DIVERSITY AND DISTRIBUTION OF HERPETOFAUNA IN GHANDRUK REGION OF ANNAPURNA CONSERVATION AREA, NEPAL

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DECLARATION

I hereby declare that the work presented in this thesis entitled "**DIVERSITY AND DISTRIBUTION OF HERPETOFAUNA IN GHANDRUK REGION OF ANNAPURNA CONSERVATION AREA, NEPAL"** has been done by myself, and has not been submitted elsewhere for the award of any degree. All the sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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RECOMMENDATION

This is to recommend that the thesis entitled **"DIVERSITY AND DISTRIBUTION OF HERPETOFAUNA IN GHANDRUK REGION OF ANNAPURNA CONSERVATION AREA, NEPAL"** has been carried out by Mr. Bivek Gautam for partial fulfillment of the requirement for Master's Degree in Zoology with the special paper of Ecology. This is his original work and has been carried out under my supervision. To the best of my knowledge, this work has not been submitted for any other degree in any institutions

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CERTIFICATE OF ACCEPTANCE

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LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
IUCN	International Union for the Conservation of Nature
DNPWC	Department of National Park and Wildlife Conservation
NTNC	National Trust for Nature Conservation
ACA	Annapurna Conservation Area
ACAP	Annapurna Conservation Area Project
CNP	Chitwan national park
MCA	Manaslu Conservation Area
DHM	Department of Hydrology and Meteorology
GPS	Global Positioning System
VES	Visual Encounter Surveys
GLM	Generalized Linear Model
HP	Hierarchical Partitioning
VPA	Variation Partitioning Analyses
EX	Extinct
EW	Extinct from the Wild
NT	Near Threatened
LC	Least Concern
DD	Data Deficient

ABSTRACT

Amphibians and reptiles share many physiological, behavioral and ecological similarities so they are kept under same group Herpetofauna. Herpetofauna are least studied group of animals in Nepal. Herpetofaunal study was performed on Ghandruk region of Annapurna Conservation Area to explore Species composition and abundance, their seasonal variation, distribution pattern along elevational gradient and habitat type. Relation of herpetofauna with multiple factors like distance to water resources, distance to road, distance to settlement, leaf litter coverage, canopy cover, shrub cover, Habitat type and elevation was also examined during the study. Diurnal and nocturnal distance and time constrain Visual encounter survey was applied on randomly selected 11 transects. Opportunistic survey was also adopted to increase the survey efficacy. Survey was performed on May for pre monsoon and October for post monsoon season. One way ANOVA, t- test, linear regression, generalized linear model, Variation partitioning analyses were performed to obtain the result. Ghandruk lies in the southern part of ACA which has an area of about 21412.977 Sq. Km. Six hundred and sixty two individuals of herpetofauna belonging to 12 species of amphibian and 13 species of reptile were recorded during this study. Amphibian diversity was significantly affected by explanatory variables like distance to water, distance to settlement and Leaf litter cover. In case of reptiles their diversity was significantly affected by Leaf litter cover, Distance of water, Distance of Settelment and canopy cover. Explanatory factors like Elevation, Habitat character, Disturbance and water distance together contribute three percent, nine percent, forty percent and thirty five percent on species richness of herpetofauna. Though diversity of herpetofauna was slightly higher in post monsoon ($H'=2.26$) than pre monsoon ($H'=2.19$) there was no any significant difference in species richness (P value $= 0.220$) and abundance (P value $= 0.478$) in between these two season. There was a declining trend in species richness and abundance with increase in altitude but their linear relationship was not significant. Herpetofauna was not uniformly distributed among different habitat type, there was significant difference ($F=3.42$, $P<0.01$) in species richness of herpetofauna in different habitat types during this study.

DIVERSITY AND DISTRIBUTION OF HERPETOFAUNA IN GHANDRUK REGION OF ANNAPURNA CONSERVATION AREA, NEPAL

1 INTRODUCTION

1.1 Herpetofauna:

Term herpetofauna indicates group of all those creatures which are known as amphibians (caecilians, salamanders, toads and frogs) and reptiles (chelonians, crocodiles, lizards, and snakes). Both are ancient group with fascinating history and important remnant of massive extinction. Amphibians and reptiles show more similarities among each other. They share many physiological, behavioral and ecological similarities so they are kept under same group Herpetofauna (Vitt and Caldwell, 2014). Both amphibians and reptiles are considered as ectothermic, they must gain heat through outside sources (sun) to raise their internal temperature. Herpetology is a scientific study of structure, classification, life history and distribution of the amphibians and reptiles (Smith, 1951). Herpetofauna are sensitive to environmental changes both in terrestrial and aquatic habitats so they serve as biological indicators of environmental stresses. Frog have semi-permeable skin and different life cycle stages while reptiles are influenced with external temperature fluctuations this makes them sensitive to environment (Zug *et al*., 2001). Furthermore, reptiles can be sensitive indicators of the impact of human activities such as intensive grazing, forest cutting, and mining (Read, 2002; Thompson and Thompson, 2005).

