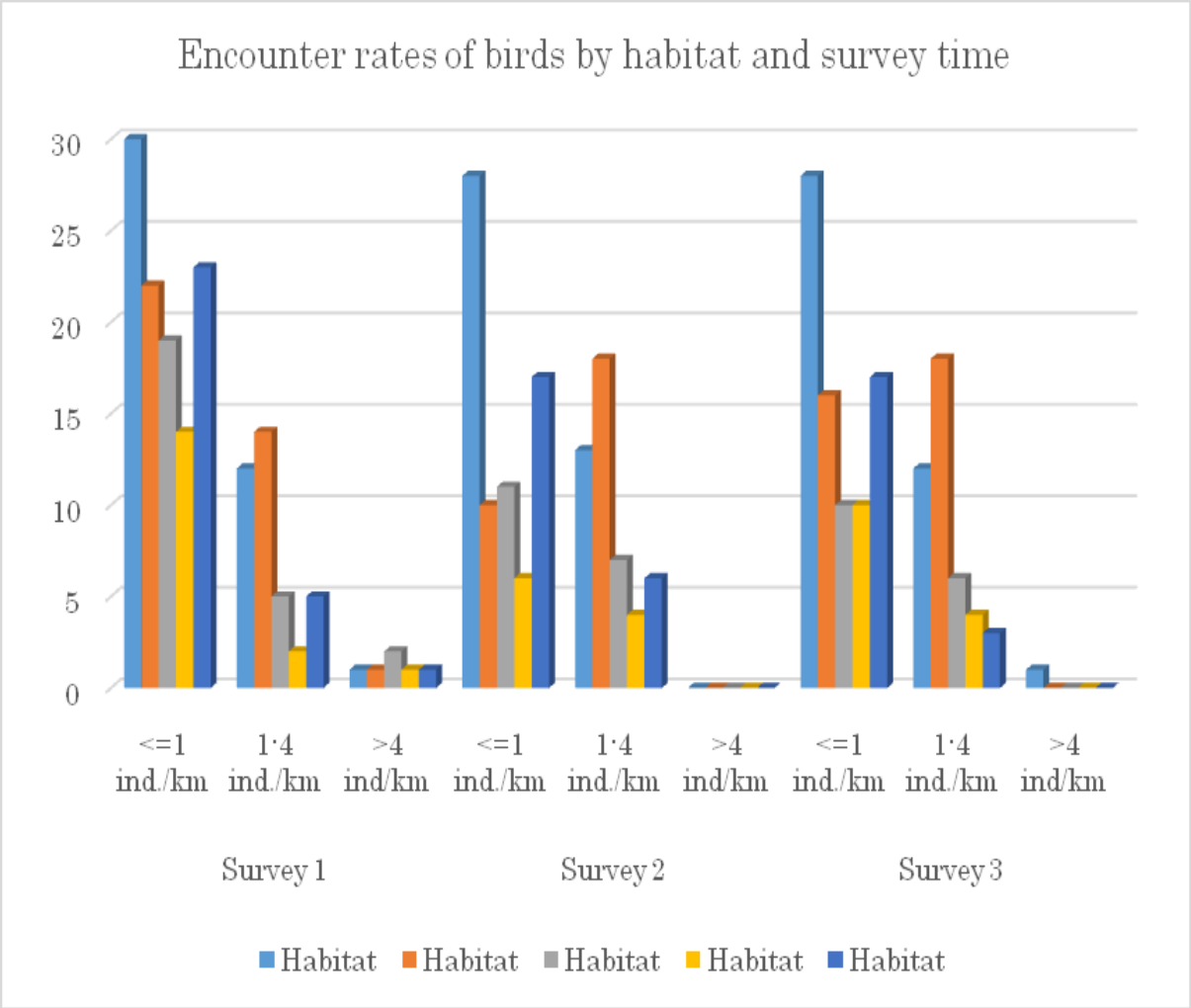


Figure 25. Encounter rates of birds by habitat and survey times

In general, 65.7% of bird have encounter rate less than or equal to 01 ind./km, while proportion of birds has encounter rate from 01 to 04 ind./km and more than 4 ind./km were 32.49% and 1.76%, respectively (Figure 25). The encounter rate shows that, while species richness is quite high, the abundance of most species is quite low. The highest encounter rate was recorded for Golden-throated Barbet in Mixed forest of tree and bamboo (7.9 ind./km).

3.1.3.4 Diversity indices of reptiles and amphibians

Like many other groups of biodiversity, the diversity indices proposed here are those conventional: the species richness, the Simpson's diversity index and Shannon's diversity index. Table 32 to Table 35 show the results from the survey.

Table 32. Diversity indices of reptiles and amphibians among streams

	Year (n=9)			Survey 1 (n=3)			Survey 2 (n=3)			Survey 3 (n=3)		
Stream	Shannon Index	Simpson Index	Richness	Shannon Index	Simpson Index	Richness	Shannon Index	Simpson Index	Richness	Shannon Index	Simpson Index	Richness
S1	1.53	0.65	10	1.74	0.80	7	0.18	0.09	2	1.43	0.68	6
S2	1.51	0.76	5	1.04	0.62	3	0.00	0.00	1	1.40	0.71	5
S3	0.95	0.52	4	1.00	0.60	3	0.60	0.31	3	0.00	0.00	1
S4	1.43	0.74	5	1.03	0.62	3	0.00	0.00	1	1.39	0.75	4

Table 33. Diversity indices of reptilies and amphibians along streams

Stream Part	Shannon Index (n=12)	Simpson Index (n=12)	Richness (n=12)
Upper stream	1.66	0.77	8
Middle stream	1.14	0.49	9
Lower stream	1.88	0.80	9

Table 34. Diversity indices of reptiles and amphibians among forest types

	Year (n=48)			Survey 1 (n=16)			Survey 2 (n=16)			Survey 3 (n=16)		
Habitat	Shannon Index	Simpson Index	Richness	Shannon Index	Simpson Index	Richness	Shannon Index	Simpson Index	Richness	Shannon Index	Simpson Index	Richness
EF	2.37	0.86	19	1.99	0.81	11	2.28	0.88	12	1.62	0.71	8
CF	1.91	0.83	8	1.55	0.78	5	1.10	0.67	3	1.39	0.75	4
MF	2.31	0.86	16	1.88	0.81	9	1.87	0.82	8	1.83	0.74	10
BF	2.06	0.85	10	1.88	0.82	8	0.00	0.00	1	0.41	0.24	2
MB	2.54	0.91	15	2.26	0.87	12	0.00	0.00	1	1.83	0.82	7

Table 35. Diversity indices of reptiles and amphibians among zones of the forest types

Stream	Core Zone (n=24)			Buffer Zone (n=24)		
	Shannon Index	Simpson Index	Richness	Shannon Index	Simpson Index	Richness
Evergreen Forest (EF)	2.06	0.80	13	1.75	0.73	11
Conifeous forest (CF)	0.00	0.00	1	1.78	0.80	7
Mixed Conifer_broadleaf Forest (MF)	1.30	0.58	7	2.35	0.89	13
Bamboo Forest (BF)	1.33	0.72	4	1.80	0.80	8
Mixed Bamboo_broadleaf Forest (MB)	2.03	0.86	8	2.21	0.87	11

3.1.3.5 Diversity indices of fishes

The diversity indices and endemism of fishes in different streams are used for fishes and the result from the last survey is provided in Table 36. The diversity values of stream S3 is highest and the lowest values belonging to the stream S4. These indices can be used as indicators for future monitoring program by comparison the fish community changing.

Table 36. Diversity indices and endemism of fishes in different streams

Drainage unit	S1	S2	S3	S4
Number of sampling locations	3	3	3	3
Total number of species	6	8	8	2
Total number of individuals	166	261	378	234
Number of endemic species	3	4	4	2
Diversity indices				
Species richness	*6*	*8*	*8*	*2*
Shannon's index H'	*1.01*	*1.06*	*1.39*	*0.33*
Simpson's index D	*0.55*	*0.57*	*0.70*	*0.19*

3.1.3.6 Diversity indices of insects

Table 37 shows habitats of BF and MB having more recorded species and abundance, while EF has the least.

Shannon's index is found the least in BF and MB, indicating that a few species are much more abundant than the others. In fact, *Mycalesis mnasicles* (butterfly) and *Nasutitermitinae spp.* (termites) are the most frequently recorded species. They use bamboo tree as niche (host plant), as noted in both inside and outside of transets. So, *Mycalesis mnasicles* and *Nasutitermitinae spp.* are recommended as indicator species for the bamboo forest.

CF and MF have lower species and individual abundances as well as lower diversity according to Simpson's index, compared to BF and MB.

Table 37. Insect diversity indices estimated from surveyed areas

Sites		#Individuals	Species Diversity	Simpson's index (D)	Shannon's index (H')
Bamboo Forest (BF)	*Buffer*	121	12	0.42	1.42
	Core	131	18	0.35	1.70
	Total	*252*	*22*	*0,38*	*0,17*
Conifeous forest (CF)	*Buffer*	8	4	0.31	1.26
	Core	38	14	0.21	2.08
	Total	*46*	*16*	*0,21*	*2,14*
Evergreen Forest (EF)	*Buffer*	0	0	0.00	0.00
	Core	4	3	0.38	1.04
	Total	*4*	*3*	*0,38*	*1,04*
Bamboo and tree mixed forest (MB)	*Buffer*	82	10	0.28	1.60
	Core	131	15	0.26	1.79
	Total	*213*	*19*	*0,26*	*0,09*
Broad-leaved and conifeous forest (MF)	*Buffer*	35	8	0.16	1.91
	Core	5	3	0.36	1.05
	Total	*40*	*10*	*0,15*	*2,06*

3.2 SPECIES INDICATORS

3.2.1 Species indicators for habitats

3.2.1.1 Species indicators for Evergreen broad-leaved forests (EF)

Plant indicators:

- Data-based: Our analyses of the data collected from the 16 plots recommends 10 indicator species with highest statistical significance for the EF, including: *Syzygium* cf. *ripicola*, *Mastixia pentandra*, *Dehaasia* sp., *Eriobotrya* sp.A, *Magnolia yunnanensis*, *Castanopsis echinocarpa*, *Cinnamomum* sp.A, *Lithocarpus* sp., *Lithocarpus* sp.G and *Syzygium* sp.B. Those not correctly identified are temporarily named in Vietnamese or with "sp".

- Expert-based: From our observations and experience, we add the following as candidate indicator species: *Choerospondias axillaris*, *Kadsura* sp.A and *Magnolia baillonii*. Their fruits are foods for birds/squirrels.

Note: Most of potential indicators are illustrated in the appendices 2 to 8.

Mammal indicators:

- Data-based: *Pygathrix nigripes* (A = 0.25, B = 0.5, p = 0.042 *) and *Callosciurus erythraeus* (A = 0.25, B = 0.5, p = 0.043). These species are easy to detect using transect methods.

- Expert-based:
  - Black-shanked douc (*Pygathrix nigripes*) is Endangered species, easy to indentify. It eats mainly leaves, fruits and floweres. It is easy to detect using transect methods.
  - Stump-tailed macaque (*Macaca arctoides*) is Vulnerable species, easy to indentify. It is omnivorous. It is easy to detect using transect methods.
  - Owston's palm civet (*Chrotogale owstoni*) is Endangered species, easy to indentify. It is canivous. It is easy to detect using camera trap methods
  - Northern Red Muntjac or Barking Deer (*Muntiacus vaginalis*) is common in LBBR, easy to indentify. Muntjacs are omnivorous, feeding on herbs, fruit, birds' eggs, small animals, sprouts, seeds, and grasses. It is easy to detect using transect methods.
  - Wild boar (*Sus scrofa*) is common in LBBR, easy to indentify. The species is omnivorous, feeding on herbs, fruit, birds' eggs, small animals, sprouts, seeds, and grasses. It is easy to detect using transect methods.

Bird indicators:

- Data-based: suggested the candidate indicator for evergreen forest include Grey-headed Canary Flycatcher (*Culicicapa ceylonensis*), Mountain Fulvetta (*Alcippe peracensis*), Large Niltava (*Niltava grandis*), Mountain Imperial Pigeon (*Ducula badia*) and Golden-throated Barbet (*Megalaima franklinii*). These species are easy to detect using transect/point methods

- Expert-based: two candidate species are recommended as bird indicators for the evergreen forest.

  - Golden-throated Barbet (*Megalaima franklinii*): the species is a common one with the encounter rate about 7.9 individuals/km, that live in the canomy of evergreen forest. Their attitudinal range is between 900 m and 2,700 m asl. They feed on seeds of plants

- Collared Laughingthrush (*Trochalopteron yersini*): a rare and endemic bird of the Lang Biang Plateau. The species live on lower canopy and the ground in less disturbed habitat and feed on insects. The species is easy to be detected by playback but seem to occur in low density. The encounter rate during this study is only 1.13 ind/km. The species faces high threats including trapping, human disturbance and habitat fragmentation.

Reptile and amphibian indicators:

– Data-based: suggested the candidate indicator for evergreen forest is *Raochestes gryllus* (with A= 0.47; B = 0.29; p.value = 0.0464)

– Expert-based: Results based on expert-knowledge give us the following candidate indicators:

- *Brachytarsophry intermedia*: is list in IUCN redlist as a Vunerable species. This species has very large size and loud calls, easy to recognise via morphology and calls. They seem restricted to evergreen forest.
- *Raochestes gryllus*: this is small tree frog, has loud calls. They often sitting and calling on the branches or leaves of the brush or tree.

Insect indicators:

– Data-based: no candidate indicator.

– Expert-based: no candidate indicator.

3.2.1.2 Species indicators for Broad-leaved and coniferous mixed forest (MF)

Plant indicators:

– Data-based: *Castanopsis spD, Pinus kesiya, Cinnamomum spB, Meliosma arnottiana, Lithocarpus spB, Lithocarpus truncatus.*

– Expert-based: *Choerospondias axillaris* (food for squirrel). In addition, *Pinus krempfii* and *P. dalatensis* may be included here as they occupy their own niches randomly scattered in this type of forest.

Mammal indicatiors:

– Data-based: no candidates.

– Expert-based:

- Black-shanked douc (*Pygathrix nigripes*) is Endangered species, easy to indentify. It eats mainly leaves, fruits and floweres. It is easy to detect using transect methods.
- Stump-tailed macaque (*Macaca arctoides*) is Vulnerable species, easy to indentify. It is omnivorous. It is easy to detect using transect methods.
- Owston's palm civet (*Chrotogale owstoni*) is Endangered species, easy to indentify. It is canivous. It is easy to detect using camera trap methods.

- Northern Red Muntjac or Barking Deer (*Muntiacus vaginalis*) is common in LBBR, easy to indentify. eMuntjacs are omnivorous, feeding on herbs, fruit, birds' eggs, small animals, sprouts, seeds, and grasses. It is easy to detect using transect methods.

- Wild boar (*Sus scrofa*) is common in LBBR, easy to indentify. the species is omnivorous, feeding on herbs, fruit, birds' eggs, small animals, sprouts, seeds, and grasses. It is easy to detect using transect methods.

Bird indicators:

– Data-based: sugguested the candidate indicator for ethis type of forest include Large Niltava (*Niltava grandis*), Mountain Imperial Pigeon (*Ducula badia*) and Golden-throated Barbet (*Megalaima franklinii*). These species are easy to detect using transect/point methods.

– Expert-based: no candidate indicator.

Reptile and amphibian indicators:

– Data-based: no candidate indicator.

– Expert-based: Based on the surveys and experiences, the herpetological potential indicator could be *Leptobrachium pullum*. This frog has a large size and loud calls (males), often sitting on the ground or litter in the evergreen forest and broad-leaved and coniferous mixed forest

Insect indicators:

– Data-based: *Actias chapae bezverkhovi* Wu & Naumann, 2006.

– Expert-based: *Actias chapae bezverkhovi* Wu & Naumann, 2006. This site includes food plants and hiding place for its circle life. Easily use light trap to collect.

3.2.1.3 Species indicators for Coniferous forest (CF)

Plant indicators:

– Data-based: *Pinus kesiya*, *Helicia* spB.

– Expert-based: *Magnolia baillonii*, *Quercus* sp., *Syzygium* sp. (food for birds), *Lantana camara* (invasive), *Codonopsis javanica* and *Galium* spA (local harvest).

Mammal indicatiors:

– Data-based: no candidates.

– Expert-based: no candidates.

Bird indicators

– Data-based: Red Crossbill (*Loxia curvirostra*) and Large Cuckooshrike (*Coracina macei*) and Vietnamese cutia (*Cutia legalleni*)

– Expert-based: Red Crossbill (*Loxia curvirostra*) is specific to pine forest but sometime found in mixed broaflaf and coniferous forest. The species is widespread but in Vietnam only found in the Lang Biang Plateau. The species feeds on pine cone.

– Vietnamese cutia (*Cutia legalleni*): the species inhabits both in Evergreen forest and Coniferous forest above 900 m asl. They live on middle and upper canopy and feeds on insects. The species is easy detected by playing back voice.

Reptile and amphibian indicators:

– Data-based: no candidate indicator.

– Expert-based: no candidate indicator.

Insect indicators:

– Data-based: no candidates.

– Expert-based: no candidates.

3.2.1.4 Species indicators for Bamboo and tree mixed forest (MB)

Plant indicators:

– Data-based: *Bambusa procera, Gigantochloa densa*.

– Expert-based: *Choerospondias axillaris* (food for squirrels), *Lithocarpus* spG, *Dipterocarpus obtusifolius*, *Syzygium* sp. (highest IVI), *Cycas micholitzii* (globally and nationally threatened).

Mammal indicatiors:

– Data-based: no candidates.

- Expert-based: Lesser mouse deer (*Tragulus kanchil*) is common, easy to indentify. It is commonly herbivores and folivores, eating leaves, buds, shrubs, and fruits that have fallen from tree. The species is easy to detect using camera-traping methods.

Bird indicators:

– Data-based: Bar-winged Flycatcher Shrike (*Hemipus picatus*), Yellow-bellied Warbler (*Abroscopus superciliaris*).

– Expert-based: no suggested indicator

Reptile and amphibian indicators:

– Data-based: no candidate indicator

– Expert-based: based on results of the surveys and experience, we could sugguest the following species:

- *Fejervarya limnocharis*: this is medium to large frog, often appear near to ponds (both inside the forest and in villages).

- *Odorrana graminea*: this large frog can move far away from the body water (stream). This species is often found in this forest type, especially in the place close to large streams.

- *Ingerophrynus galeatus:* this toad has a medium size, move slowly, easy to recognise. This toad also often occurs in this forest type.

Insect indicators:

– Data-based: *Nasutitermitinae spp.*; *Mycalesis mnasicles*. Dominant species, easy to recognise.