1.1.1 Amphibians

Approximately 350 million years ago, a fish ancestor developed limbs instead of fins and took the first steps towards life on land. This gave rise to a group of animals called tetrapods which eventually evolved into the amphibians. Amphibians are vertebrates with four limbs having hands with four digits and feet with five digits with the exception of the limbless caecilian (Schleich and Rai, 2012a). They are generally regarded as an intermediate group of animals that provide an evolutionary link between fishes and reptiles. These are the first creatures to depart from aquatic habitats and develop lungs that enabled them to breathe on land. The young ones emerge from the eggs as tadpoles before becoming adults and, with a few exceptions, undergo a change, as their limbs appear and they transform from gill breathing to lung-breathing creatures. Amphibians have thin soft and moist granular skin without scales and claws. They exchange gases and water through their permeable skin during aquatic mode of life. Most amphibians are oviparous and need water to lay egg, most of them develop their early life cycle in water and development is through process of

Metamorphosis. All adult are carnivores they feed on a variety of small creatures such as insects and worms. Nepalese amphibians are the frogs and toads (Order Anura, tailless amphibians), while salamanders and caecilians (Orders Caudata and Gymnophiona) are represented by only one species each.

1.1.2 Reptiles

The term 'reptile' is used generally to describe the group of creeping and crawling vertebrate creatures that evolved from amphibians during the carboniferous period more than 200 million years ago (Thapa, 2016). All reptiles are tetrapod's, which simply means that they have either four limbs (like turtles and crocodiles) or are descended from four-limbed animals (like snakes). There are many lizards with reduced limbs and digits. Reptile skin is covered by horny structures (scales, plates, granules, tubercles etc.) that prevent them from losing moisture through their skin and provided with few glands. In evolutionary terms, reptiles are intermediate between amphibians (which have moist skin and need to stay near bodies of water) and mammals (which have warm-blooded metabolisms and have diversified into every habitat on earth). Over millions of years, true reptiles evolved into creatures more terrestrial and less dependent upon water. Reptiles are amniotic animals, which mean that the eggs laid by females contain an elastic sac within which the embryo develops. Most of them are oviparous, laying hard-shelled eggs, but a few squamate lizards are viviparous, giving birth to live young that develop inside the females' bodies. Reptile do not undergo metamorphosis process as amphibians, their young are smaller versions of the adults, needing only to gain in size to become adults.

1.2 Diversity and Distribution of Herpetofauna:

Biodiversity is the variety of life on earth and includes variation at all levels of biological organization from genes to species to ecosystems. Genetic diversity is a variation of genes within the population of same species. Species diversity is a variety of species (richness) within a particular region. Ecological diversity is the variation in the ecosystems found in a region or over the whole planet. Niche width and habitat diversity are also key components of ecological diversity (Hamilton, 2005). Niche width describes the availability of resources to an organism over spatial and temporal scales. Habitat diversity represents the structural complexity of the environment (Mumby, 2001). Diversity of herpetofauna means variety of amphibian and reptile species in a particular area at particular time.

These fascinating creatures have invaded varieties of habitats ranging from the hot lowland to the cold mountain summit and from scorching desert to cool forest. They have a very important role in food chain and controlling a wide variety of agricultural pests (Pokhrel and Thakuri, 2016). There are 7,787 amphibian species in the world among them 6,864 belongs to order Anura (frogs and toads), 716 to Caudata (newts and salamanders) and 207 to order

Gymnophiona (caecilians) (Frost, 2018). International Union for the Conservation of Nature (IUCN) examines the status of 6,260 amphibian species and found that nearly one-third of species (2,030) are globally threatened or extinct. Thirty-eight of the 2,030 species are already Extinct (EX) and one is Extinct from the Wild (EW). Another 2,697 species are classified as Near Threatened (NT) or Least Concern (LC) and 1,533 species still lacks sufficient information so categorized as Data Deficient (DD) (IUCN, 2018). Around the world 10,639 reptilian species are discovered till the dates, of which 193 are Amphisbaenia (amphisbaenians), 6,399 are Sauria (lizards), 3,672 are serpentes (snakes), 350 are Testudines (turtles), 24 are Crocodylia (crocodiles) and one is Rhynchocephalia (tuataras) (Uetz *et al.*, 2018). Out of the 19% of reptiles threatened with extinction, 12% classified as Critically Endangered, 41% Endangered and 47% Vulnerable (IUCN, 2018).
South Asia is rich in herpetofaunal diversity several unique and endemic Species are found on this region (Shah and Tiwari, 2004). Only about 50% of the biodiversity of amphibians in South Asia has been discovered. South Asia claims over 900 species of Amphibians and reptiles (Shah and Tiwari, 2004). India has 342 species of amphibian (Vasanthi *et al*., 2014).