– Expert-based: *Nasutitermitinae spp.*; *Mycalesis mnasicles.* Dominant species, easy to recognise.

3.2.1.5 Species indicators for Bamboo forest (BF)

Plant indicators:

– Data-based: *Bambusa procera*.

– Expert-based: *Quercus* spA., *Lithocarpus s*pG (trees indicating succession to evergreen), *Ficus* spJ. (food for animals)

Mammal indicators:

– Data-based: *Rhizomys pruinosus* (A = 0.3333 B = 0.577, p = 0.007 **, and *Tragulus.kanchil* A = 0. 4167, B = 0.546 , p = 0.015 *). These species are easy to detect using camera-traping methods.

– Expert-based: *Rhizomys pruinosus* and *Tragulus.kanchil*

Bird indicators:

– Data-based: Bar-winged Flycatcher Shrike (*Hemipus picatus).* Dominant species, easy to recognise.

– Expert-based: Yellow-bellied Warbler (*Abroscopus superciliaris*). Dominant species, easy to recognise.

Reptile and amphibian indicators:

– Data-based: no candidate indicator.

– Expert-based: no candidate indicator.

Insect indicators:

– Data-based: *Nasutitermitinae spp.*; *Mycalesis mnasicles.* Dominant species, easy to recognize.

– Expert-based: *Nasutitermitinae spp.*; *Mycalesis mnasicles.* Dominant species, easy to recognize.

3.2.1.6 Species indicators for Aquatic bodies (AQ)

Reptile and amphibian indicators:

- Data-based: results from the data-based analysis give us options as follow:
  - *Limnonectes poilani* + *Odorrana graminea* (with A= 0.70 & B= 0.5)
  - *Odorrana graminea* + *Xenophrys major* (with A= 1.00 & B= 0.3)
  - *Xenophrys major* (with A= 0.75 & B= 0.3)
  - *Odorrana graminea* (with A= 0.56 & B= 0.44, p.value = 0.0061)
  - *Fejervarya limnocharis* (with A= 0.91 & B= 0.22, p.value = 0.01)
  - *Hylarana montivaga* (with A= 0.57 & B= 0.33, p.value = 0.0085)
  - *Hylarana milletti* (with A= 0.47 & B= 0.22, p.value = 0.0438)
  - *Ophryophryne* sp. (with A= 0.81 & B= 0.22, p.value = 0.0098)
- Expert-based: Results based on expert-knowledge give us the following potential indicators:
  - *Odorrana graminea:* is *very* common in streams (both inside forests and villages). this species has characteristics of a good indicators: large size; easy to find. This species is used by the local people as food.
  - *Limnonectes poilani*: is large size frog and quite restricted to streams inside forests.
  - *Ophryophryne* sp.: this is a small frog but the male has loud calls. This species seems restricted to small, shallow streams inside evergreen forests.
  - *Cyrtodactylus bidoupimontis*: this species often occurs at trees and in rocky cliffs along the streams

Fish indicators:

- Data-based: *Nemacheilus* sp.; *Ungen* sp.
- Expert-based: *Nemacheilus* sp.; *Ungen* sp.; *Schistura* sp.

Two species (*Nemacheilus* sp. and *Ungen* sp.) were only found at the S4 stream, where the forest is still in good condition with almost no arthropogenic activities encoutered. At the third field trip (dry season), the late species had been also found at the upper reaches of the streams S2 and S3 with limited records. This may indicate the decreasing of environment quality. Contrarily, the *Schistura* sp. was quite common at three streams S1 (only lower reach), S2 and S3, this shows the torrerance of the fish with water variables. However, due to the short distance to the village, this fish alongs with other abundanced fishes are possibly impacted by fishing activities.

Insect indicators:

- Data-based: none
- Expert-based: *Anisopleura bipugio*, *Rhinocypha seducta*, *Coeliccia spp.* Characteristic of primary and regenerating forest habitats, easy to recognise. The variability of these species relates to changes in quality of forest and water.

3.2.2 Species indicators for niches

3.2.2.1 Species indicators for soils

Reptile and amphibian indicators

– Expert-based: no candidate indicator

Insect indicators

– Data-based: *Mycalesis mnasicles.* for Bambuseae niches (Poaceae family).

– Expert-based: *Mycalesis mnasicles.* for Bambuseae niches (Poaceae family)

3.2.2.2 Species indicators for the ground layer

Mammal indicators:

– Expert-based:

  - Stump-tailed macaque (*Macaca arctoides*) is Vulnerable species, easy to indentify. It is omnivorous. It is easy to detect using transect methods.
  - Owston's palm civet (*Chrotogale owstoni*) is Endangered species, easy to indentify. It is canivous. It is easy to detect using camera trap methods.
  - Northern red muntjac or barking deer (*Muntiacus vaginalis*) is common in LBBR, easy to indentify. Muntjacs are omnivorous, feeding on herbs, fruit, birds' eggs, small animals, sprouts, seeds, and grasses. It is easy to detect using transect methods.
  - Wild boar (*Sus scrofa*) is common in LBBR, easy to indentify. This species is omnivorous, feeding on herbs, fruit, birds' eggs, small animals, sprouts, seeds, and grasses. It is easy to detect using transect methods.

Bird indicators:

– Expert-based: Collared Laughingthrush (*Trochalopteron yersini*): a rare and endemic bird of the Lang Biang Plateau. The species live on lower canopy and the ground in less disturbed habitat and feed on insects. The species is easy to be detected by playback but seem to be occur in low density. The encounter rate during this study is only 1.13 ind/km. The species faces high threats including trapping, human disturbance and habitat fragmentation.

Reptile and amphibian indicators:

– Expert-based: the frogs often used the ground for their activities as follows:

  - *Leptobrachium pullum*: were often found sitting or calling on the ground or under the litter.
  - *Ingerophrynus galeatus*: this frog often sitting on the ground in the forests.

- *Brachytarsophry intermedia*: this species was often found moving/ sitting on the ground, or hiding in rocky cave, in the evergreen forests.

- Genus *Microhyla:* were often found sitting or calling on the ground or under the litter. But these species have a small size and quite difficult to see.

3.2.2.3 Species indicators for the shrub layer

Bird indicators

– Expert-based: Rufescent Prinia (*Prinia rufescens*) occurs in grasses and shrub layer in coniferous forest.

Reptile and amphibian indicators

– Expert-based: the frogs that were often found sitting or calling on the branches/ leaves of brush as follows:

- *Ophryophryne* sp.
- *Raochestes gryllus*
- *Pareas hamptoni*
- *Takydromus sexlineatus*

3.2.2.4 Species indicators for the under-canopy layer

Mammal indicators:

– Expert-based:

- Black-shanked douc (*Pygathrix nigripes*) is Endangered species, easy to indentify. It eats mainly leaves, fruits and floweres. It is easy to detect using transect methods.

- Stump-tailed macaque (*Macaca arctoides*) is Vulnerable species, easy to indentify. It is omnivorous. It is easy to detect using transect methods.

- Souther yellow-cheeked gibbon (*Nomascus gabrielle*) is Endangered species, easy to indentify. It eats mainly leaves, fruits and floweres. It is easy to detect using transect methods and listening posts.

Reptile and amphibian indicators

– Expert-based: the frogs and reptiles that were often found sitting, calling or feeding on the branches/ leaves of trees in the under-canopy layer as follows:

- *Raochestes gryllus*
- *Polypedates megacephalus*
- *Cyrtodactylus bidoupimontis*
- *Physignathus cocincinus*

3.2.2.5 Species indicators for the canopy layer

– Expert-based: no indicator for any group.

3.2.2.6 Species indicators for the emerging layer

– Expert-based: no indicator for any group.

3.3 A FRAMEWORK OF MONITORING BIODIVERSITY SUGGESTED FOR LBBR

The above potential monitoring indicators have been presented and intensively discussed about during the scientific workshop participated by presentatives from MARD, MONRE, provincial and district authorities, LBBR and Japanese experts from JICA and NK. Proceedings of the workshop and guidelines for discussion were provided to al participants. All comments and ideas were noted and later integrated into a biodiversity monitoring framework that has been submitted to JICA and NK for experts' reviews. Here is the final version.

3.3.1 The biodiversity monitoring system for LBBR

Table 38 synthesises the biodiversity monitoring system which shows two key objectives of the monitoring: monitor possible changes at the ecosystem and species levels. In total 20 indicators have been identified and grouped into ten criteria, with five criteria for each level. Those include 14 indicators for the ecosystem level and 6 for the species level.

At the ecosystem level, the five criteria include: Environment conditions, Vegetation change, Habitat quality, Ecosystem processes and Human impacts.

At the species level, those include: Capacity to support the survival of endangered species, Occurrence of invasive species, Key/ecologically important species, Highly frequently exploited species and Cultural aspect of biodiversity.

Below we describe in more detail those indicators following the above order.

Objective 1: Monitoring biodiversity at ecosystem level

Ecosystems include biotic and abiotic (such as air, water and mineral soil) components which are linked together through nutrient cycles and energy flows. They are defined by the network of interactions among organisms, and between organisms and their environment. Therefore, monitoring biodiversity at an ecosystem requires regular inventories of living organisms and their community as well as the environment elements where they live. In total 14 indicators are recommended, grouped into 5 criteria

Criterion 1.1: Environment conditions

Environment acts as a surrounding for living organisms to live in. It and its interaction with living organisms define the community of an ecosystem. In turn, living organisms interact with the environment to maintain the stability in ecosystems. Several key indicators for environment conditions are the target for monitoring the ecosystem.