Nepal comprises an outstanding number of herpetofauna. Due to presence of high habitat diversity in Nepal (Pokhrel and Thakuri, 2016) herpetofaunal diversity is also high. Herpetofauna of Nepal represents Palearctic, Oriental, Indo-Chinese and Himalayan species (Shah and Tiwari, 2004). Hills and mountain shares Palearctic fauna and plain Tarai shares oriental fauna but most of Himalayan and indo Chinese species are commonly found in Nepal. Due to the presence of variations on geography country is divided into five major physiographic regions -Tarai (Plains), Siwaliks, Mid-hills, High Mountains and Himal. This variation in geography and isolation of landscape favors the evolution results in high diversity and endemism. In Nepal, herpetofauna are distributed across wide range of altitude from 80m to 5,490m (Thapa, 2016). Based on their distribution and habits they utilize forests, grasslands, alpine meadows, trees, tunnels, cliffs, rocks, different aquatic bodies, agricultural lands and settlements as macro and microhabitats (Pokhrel and Thakuri, 2016).

Schleich and Kastle (2002) provide an account of 50 amphibians and 123 reptiles in Nepal but there are over 206 species and sub-species of amphibians and reptiles (Shrestha 2001; Shah and Tiwari, 2004). Seventeen species of the Nepalese herpetofauna are nationally threatened among them six species are globally threatened (Bhuju *et al*., 2007). Out of all species recorded till date from the country, 22 species (Toad 1, Frogs 10, Lizards 10 and Snake 1) are endemic to Nepal (Shah and Tiwari, 2004). Reptiles of Nepal are grouped under three orders: Crocodylia (Crocodiles), Squamata (scaled reptiles- lizards and snakes) and Testudines (turtles and tortoises).

Among vertebrates, amphibians are still poorly known and are highly threatened (Rodrigues *et al*., 2010) and their population decline is a major concern (Wyman, 1990; Stuart *et al*., 2004). Reptilian species are also facing similar types of problems and they are experiencing

severe range reductions and declines in abundance (Gibbons *et al.*, 2000; Araujo *et al.*, 2006). Most of the herpetofauna are threatened and are declining more rapidly compared to birds and mammals (Stuart *et al*., 2004). Herpetofauna has cultural and religious connections on Nepal, Hindu and Buddhist people worship Frogs, snakes and turtles. Yet, herpetology in Nepal remains one of the least studied subjects in Zoological Science. As herpetofauna is a poorly studied in Nepal, their present status is also poorly known (Aryal *et al*., 2015). Few study on herpetofauna have been done on Arun Valley, the Annapurna-Dhaulagiri region and Chitwan National Park, Koshi Tappu Wildlife Reserve, Bardiya National Park, Suklaphanta Wildlife Reserve, eastern and central Nepal (Thapa, 2016). However mid- and far- western regions of Nepal remain least studied due largely to their remoteness and inaccessibility (Shah and Tiwari, 2004).

According to IUCN Global Amphibian Assessment 2006, 4% endemic species are found in Nepal and species composition had reduced compared to 2001 IUCN checklist (Molur, 2008). Very few species have been described from disturbed habitats, indicating a diminished species composition when compared with the original habitat. Amphibian and reptiles of Nepal face severe threat of extinction. Major threats include rapid deforestation, soil and water pollution, land use changes, habitat loss and unplanned resource extraction. Limited dispersal ability of amphibians and reptiles may further increase the vulnerability to changes in climate (Pokhrel *et al*., 2011). Herpetofaunal conservation efforts is limited in country (Shah and Tiwari, 2004; Rai *et al.*, 2006), people consider all reptiles as poisonous and killed at sight. Tendency of indiscriminate exploitation of herpetofauna in the country has threatened the survival of some species such as turtle, Paha spp (Shah, 1995).

In this context, a brief survey of herpetofauna along the ACA has been conducted to explore their diversity, identify the species composition and assemblage. Additionally, study of the habitat selection and species association with elevation in this study are expected to add a new dimension in herpetological research in Nepal.

1.3 Research Objective

1.3.1 General objective

To investigate the diversity and distribution of herpetofauna in Ghandruk region of Annapurna Conservation Area (ACA), Nepal.

1.3.2 Specific objectives

I. To investigate the Species composition and abundance of herpetofauna
II. To examine the seasonal variation of herpetofauna
III. To understand the distribution pattern of herpetofauna along elevational gradient
IV. To evaluate the distribution of herpetofauna in different habitats

1.4 Rational

Most of the research work has been carried on large mammals and birds; very little attention has been given to study of other fauna in Nepal. Herpetofauna are least studied group in Nepal, very little scientific information on this group of animal is available from Nepal. Due to their small habitat range, amphibians and reptiles are facing strong negative impacts. Anthropogenic activities like deforestation, expansion in agriculture and exploitation of herpetofauna by different ethnic groups for different purposes is another major cause for their population decline. Among Herpetofaunal research, most of the studies focused on collection and preservation of checklist in Nepal.

Some studies have been conducted in this area and its periphery but still there is information gap on herpetofauna of this study area. Two studies on herpetofauna and one on amphibian has been already done in Annapurna conservation area but this study is different from previous study. Previous studies covers large area but this study will be confined on Ghandruk region of Annapurna conservation area only. Those studies just prepare the checklist of herpetofauna from ACA locality and mentioned their ethno value but there are still so many aspects of herpetofauna that need to be studied. This study will explore the relation of herpetofauna with multiple factors like water resources, road, settlement, leaf litter coverage, canopy cover, shrub cover, Habitat type and elevation in Ghandruk. Study of Seasonal variation in herpetofauna has not been performed in Nepal till date, so this study will be new for Nepal.