Table 38. Matrix of Criteria, Indicators and Parameters of Biodiversity Monitoring in LBBR.

Level	Criteria	Indicators	Parameter/ Measure	Method/ Technique	Data Source	Implementer(s)
1. Ecosystem	1.1. Environment conditions	1.1.1. Climate condition	– Precipitation – Air humidity – Temperature – Air pressure – Wind – Total hours/days of sunshine – Number of rainy days	– Quantitative analysis	– Field station – Meteorological stations in LBBR	– LBBR staff – DONRE
		1.1.2. Possible water pollution	– Water chemistry (Clarity, BOD, COD, Conductivity, Total Dissolved Solids, etc.) – Stream invertebrate index	– Quantitative analysis	– Fieldwork – DONRE of Lam Dong (?)	– LBBR staff – DONRE
		1.1.3. Soil condition	– Soil types – Depth – Carbon	– Quantitative analysis	– Fieldwork	– LBBR staff – DONRE – Consultancy
	1.2. Vegetation change	1.2.1. Land cover type	– Area, proportion & distribution of land cover	– GIS/Remote Sensing – Drones	– Satellite Imagery (Landsat/SPOT) – Drones – MARD	– DARD/DONRE – LBBR staff – Consultancy
		1.2.2. Land use type	– Area, proportion & distribution of land use	– GIS/Remote Sensing – Drones	– Maps – Satellite Imagery (Landsat/SPOT) – Drones	– LBBR staff – Consultancy

Level	Criteria	Indicators	Parameter/ Measure	Method/ Technique	Data Source	Implementer(s)
					– MARD	
		1.2.3. Ecosystem/ Habitat Type	– Area, proportion & spatial distribution of habitat/ecosystem types	– GIS/Remote Sensing – Drones	– Maps – Satellite Imagery (Landsat/SPOT) – MARD	– DARD/DONRE – LBBR staff – Consultancy
	1.3. Habitat quality	1.3.1. Species diversity	– Species richness index – D (Simpson's diversity) – H' (Shannon's diversity Index) – Evenness Index	– Plot-based quantitative analysis – Biodiversity database – Quantitative analysis	– Primary data, Field surveys	– LBBR staff – Consultancy
		1.3.2. Composition of dominant species	– Species composition index	– Plot-based quantitative analysis	– Published data – Field surveys	– LBBR staff – Consultancy
		1.3.3. Condition of forest stand	– Forest vertical structure – Distribution of stand size – Stand density/density of forest cover – NDVI (normalized difference vegetation index)	– Plot-based quantitative analysis – Mapping – Drones	– Published data – Satellite/drones Image data – Fieldwork	– LBBR staff – Consultancy
			–	–	–	–

Level	Criteria	Indicators	Parameter/ Measure	Method/ Technique	Data Source	Implementer(s)
	1.4. Ecosystem processes	1.4.1. Community biomass	– Vegetation biomass	– GIS/Remote Sensing – Drones	– Maps – Satellite Imagery (Landsat/SPOT) – Drones	– Consultancy
		1.4.2. Nutrition cycle	– Litter fall	– Quantitative analysis	– Fieldwork	– LBBR staff – Consultancy
		1.4.3. Phenology	– Phenological changes in target species and community	– Quantitative analysis	– Fieldwork	– LBBR staff – Consultancy
	1.5. Human impacts	1.5.1. Use of forest resources	– Exploiting amount of timber – Exploiting amount of non-timber forest products – Number of exploited timber species – Number of exploited species providing non-timber forest products – Number of violation of forest protection	– Quantitative analysis – Data statistics – Ethnobotanical tools	– Primary Data, Fieldwork	– LBBR staff – Consultancy – Community
		1.5.2. Threats of Forest Fire	– Probability of forest fire – Number of actual	– GIS/Remote sensing – Drones – Fieldwork	– Satellite Image (Landsat/SPOT), hotspots	– LBBR staff – Community – Consultancy

Level	Criteria	Indicators	Parameter/ Measure	Method/ Technique	Data Source	Implementer(s)
			controlled and uncontrolled forest fire cases		– MARD system of forest fire monitoring	
2. Species	2.1. Capacity to support the survival of endangered species	2.1.1. Home range and habitat suitability	– Distribution, area, proportion of home range of target species – Distribution, area and proportion of area with high habitat suitability for target species – Fragmentation of area suitable for target species	– GIS/Spatial analysis, Maximum Convex Polygon, Kernel Density – GPS: position marking – Mapping Biodiversity database – Habitat suitability index – Plot/transect based quantitative/qualitative Analysis	– Primary data, – Field surveys	– LBBR staff – Local communities – Consultancy
	2.2. Occurrence of invasive species	2.2.1. Distribution of invasive species	– Number of invasive species – Area and distribution of invasive species	– GIS/Spatial analysis, GPS: position marking – Mapping Biodiversity database – Plot/transect based quantitative/qualitative Analysis	– Primary data, – Fieldwork	– LBBR staff – Local communities – Consultancy
	2.3. Key/ecologically important species	2.3.1. Indicative species for habitat health	– Presence/absence – Number of individuals – Composition (age, sex ratio, etc.)	– GIS/Spatial analysis, GPS: position marking – Mapping Biodiversity database – Plot/transect based quantitative/qualitative Analysis	– Primary data, Field surveys	– LBBR staff – Community – Consultancy
	2.4. Highly frequently exploited species	2.4.1. Natural availability	– Area of distribution – Natural stock	– GIS/Spatial analysis, GPS: position marking – Mapping Biodiversity	– Primary data, – Fieldwork	– LBBR staff – Local communities

Level	Criteria	Indicators	Parameter/ Measure	Method/ Technique	Data Source	Implementer(s)
				database – Plot/transect based quantitative/qualitative Analysis		– – Consultancy
		2.4.2. Harvest of target species	– Harvested amount – Number of harvesting households – Benefit from harvesting	– Ethnobotanical tools	– Primary data, – Fieldwork	– LBBR staff – Local communities – Consultancy
	2.5. Cultural aspect of biodiversity	2.5.1. Species utilization by local community	– Index of Cultural Significance (ICS)	– Ethnobotanical tools	– Primary data, – Fieldwork	– LBBR staff – Local communities – Consultancy

Indicator 1.1.1: Climate condition

Climate is an important environmental factor influencing *ecosystems*. It is a key influence on the distribution of vegetation types. In other words, vegetation types exist in a certain climate, or climate conditions control vegetation types. Therefore, climate change is expected to cause changes in ecosystems and biodiversity. Changes may include displacement or loss of species and habitats.

Reliability	Measurement techniques well developed and popular.
Parameters/measures	– Precipitation – Air humidity – Temperature – Air pressure – Wind – Total hours/days of sunshine – Number of rainy days
Compatibility with national and international approaches	Conventionally compatible with local, national and international approaches.
Availability of data	Data should be available for some past years from the regular monitoring system of Lam Dong DONRE.
Methods	Data provided from Lam Dong DONRE New weather stations should be installed.
Implementer(s)	Lam Dong DONRE: a professional in the field. LBBR staff: need some training in skills of data collection and analysis.
Frequency:	Yearly

Indicator 1.1.2: Possible water pollution

Water resource is a significant part of all ecosystems. Organisms need water to live and reproduce. Therefore, water helps maintain existence of the community and functions and stability of ecosystems. This is more pronounced in aquatic ecosystems which is presented by stream systems in LBBR. Pollution in these water courses will cause critical consequences in not only the aquatic ecosystems but also the terrestrial ones and their communities.

Reliability	Measurement techniques well developed and popular.
Parameters/measures	– Water chemistry (Clarity, BOD, COD, Conductivity, Total Dissolved Solids, etc.) – Stream invertebrate index.
Compatibility with national and international approaches	Analysis of water chemistry is conventionally compatible with local, national and international approaches. Stream invertebrate index is an indicator of the health of aquatic ecosystems applied in different areas in the world although it is seldom in Vietnam.
Availability of data	Not available for many years for LBBR but available at Lam Dong DONRE for some sites in LBBR.
Methods	Quantitative analysis; Fieldwork; Lam Dong DONRE (?)
Implementer(s)	Lam Dong DONRE: a professional in the field. LBBR staff: need some training in skills of data collection and analysis.
Frequency:	Monthly to Yearly

Indicator 1.1.3: Soil condition

Soil is a component of terrestrial ecosystems, but it can be considered as an ecosystem itself. Anyway, soil is considered as an ecological factor that shapes vegetation sub-types (or edaphic vegetation types) with certain plant community and in fact play an important role in ecological cycles (carbon, nitrogen, oxygen, water and nutrient).

Reliability	Measurement techniques for soil characteristics well developed and conventional.
Parameters/measures	– Soil types – Depth – Carbon
Compatibility with national and international approaches	Soil analysis is universally part of ecological studies worldwide.
Availability of data	Some data for LBBR available at Lam Dong DONRE and research institutions.
Methods	Quantitative analysis; Fieldwork
Implementer(s)	Lam Dong DONRE: a professional in the field. LBBR staff: need some training in skills of data collection and analysis. Consultancy: Research institutions.
Frequency:	5 years for soil types and depth. Yearly for carbon monitoring

Criterion 1.2: Vegetation change

Vegetation include communities of plants and the space thy provide. Obviously, vegetation provides shelter for other groups of biodiversity such as animal, fungi, bacteria, etc. Vegetation is not static as their plant communities are temporally and spatially dynamic.

Indicator 1.2.1: Land cover type

Land cover types in LBBR have been reported in different documents and most recently in the present study. They are an important indicator to monitor the local vegetation.