1.5 Limitations

i) High altitude herpetofaunal survey requires extensive survey period, due to limited academic research period this study cover mid-hill range of Ghandruk.

ii) Due to extreme rainfall (cloud outburst 2017) in monsoon and possibilities of natural hazard, data were not collected during peak monsoon period.

2 LITERATURE REVIEW

The early works on the herpetofauna of Nepal were the collections made by Hodgson during 1826-1854 (Gunther, 1860; Gunther, 1861). In 1858 he collected 84 reptiles and drawing of 55 sheet of reptiles from Nepal (Hunter, 1896). Hodgart in 1907 collected two species of frog, five species of lizards and five species of snakes from in and around of Kathmandu valley (Swan and Leviton, 1962). Oleg Polunin visited western Nepal in 1952 and collected 6 new herpetofauna (Smith and Batterby, 1956). In 1954, Californian team travels to Makalu region where Lawrence swan lead the group to collect amphibians and reptiles from vicinity of Arun River. They deposited specimen on Natural History Museum of Stanford University and later in 1956 this work was reported by Alan Leviton, George Myers and Lawrence swan (Swan and Leviton 1962).

A large number of contributions exist on Zoogeographic distribution of Trans Himalayan animals (Darlington, 1963). But there is limited information on biogeography of amphibians and reptiles of Nepal. Swan and Leviton (1962) carried out detailed zoogeographical analysis and published "The herpetology of Nepal: A history, Check list and Zoogeographical analysis of the herpetofauna" on California where they listed 16 amphibians and 53 reptiles on checklist of herpetofauna of Nepal. Singh *et al*. (1968) gave a checklist of amphibians, reptiles and mammals of Nepal in the regional seminar of ecology of the Tropical Highlands, held in Kathmandu. Dubois (1974) reported 21 species of amphibians from western and central Nepal. Fleming and Fleming (1974) reported 29 species of snakes mainly from the central and eastern Nepal, out of which 12 species of snakes were new record for Nepal. Shrestha and Majupuria (1977) made contribution on herpetology of Nepal by studying poisonous snakes particularly of Elapidae. In 1968, small team of Hokkaido University collected 16 specimens of amphibians and reptiles namely *Bufo melanostictus, B. himalayanus, Agama tuberculata, Calotes versicolor, Japalura tricarinata, Boiga cptanea and Trimeresurtts albolabris* from Nepal (Matsui*et al*., 1980). The distribution of amphibians and reptiles in the Annapurna-Dhaulagiri region was studied by (Nanhoe and Ouboter, 1987).

Schleich (1993) contributed to the systematic of amphibians and reptiles by providing a checklist of one salamander, 36 anuran, two crocodiles, 22 lizards, 10 Testudines and 53 snakes. Shrestha (1994) contributed a series of papers on herpetology and shed light on the conservation status of amphibians and reptiles of Nepal. Zug and Mitchell (1995) collected and studied herpetofauna of Royal Chitwan national park at April and November of 1985. They performed pre monsoonal and post monsoonal survey and reported habitat preference and checklist of 11 species of amphibians and 44 species of reptiles (two crocodiles, eight turtles, ten lizard and 24 snakes) with keys to identify them. Shah (1995) recorded a total of 143 species of amphibians and reptiles for Nepal including 43 species of amphibians (one salamander, 38 frogs and four toads) and 100 species of reptiles (24 lizards, two crocodiles, 60 snakes and 14 species of turtles) comprising 11 endemic species (nine frogs and toads,

one lizard, and one snake species). Shrestha (1996) collected and reported 156 species of amphibians and reptiles in Nepal. Orlov and Helfenberger (1997) have made contribution on new mountain green pit viper species of *Trimeresures* from the Himalayas. Shah (1997) conducted a study to document the food and medicinal uses of herpetofauna and the traditional and modern methods associated with their use in different ethnic communities in Nepal.

Thakulla (1999) surveyed in Ghodaghodi Lake and identified 36 species of herpetofauna. Out of which six amphibians, 10 lizards, 15 snakes and five turtles were recorded. Shrestha (2001) has described herpetology of Nepal and claimed the occurrence of 59 amphibians and 147 reptiles in Nepal in the "field guide of Amphibians and Reptiles of Trans- Himalayan region of Asia" which gives the knowledge of herpetofauna, their distribution, economic importance and conservation strategies. Schleich and Kastle (2002) provided an account of 50 amphibians and 123 reptiles for Nepal. Rai (2002) identified 36 species of amphibians and 66 species of reptiles from Eastern Development Region. Shah and Tiwari (2004) have described 53 amphibians and 137 reptiles of Nepal.

Bhuju *et al*. (2007) provided a checklist of 195 species of herpetofauna from Nepal. Khatiwada and Ghimire (2009)investigate the status and distribution of yellow monitor lizard *Varanus flavescens* in Chitwan national park; they found 13 individuals of lizard on Forest, grassland and in agricultural land. Bista and Shah (2010) recorded 43 species of herpetofauna from Ghodaghodi Lake consisting eight amphibians and 35 reptiles, including 10 lizards, one crocodile, 11 turtles, and 13 snakes. Bista and Shah (2010) recorded 11 species of turtles including one critically endangered, two endangered and one vulnerable species from Ghodaghodi Lake. On Koshi Tappu Wildlife Reserve (Chhetry, 2010) explore 23 species of herpetofauna of which 8 species were amphibians and 15 species were reptiles.

Aryal *et al*. (2010) provided an account of 17 species of turtles from Nepal. Rai (2011) reported 29 confirmed species and 2 probable new species of amphibians from Kangchenjunga-Singalila complex Nepal. Dhungana (2011) recorded 32 species of herpetofauna from Beeshazari lake complex, Chitwan, Nepal. Khatiwada (2011) studied Amphibian assemblages along an elevation gradient from 200-1500 m in a degraded landscape in Chitwan, Nepal. On Nagarjun forest of Shivapuri National Park (Pokhrel *et al*., 2011) observed 134 individuals of 11 species among them three were amphibians and eight reptiles. Ghimire and Phuyal (2011) studied impact of community forest on bengal monitor lizard and observed 64 individuals of lizard at Jana Jagaran Community Forest of Kanchanpur district. Pandey (2012) recorded 26 species of snakes from Chitwan national park (CNP) belonging to 20 genera, of which 12 were non-venomous Species, five were mildly venomous, and nine were venomous. Kharel and Chhetry (2012) recorded 67 individuals of turtles from Kankai river, out of which 4 species were hard-shelled turtles and rest of 4 species were soft-shelled turtles.

Khambu (2013) proposed a new species of paa genus from Patenagi of Illam district and proposed new name as *Paa patenagensis* (Banded fingered hill frog). Similarly, (Chettri and Chhetry, 2013) reported 21 snake species from Sarlahi among these 5 were deadly venomous, 4 were mild venomous and the remaining 12 were non venomous.

Lamsal (2014) reported a total of 55 species of amphibian and reptile comprising 13 amphibians and 42 reptiles from Madi Valley, Chitwan and claimed an anuran *Kaloula taprobanica* to be first record for Chitwan. Baral (2014) performed habitat modeling of golden monitor lizard (*Varanus flavescens*) after surveying 235 km in Jagdispur reservoir area and he documented 19 individual through direct observations and 13 indirect signs.

Ghimire and Shah (2014) conducted a survey to find out status and habitat uses by yellow monitor lizard in Parasan of Kanchanpur district and observed 25 individuals during their four months of study. They found 8% of lizards in open areas of agriculture land, 52% were associated with bush, and 40% were associated with *Ipomoea carnea*in or around agricultural land.

Khatiwada and Haugaaswn (2015) investigated on anuran species richness and abundance along elevation gradient in CNP and found total of 17 frog species where species shows declining trend in richness and abundance with increasing elevation. Bhattarai (2015) documented *Axix axix* hunting behavior of mugger crocodile (*Crocodylus palustris*) from Bardiya national park. Khatiwada *et al*. (2015) described a new species (*Tylototriton himalayanus*) of the genus *Tylototriton* from eastern Himalaya based on molecular and morphological comparisons. Pokhrel and Thakuri (2016) reported 7 amphibians and 9 reptiles from Manaslu Conservation Area (MCA). Khatiwoda *et al*. (2016) again reported 13 species from 44 transects and they also found frogs as important predator of crop pests in CNP. Herpetofauna of Manaslu Conservation Area (MCA) was studied by (Pokhrel and Thakuri, 2016) and (Shrestha and Shah, 2017) and prepared checklist of 16 and 22 herpetofauna respectively. Bhattarai *et al*. (2017a) summarized the distribution of the Himalayan Stripe-necked Snake (*Liopeltis rappi*) in Nepal. Khatiwada *et al*. (2017a) described a new species of frog (*Microhyla teraiensis*) based on molecular and morphological comparisons. Bhattarai *et al*., (2017b) again surveyed the herpetofauna at Beeshazar and associated lakes of Chitwan National Park and recorded 47 species comprising 13 anurans, 11 lizards, 18 snakes, four turtles, and one crocodilian. In Baglung district, (Rana, 2017) explore hibernation ecology and threats of hibernating Liebig's Frog (*Nanorana liebigii*) where he identified 40 occupied and 20 unoccupied hibernating sites in seven streams and finds hunting as important threat to frog. Again from Jamun Khadi Jhapa, (Khatiwada *et al*., 2017b) sequenced complete mitochondrial genome of newly found *Microhyla taraiensis* and performed phylogenetic analysis.

Most of the studies focused on collection and preservation of checklist of Herpetofauna in Nepal. However few molecular studies have raised the reliability and standard of taxonomic research on herpetofauna. Several new species are discovered after molecular study on Nepal. In many areas, even presence absence survey, preparation of checklist has not been performed. Few altitudinal gradient studies have been performed to understand the distribution pattern of herpetofauna. Beside this, some of the molecular study has also been performed in Nepal. There are still so many aspects of herpetofauna that need to be studied. This study will explore the relation of herpetofauna with different environmental factors in Ghandruk.