Reliability	Measurement techniques for land cover type well developed and conventional.
Parameters/measures	Area, proportion & distribution of land cover
Compatibility with national and international approaches	Yes
Availability of data	– MARD – Satellite Imagery (Landsat/SPOT) – Drones
Methods	– GIS/Remote Sensing – Drones
Implementer(s)	– DARD/DONRE – LBBR staff – Consultancy
Frequency:	5 years

Indicator 1.2.2: Land use type

Likewise, land use types in LBBR have been reported in different documents and most recently in the present study. They are an important indicator to monitor the local vegetation.

Reliability	Measurement techniques for land use type well developed and conventional.
Parameters/measures	Area, proportion & distribution of land cover
Compatibility with national and international approaches	Yes
Availability of data	– MARD – Satellite Imagery (Landsat/SPOT) – Drones
Methods	– GIS/Remote Sensing – Drones
Implementer(s)	– DARD/DONRE – LBBR staff – Consultancy
Frequency:	5 years

Indicator 1.2.3: Ecosystem/habitat type

It is not surprised that ecosystems and habitats in LBBR have been reported in different documents and the most recently was made by MARD in 2014. In the present study, an updated vegetation map has been made for 1990, 2000 and 2010. They are an important base to monitor the local vegetation in the long run.

Reliability	Measurement techniques for ecosystem/habitat type well developed and conventional.
Parameters/measures	Area, proportion & spatial distribution of habitat/ecosystem types
Compatibility with national and international approaches	Yes
Availability of data	– MARD – Satellite Imagery (Landsat/SPOT) – Drones
Methods	– GIS/Remote Sensing – Drones
Implementer(s)	– DARD/DONRE – LBBR staff – Consultancy
Frequency:	5 years

Criterion 1.3: Habitat quality

The quality of a habitat is crucial for the existence of species and their communities. It can be reflected through different indicators, some keys of them are recommended below.

Indicator 1.3.1: Species diversity

Species diversity is the number of different species represented in a particular community or region. It illustrates the abundance of different animal, plant and microorganisms and can be reflected by several measures such as: species richness index, D (Simpson's diversity), H' (Shannon's Diversity Index) and J (Pielou's Evenness Index).

Reliability	Measurement techniques well developed and conventional.
Parameters/measures	species richness index, D (Simpson's diversity), H' (Shannon's Diversity Index) and J (Pielou's Evenness Index)
Compatibility with national and international approaches	Yes
Availability of data	– LBBR – Research institutions – Published documents
Methods	– Plot-based quantitative analysis – Biodiversity database – Quantitative analysis
Implementer(s)	– LBBR staff – Consultancy
Frequency:	Every 5 years

Indicator 1.3.2: Composition of dominant species

Dynamism in vegetation is defined primarily dominant tree species. Therefore, composition of dominant species is recommended as an indicator for monitor changes of ecosystem or vegetation types.

Reliability	Measurement techniques well developed and conventional.
Parameters/measures	Species composition index
Compatibility with national and international approaches	Yes
Availability of data	– Published data – Field surveys
Methods	– Plot-based quantitative analysis
Implementer(s)	– LBBR staff – Consultancy
Frequency:	Every 5 years

Indicator 1.3.3: Condition of forest stand

As forest stand is home to many organisms and harbor large part of species biodiversity in LBBR, monitoring the condition of a forest stand is essential to track changes in forest and associated biodiversity.

Reliability	Measurement techniques well developed and conventional.
Parameters/measures	– Forest vertical structure – Distribution of stand size – Stand density/density of forest cover – NDVI (normalized difference vegetation index) – Biomass
Compatibility with national and international approaches	Yes
Availability of data	– Published data – Satellite/drones Image data – Fieldwork
Methods	– Plot-based quantitative analysis – Mapping – Drones
Implementer(s)	– LBBR staff – Consultancy
Frequency:	Every 5 years

Criterion 1.4: Ecosystem processes

Ecosystem can be monitored at their processes (cycles) which reflect their status of decomposition, production, nutrient cycling, and fluxes of nutrients and energy. In the case of LBBR, several indicators are recommended as follows:

Indicator 1.4.1: Community biomass

The community biomass includes the mass of all living organisms living in a given area or ecosystem. It can be represented by its part - the vegetation biomass which is an indicator measurable to reflect the mass of the plant community. Studies in vegetation biomass become more common in Vietnam nowadays. It may serve as a foundation for estimating payments for ecosystem services.

Reliability	Measurement techniques conventional.
Parameters/measures	– Presence/absence records
Compatibility with national and international approaches	Yes
Availability of data	– Not available
Methods	– GIS/Remote Sensing – Drones
Implementer(s)	– Consultancy
Frequency:	Every 5 years

Indicator 1.4.2: Nutrition cycle

Nutrition cycle is a recycling system of nature using energy in the process of putting material resources back into use. This ecological process occurs in the food web of all ecosystems where biodiversity is employed.

Reliability	Measurement techniques conventional.
Parameters/measures	Litter fall
Compatibility with national and international approaches	Yes
Availability of data	Not available
Methods	Litter fall trapping
Implementer(s)	Consultancy
Frequency:	Every 1 or 5 years

Indicator 1.4.3: Phenology

The periodic cycle events in plant and animal life are their living characteristics influenced by seasonal and interannual variations in biological and environmental factors. Their changes reflect variation in environment and organisms' adaptation.

Reliability	Measurement techniques conventional.
Parameters/measures	Phenological changes in target species and community. Candidates may be: timing of flowering of dominant trees, timing of defoliation of *Acer* species, emergence of insects, etc.
Compatibility with national and international approaches	Yes
Availability of data	Not available
Methods	Quantitative analysis based on field observation and records
Implementer(s)	– LBBR staff – Community – Consultancy
Frequency:	Every 1 or 5 years

Criterion 1.5: Human impacts

Human cause impacts to ecosystems and biodiversity and should be monitored their impacts through their activities and consequences. However, not all can be monitored and only a few are recommended for their feasibility.

Indicator 1.5.1: Use of forest resources

Local communities depend on forest resources at various extents but obviously forest products play an important role on their economy and culture. Monitoring their use of forest resources will help understand their dependence on natural products and consequent impacts to the local ecosystems. This can be done by observing their exploited products.

Reliability	Measurement techniques conventional.
Parameters/measures	– Exploiting amount of timber – Exploiting amount of non-timber forest products – Number of exploited timber species

	– Number of exploited species providing non-timber forest products – Number of violation of forest protection
Compatibility with national and international approaches	Yes. This can be done together with biodiversity databasing.
Availability of data	Some initial understanding available but not systemized.
Methods	– Quantitative analysis – Data statistics – Ethnobotanical tools
Implementer(s)	– LBBR staff – Community – Consultancy
Frequency:	Every 1 or 5 years

Indicator 1.5.2: Threats of Forest Fire

Forest fire can be made by naturally and man. The first cause has seldom been known in LBBR. In addition, the local authorities employed a controlled forest fire to control uncontrolled forest fire which is learned to cause mass destruction of pine forests and threats to biodiversity and natural ecosystems. However, controlled forest fire may cause similar threats but are believed to be at much lessen extents. In any case, forest fire will emit carbon dioxide.

Reliability	Measurement techniques conventional.
Parameters/measures	– Probability of forest fire – Number of actual controlled and uncontrolled forest fire cases
Compatibility with national and international approaches	Yes.
Availability of data	– Satellite Image (Landsat/SPOT), hotspots – MARD system of forest fire monitoring
Methods	– GIS/Remote sensing – Drones – Fieldwork
Implementer(s)	– LBBR staff – Community – Consultancy
Frequency:	Every year

Objective 2: Monitoring biodiversity at species level

It is targeted to know changes in population trends, impacts of threats, and effectiveness of species protection and management. In total six indicators are recommended, grouped into 5 criteria.

Criterion 2.1: Capacity to support the survival of endangered species

The endangered species are often sensitive to habitat changes and human disturbance; and they need vital area of habitat/niche to live. In addition, the presence of endangered species in a specific

area is one of the most important criteria to evaluate biodiversity conservation value as well as the efforts of management and conservation. Moreover, the status of endangered species over time will reflect the management strategy and efficiency. Therefore, understanding the status of endangered species over time can help the managers adjust their actions for more efficiency. In this type of criteria, we propose two indicators for monitoring as below:

Indicator 2.1.1: Home range and habitat suitability

This indicator is to reflect possible changes of home range and habitat suitability of flora and fauna of LBBR. In general, the suitable habitat for certain species may be limited and changed negatively or positively due to different causes, such as deforestation, pollution, forest fire, etc. When this occurs, their home range changes accordingly. Knowing such trend is very foundational for conservation and management programs.

Reliability	Measurement techniques well developed and popular.
Parameters/measures	– Distribution, area, proportion of home range of target species – Distribution, area and proportion of area with high habitat suitability for target species – Fragmentation of area suitable for target species
Compatibility with national and international approaches	Compatible with the employed work by Bidoup-Nui Ba National Park.
Availability of data	Data should be available for some past years from the regular monitoring system of Bidoup-Nui Ba National Park.
Methods	Quantitative data will be collected from GIS database for spatial analysis, Maximum Convex Polygon, Kernel Density – GPS: position marking – Mapping Biodiversity database – Habitat suitability index – Plot/transect based quantitative/qualitative Analysis.
Implementer(s)	Lam Dong DONRE: a professional in the field. LBBR staff: need some training in skills of data collection and analysis.
Frequency:	Yearly
Target species	Animals will be the key target, such as yellow-checked gibbon, black-shanked douc, Owston's civet, collared Laughingthrush. Endemic and restricted plants such as *Pinus krempfii*, *P. dalatensis*, etc. should be monitored within this indicator. For each vegetation, extension of the target may be for indicator species that have been determined based on the field data and experts' opinions. Although all of them are important, selection of species to be monitored depends on available resources of time, human and finance as well as combination of their significance of conservation and ecology.