3 MATERIALS AND METHODS

3.1 Study area

3.1.1 Location and Geography

Annapurna Conservation Area (ACA) covers an area of 7,269 square kilometers (Paudel and Rayamajhi, 2014). This Conservation area is managed by Annapurna Conservation Area Project (ACAP) under National Trust for Nature Conservation (NTNC). ACA is the first and largest conservation area of Nepal that was established in 1986. This conservation area spread over Manang, Mustang, Kaski, Myagdi and Lamjung district.

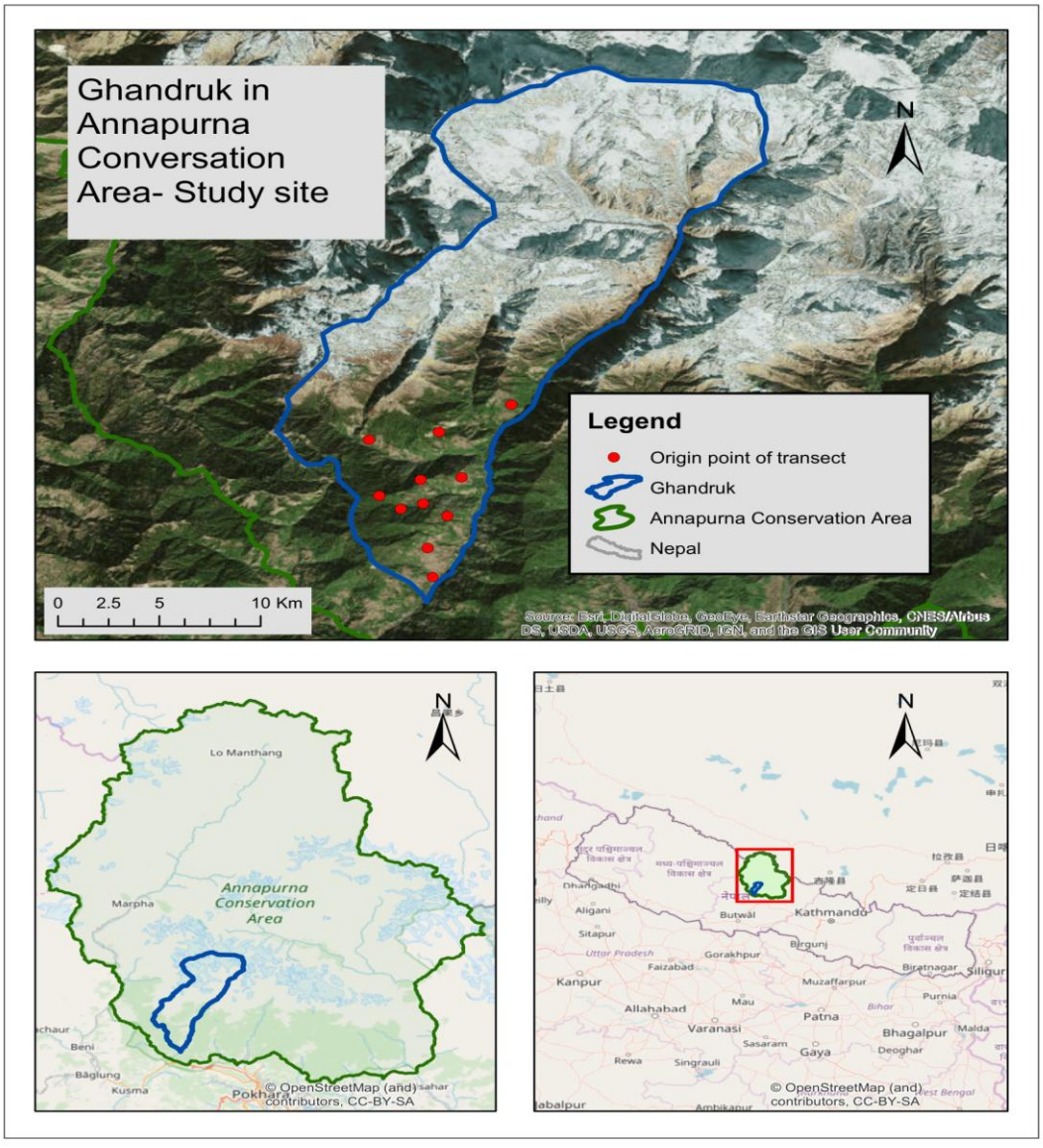


Figure 1: Study area map showing Ghandruk, ACA, Nepal

Ghandruk (28.49°N 83.84° E) is situated in the southern part of ACA (Figure 1) in Kaski district and has an area of about 21412.977 Sq. Km. Ghandruk lies to the distance of 55 km north of Pokhara. This is heterogeneous region where 22.50 percent is covered by forest, 18.50 percent is covered by Himalaya, 5.60 percent is covered by rocks, bare land and hills, 0.80 percent is covered by infertile land, 0.50 percent is covered by residential area and rest of the area 52.10 percent is covered by agricultural land (Shrestha, 2014). The geography of the study area is steep forest, with the slopes ranging from about 3° to about 75° and land features ranging from flat land to cliffs (Giri *et al.*, 2011). This region is surrounded by hills full of rhododendron flowers on one side and breathtaking scenery of mountains on the other.