2.2. Occurrence of invasive species

Indicator 2.2.1. Distribution of invasive species

Invasive species are a serious issue to biodiversity because they directly affect native species. To control and manage the presence and dispersal of alien species, their population size and present and potential distribution must be known and monitored.

Reliability	Measurement techniques easy and popular.
Parameters/measures	– Number of invasive species – Area and distribution records of invasive species
Compatibility with national and international approaches	Compatible with the employed work at Lam Dong DONRE and elsewhere although new hydro stations should be installed in LBBR for higher resolutions of data.
Availability of data	Not available
Methods	Quantitative data will be collected by direct observation and tracks from field surveys. – GIS/Spatial analysis, GPS: position marking – Mapping/Biodiversity database – Plot/transect based quantitative/qualitative Analysis
Implementer(s)	– LBBR staff – Local communities – Consultants/Researchers/Students
Frequency	Yearly
Target species	*Lantana camara*

2.3. Key/ecological important species

Indicator 2.3.1: Indicative species for habitat health

The health of habitats can be reflected through observations of indicative species which are sensitive to environment changes. In this study, several animals have been determined as monitoring candidates for this purpose. The demography of population of target species reflects the dynamics and population change in future. It is essential to understand the current demography of target species in LBBR and their changes in population age and gender in order to provide hints for support their existence and growth.

Reliability	Measurement techniques well developed and popular.
Parameters/measures	– Presence/absence records – Number of individuals – Composition (age, sex ratio, etc.)
Compatibility with national and international approaches	Yes
Availability of data	– Some initial results from this study
Methods	– GIS/Spatial analysis, GPS: position marking – Mapping/Biodiversity database – Plot/transect based quantitative/qualitative data collection and analysis – Candidate species: plants (*Pinus krempfii*,bamboos,

	plants providing foods for animals), moth (*Actias chapae bezverkhovi)*, dragonfly, dam fly, fish, amphibian (*Brachytarsophrys intermedia*), bird (Collared Laughingthrush), mammal (yellow-checked gibbon)
Implementer(s)	– LBBR staff: need training in skills of data collection and analysis. – Local communities may take part in collecting data. – Consultants/Researchers/Students
Frequency:	Every year

2.4 Highly frequently exploited species

Forest resources are important for the livelihood of local people and reflect their culture and experience but are affected by their harvest. It is critical to monitor the natural availability and changes of highly frequently exploited species.

Indicator 2.4.1. Natural availability

The natural availability of many exploited species provides unique sources for local people as most of them are not cultured. It is important for managers to understand the status of forest resources often exploited by local people to plan and implement suitable management measures.

Reliability	Measurement techniques well developed and popular.
Parameters/measures	– Area and distribution – Natural stock
Compatibility with national and international approaches	Inventory of natural resources of forest products has been employed in different areas in the Vietnam and other countries, using conventional methods. Some plant species have been inventoried in BDNB that can be served as a baseline for monitoring.
Availability of data	Data should be collected newly as a baseline for future monitoring.
Methods	Ethnological tools will be applied for collecting data; Qualitative and quantitative assessments will be taken to assess the impacts to protection and management in LBBR.
Implementer(s)	– LBBR staff: need some training in skills of data collection and analysis. – Community. – Consultants/Researchers/Students
Frequency	Every 1 to 5 years
Target species	*Codonopsis javanica, Galium* sp., fishes, wild boar

Indicator 2.4.2. Harvest of target species

Understanding the quantity of exploitation and the importance of these activities to the local people can help understand how dependent they rely on natural products and so suitable strategy of management can be employed effectively.

Reliability	Measurement techniques are well developed and popular.
Parameters/measures	– Harvested amount – Number of harvesting households – Benefit from harvesting
Compatibility with national and international approaches	Compatible with monitoring database of Bidoup-Nui Ba.
Availability of data	For the future monitoring program, data should be collected as a baseline data with standardized methods.
Methods	Ethnological tools will be applied for collecting data; Qualitative and quantitative assessments will be taken to assess the impacts to protection and management in LBBR.
Implementer(s)	– LBBR staff: need some training in skills of data collection and analysis. – Community. – Consultants/Researchers/Students
Frequency	Seasonally or yearly
Target species	*Codonopsis javanica*, *Galium* sp., fishes, wild boar

2.5. Cultural aspect of biodiversity

Indicator 2.5.1: Species utilization by local community

For the sustainable development, the biodiversity conservation should be integrated with the development of human communities and respect to their culture and tradition. In LBBR, at least ten ethnic people groups live in the core zone and buffer zone, and their culture and tradition rely on forest and natural resources. Hence, many native plant and animal species play an important role in their culture and knowing the cultural significance of those species is essential to provide suitable strategy for preserving these species and their culture and tradition.

Reliability	Measurement techniques are well developed and popular.
Parameters/measures	– Index of Cultural Significance (ICS)
Compatibility with national and international approaches	Similar studies have been conducted in many countries.
Availability of data	Not available, Data should be collected newly as a baseline for future monitoring.
Methods	Quantitative assessments in ethnobotany is employed to evaluate the cultural significance of particular species in a community's inventory of plants and animals
Implementer	– LBBR staff: need some training in skills of data collection and analysis. – Community. – Consultants/Researchers/Students
Frequency	Every 1 or 5 years
Target species	The target species will be derived from an on-going baseline survey in local communities at SIE.

3.3.2 Organisation of monitoring

The management board of Lang Biang Biosphere Reserve (LBBR) should be responsible for organisation and management of monitoring programs. As the core zone is actually the Bidoup-Nui Ba National Park (BDNB), its management board should play a key role in monitoring the

biodiversity of the core zone. Meanwhile, monitoring biodiversity in the buffer zone should include the management board of the protection forests (PFs) as key players. Technical scientific advices may come from the scientific panel of LBBR that includes experts. Depending on the complexity of the activities, the participation of the local staff/villagers and invited experts can be employed for a project which may include one or more activities under coordination by a member of maganement board of LBBR.

3.3.3 Cycle of monitoring

Most of the indicators should be monitored in a cycle of 5 years but the environmental indicators (e.g. indicators of soils, water and weather) should be recorded on a shorter regular repeat to provide solid and reliable data. Likewise, some sensitive species should be monitored on short cycles if resources are available.

IV. CONCLUSION AND RECOMMENDATIONS

The results from this survey has addressed the objectives of the contract, i.e. *(i)* building a biodiversity database at ecosystem and species levels based on selected available sources of data and new field surveys and *(ii)* developing a long-term biodiversity monitoring system with conventional indicators and those locally specific and derived from the fieldwork.

The results include a set of maps built for understanding the past changes at landscapes, landuse and land cover and for long term monitoring their changes. A database of main groups of biodiversity of LBBR (plants, mammals, birds, reptiles, amphibians and insects) has been made based on refining available published and unpublished data/reports and field trips. Finally, based on existing systems of biodiversity monitoring, field works on environmental conditions and biodiversity, and consultations with relevant authorities and experts, a framework of monitoring biodiversity for LBBR has been determined, with 20 indicators and many determined potential indicative species to monitor biodiversity at both ecosystem and species levels.

This framework is a general guideline for long term monitoring at LBBR and can be adopted for real situations and available resources of time, personnel and finance. However, it is recommended to apply as many suggested indicators as possible in order to provide better understanding of changes in biodiversity. Although some indicators seem to be easy to monitor, a detailed manual should be developed to facilitate the development of the monitoring system, including training of monitoring partipants so that they can understand the purpose of monitoring, methods of data collection/analysis and apply properly in reality. Experienced experts should be involved at the very beginning of any monitoring system, especially in training and supervision. Transferring of knowledge and skills cannot be made simply.

It is noticed that despite its update, the built database still has abundant gaps and should be enriched with true data collected directly from the field work and with appropriate methodology. For this, guidelines from the Global Biodiversity Information Facility should be consulted and applied. Nevertheless, databasing biodiversity is a long-term work that should need continued implementation and supports.

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Appendix 1. Some photos of field workings

Dr. Kashio, Dr. Truong and Dr. Quyet discussed in the first field trip

Huynh Quang Thien measured physical properties of water

Discussing on setup transects in forest (Dr. Kashio, Dr. Truong, Dr. Dao and Dr. Cuong)

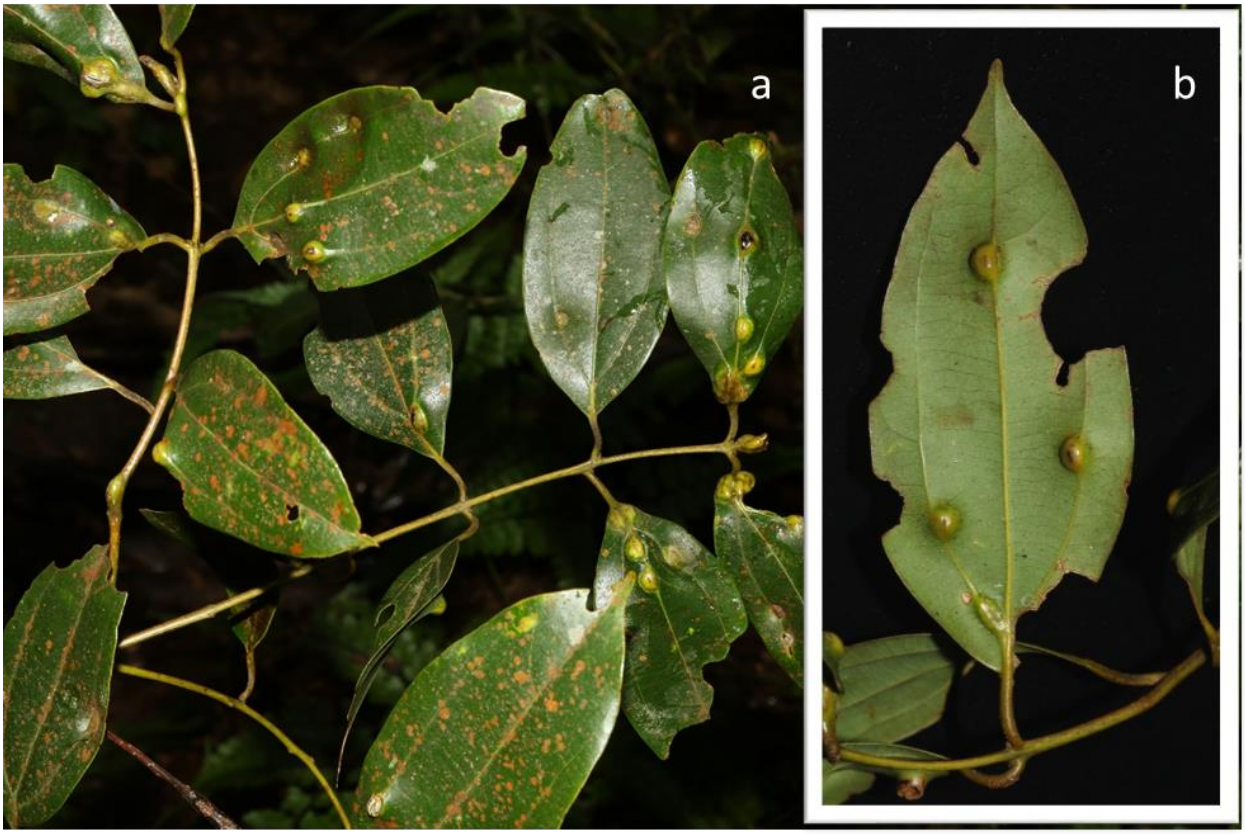
Dr. Dao and her colleague collected data in field

Appendix 2. Some plant species as potential indicators

Syzygium cf. *odoratum* - Trâm thơm

Magnolia yunnanensis - Ngọc lan Vân Nam (a: phát hoa, b: thân cây, c: hoa)

Castanopsis echinocarpa – Khu thụ (trái: phát hoa, phải: thân cây)

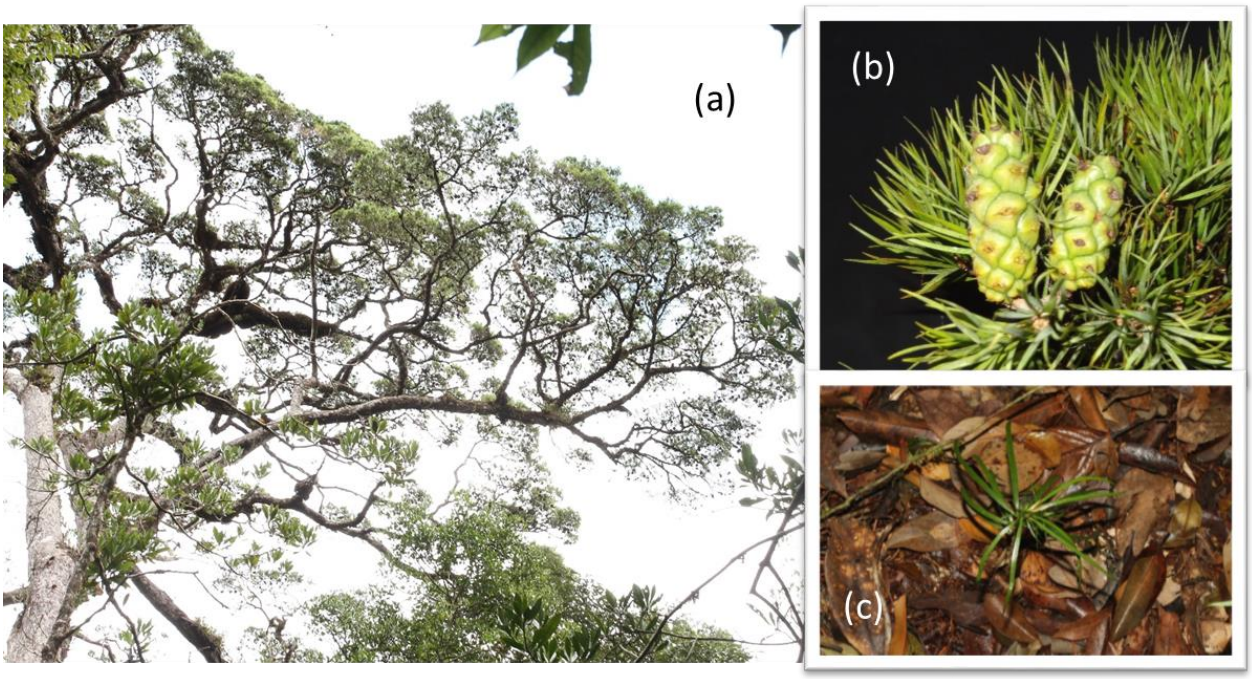


Cinnamomum spA. - Quế sp.A (a: mặt trên, b: mặt dưới lá)

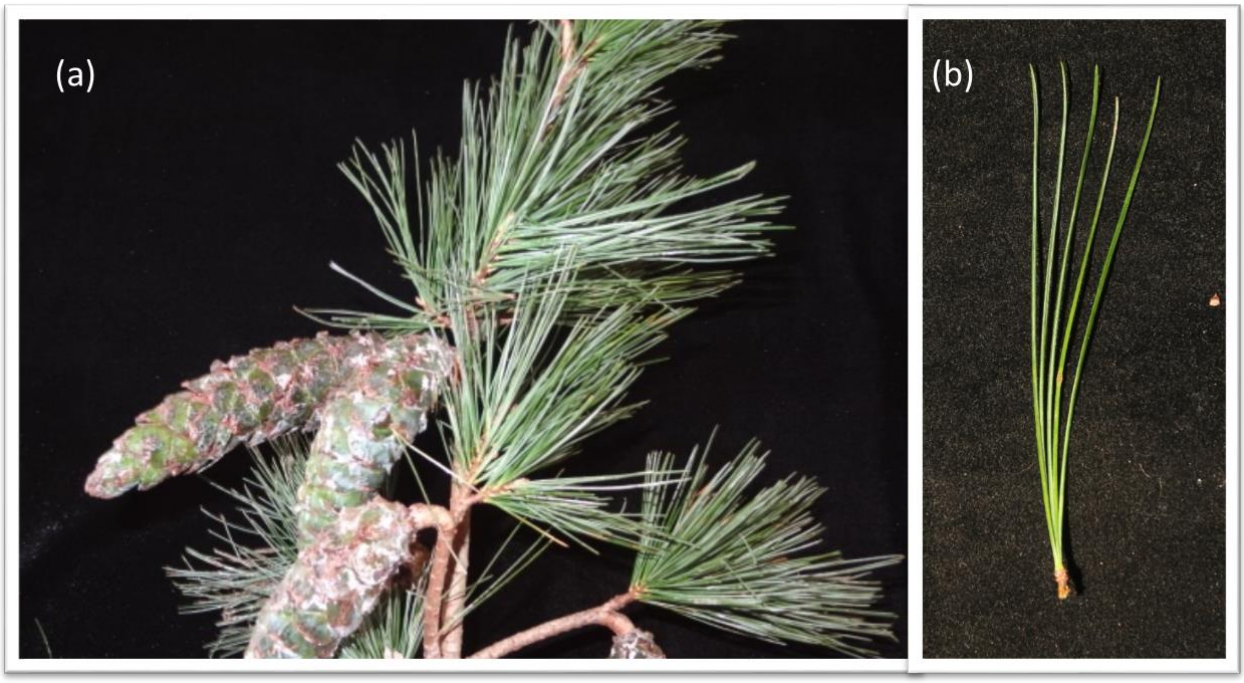
Meliosma arnottiana - Mật sạ (a: phát hoa, b: trái)

Lithocarpus truncatus - Dẻ cắt ngang (a: phát hoa, b: mắt dưới lá, c: trái)

Bambusa procera - Lồ ô (a: cấu trúc lá, b: cuống lá, c: mắt thân)