3.1.2 Climate

Herpetofauna is strongly associated with climate. In Ghandruk, monsoonal rainfall begins at May and peaks at July (Figure 2). Monthly rainfall at July was 1600 mm and zero at February, November and December.

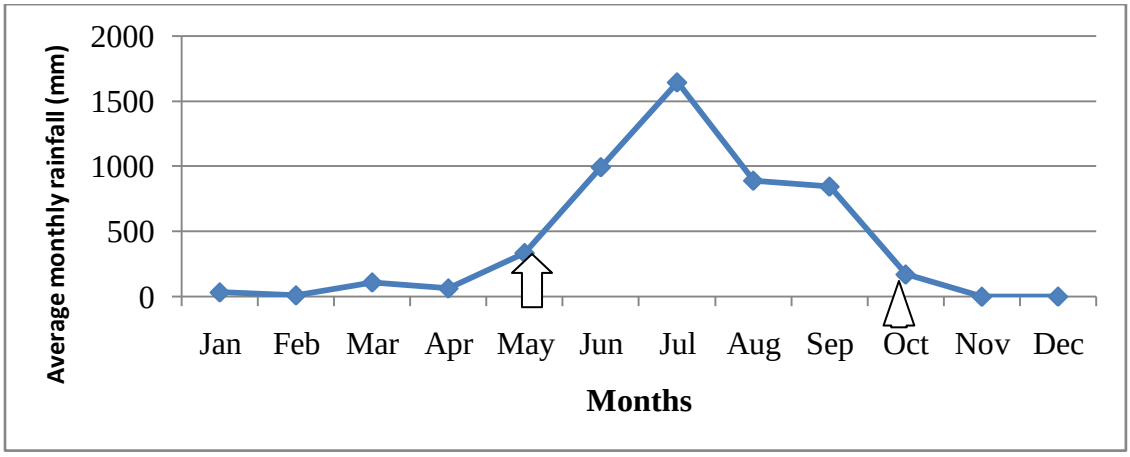


Figure 2: Monthly rainfall (mm) pattern in Ghandruk in 2017 (Source: DHM, 2017).

Data were collected during the month of May and October. Total monthly rainfall of May and September were 335.5mm and 845.6mm respectively.

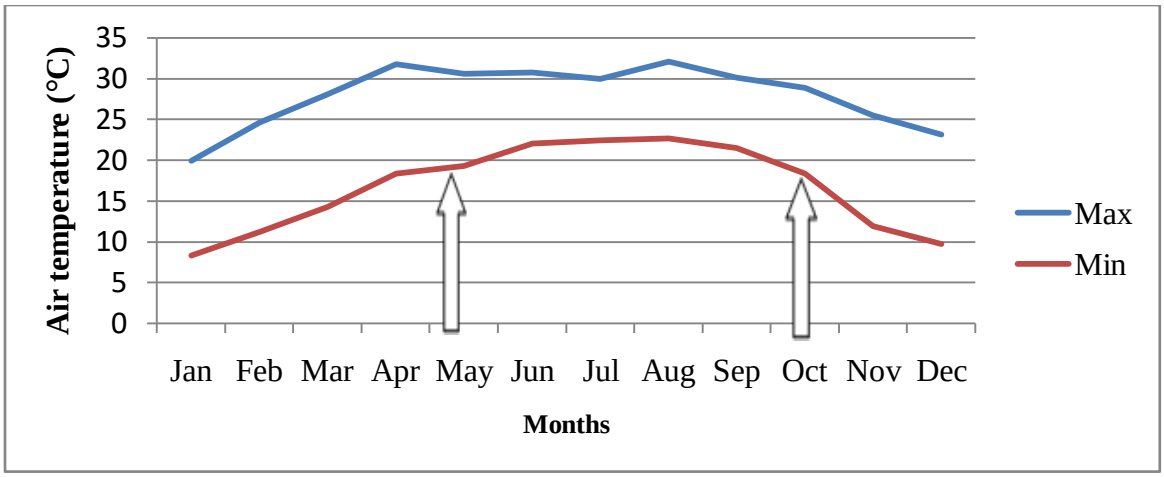


Figure 3: Maximum and minimum mean temperature of Kaski (Source: DHM, 2017).

There was similar temperature in two seasons at Ghandruk during the period of field survey. Average maximum temperature during the month of May and October was 30.6 and 30.1 respectively.

3.1.3 Biodiversity

The area is considered in terms of cultural diversity, bio-diversity and a house for 1,226 species of plant species, 38 orchid species, nine rhododendron species, 101 mammals, 474 birds, 39 reptiles, and 22 amphibians (Paudel and Rayamajhi, 2014).