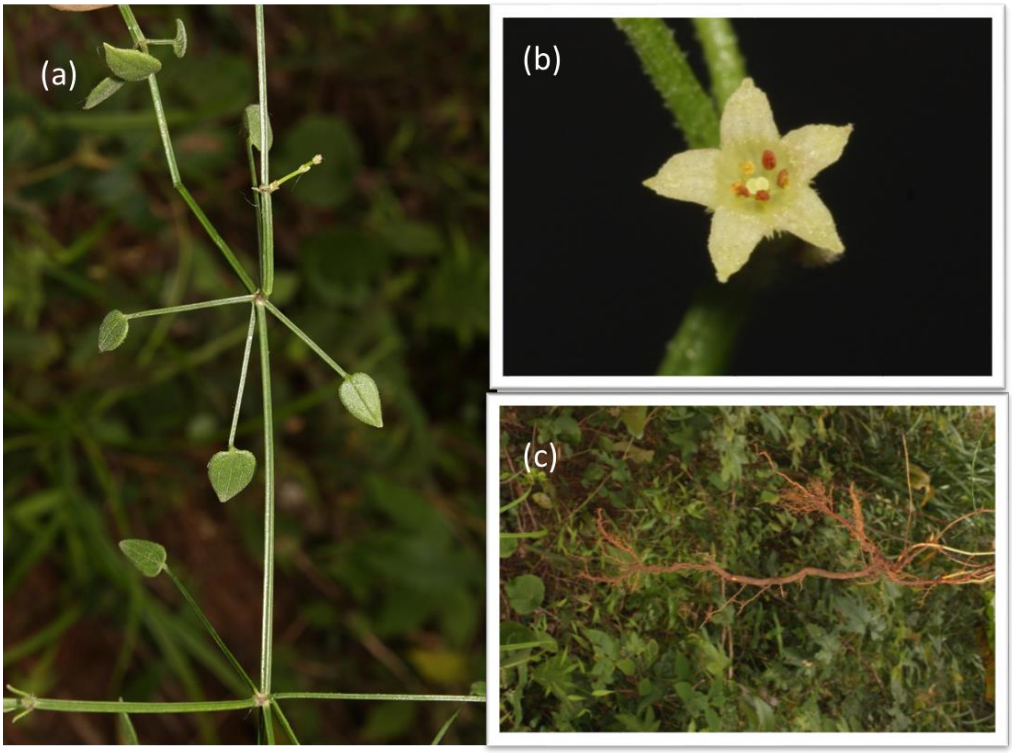


Pinus krempfii - Thông hai lá dẹt (a: tán cây, b: quả, c: cây non)



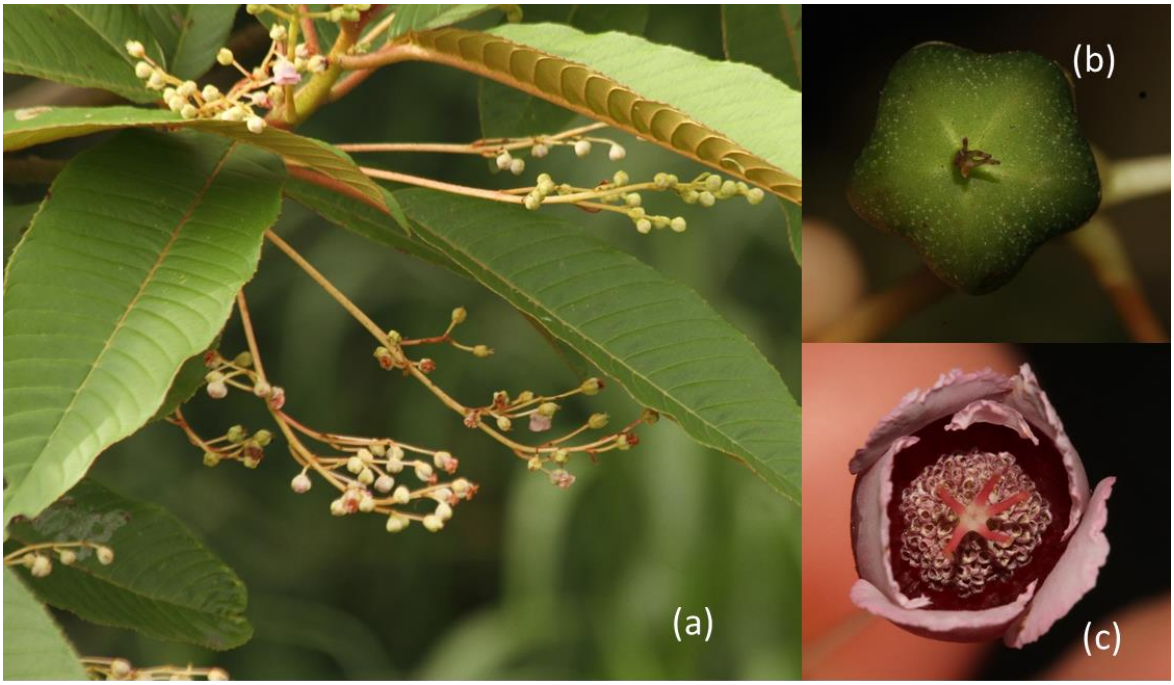
Pinus dalatensis - Thông Đà lạt (a: cành và nón thông; b: lá)

Codonopsis javanica - Đẳng sâm (a: phát hoa, b: củ sâm)



Galium spA. - Sâm đỏ (a: cây, b: hoa, c: củ sâm)

Dipterocarpus obtusifolius - Dầu trà beng (a: lá, b: hoa)



Saurauria nepalensis – Nóng (a: phát hoa, b: trái, c: hoa)

Litsea viridis var. *clemensii* - Bời lời Clemens (a: cành mang trái, b: trái, c: hoa)

Adinandra donnaiensis - Sum Đồng Nai (a: cây, b: mặt sau lá, c: hoa)

Lantana camara - Ngũ sắc (a: phát hoa, b: cận cảnh hoa)

Appendix 3: Some mammal species as potential indicators

Black-shanked douc

Stump-tailed macaque

Owston's Civet

Common barking deer

Appendix 4: Some bird species as potential indicators

Collared Laughingthrush

Golden-throated Barbet

Vietnamese cutia

Red crossbill (Female)

Black-hooded Laughingthrush

Mountain Imperial Pigeon

Fulvescent Prinia

Mountain Fulvetta

Grey Bushchat

Green-backed Tit

Flavescent bulbul

Grey-headed Canary Flycatcher

White-crested Laughingthrush

Ashy Woodswallow

Appendix 5: Some photos of reptiles

Cyrtodactylus bidoupimontis

Pareas hamptoni

Trimeresurus vogeli

Pseudoxenodon macrops

Appendix 6: Some amphibian species as potential indicators

Odorrana graminea

Xenophrys major

Raorchestes gryllus

Limnonectes poilani

Appendix 7: Some fish species as potential indicators

Schistura sp.

Ungen sp.

Nemacheilus sp.

Appendix 8: Some insect species as potential indicators

Nasutitermitinae spp.

Mycalesis mnasicles

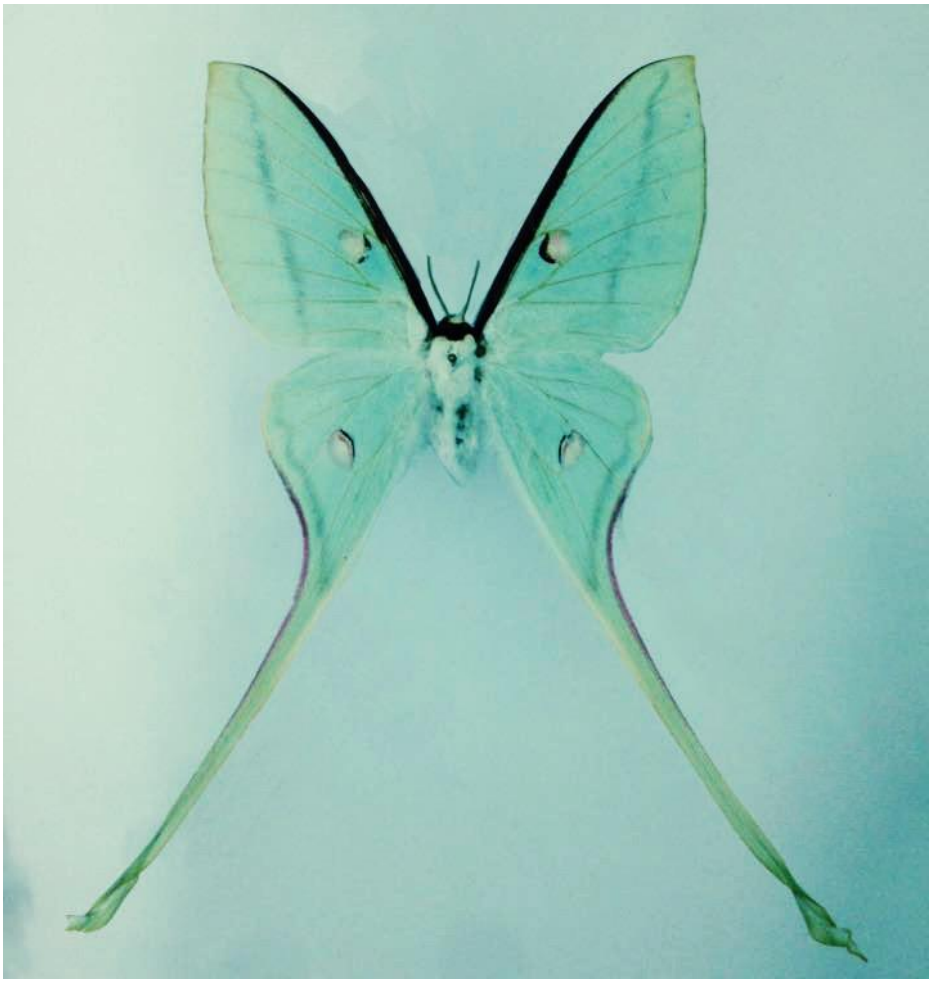
Coeliccia mattii

Coeliccia scutellum

Coeliccia sp.

Anisopleura bipugio

Rhinocypha seducta



Actias chapae bezverkhovi