The vegetation around the Birethati is dominated by riverine *Alnus nepalensis* forests associated with *Ficus semicordata, Erythrina stricata, Colebrokia oppositifolia* and *Dioscorea bulbifera*. Between Syaulibazar and Ghandruk, the major dominant forest is of *Alnus nepalensis, Prunus coronata, Rubia cordifoli* and *Hippophae salicifolia*. The south facing forests of Kyumrong mainly consisted of *Rhododendron aroboreum, Juglans regia* and *Lyonia ovalifolia* as dominant species. Small herbs like *Impatiens sulcata, Begonia dioica*, and *Swertia chirayta* are also found in this region. The north facing forests of Chhomrong consist of *Albizzia* spp. *Rhododendron aroboreum, Juglans regia,* and *Q. semecarpifolia*. Vegetation around Bamboo consisted of *Arundo donax, Prunus nepalensis, Persea odoratissima,* and *Vibrunum erubescens* as the main tree species. Herbs such as *Corydalis*spp, *Polygonium*spp, *Urtica dioica,* and *Chlorophytum nepalensis* are also distributed on this area (Rajbhandary, 2011).

This region has mammals like *Panthera uncia, Pseudois nayaur, Vulpes uulpes. Marmota himalayana, Ochotona roylei, Mustela nivalis, Martes foina*, and *Alticola sikkimensis*. The avifauna is relatively diverse and includes *Tetraogallus tibetanus, Tetraogallus himalayensis,* and *Alectoris chukar* (Oli *et al*., 1993). Herpetofauna of this region include *Bufo himalayanus, Bufo melanostictus, Megophrys parva, Amolops formosus, Chaparana*

sikkimensis, Paa liebigii, Paa blanfordii, Laudakia tuberculata, Varanus flavescens, Oligodon erythrogaster (Shah, 2001)

3.2 Materials used

Following tools were used in the study:

a) Measuring tape
b) Snake tong
c) Head light
d) Flash light
e) Field note book
f) Pencil
g) Gloves
h) GPS device (Garmin - Etrex10)
i) Magnetic Compass
j) Topographic Map
k) Field guide books of herpetofauna

3.3 Methods

3.3.1. Preliminary survey and sampling design

Prior to the field sampling, a preliminary survey was carried done in April 2017 so as to get knowledge on geography and feasibility of possible sampling sites. During this preliminary survey, interactions with local people and an assessment of potential sites was done before sampling design. During preliminary survey all the possible route and location was recorded on GPS and later transects was designed (Figure 1) on the basis of habitat and feasibility to conduct nocturnal survey. Eleven points were randomly generated (Table 1) on previously known locations through ArcGis. From each point 500m distance to any directions on possible trail was considered as one transects.

Table1: Detail of line Transects (T= Transect)

Site	Latitude	Longitude	Elevation	Habitat
T1	28.396	83.816	1060	Wetland
T2	28.3431	83.8033	1195	Wetland
T3	28.42	83.806	1911	Agriculture
T4	28.416	83.775	1645	Wetland
T5	28.3755	83.80975	2072	Settlement
T6	28.35858	83.801	1759	Agriculture
T7	28.39474	83.79782	2132	Barren land
T8	28.38211	83.79902	1876	Grassland
T9	28.43455	83.83819	2331	Forest
T10	28.37922	83.789	2223	Forest
T11	28.38622	83.7795	2537	Forest

Nepal has four distinct climatic seasons: pre-monsoon (March to May), Summer Monsoon (June to September), post-monsoon (October to November), and the winter season

(December to February) (Pokharel and Hallett, 2015). Data were collected during end of May for pre monsoon season and October for post monsoon season. In each season, 10 days field work was carried out with both nocturnal and diurnal survey in transects (Figure 1).

A 2 meter distance from the line was chosen to have a reasonable search area of [500m × (2m+2m)] =2000m^2 (Lamsal, 2014). On sighting herpetofauna, data on number of individuals, coordinate, altitude, distance to water/settlement/road, leaf litter cover, canopy cover, shrub cover and microhabitat types were recorded. Minimum distance of water source, settlement and road from observation site was measured. Canopy cover was measured with the help of densitometer. Among 96 dots in smaller square areas within the grid, number of dots with tree shadow was observed and then multiplied by 1.04 to obtain the percent of canopy cover. Leaf litter and shrub cover percentage was recorded through visual estimation method.

3.3.2. Time and distance constrained visual encounter surveys (VES)

Visual encounter survey is widely used in herpetofaunal survey (Heyer *et al*., 1994). VES was adopted in each transect on both season. This method is widely used as a sampling method for reptiles and amphibians (Crump and Scott, 1994; Doan, 2003). Two observers walked through 11 transects and 1 hour was spend on each transect. VES was done during day and night to record both diurnal and nocturnal species. Rigorous search was conducted in all probable microhabitats such as boulders, fallen logs; leaf litter and other debris to capture species. The search was conducted during day (10:00 to 16:00) and evening (18:00 to 22:00) hours. For nocturnal survey a torch beam was used to locate the animal (Behangana and Arusi, 2004).

3.3.3 Opportunistic Survey

It is a method which ensures inclusion of species found besides other standardized methodologies (Durkin *et al*., 2011).These were records and observations of species that were obtained incidentally rather than during a specific sampling occasion. Such species records were pooled with that of the other systematic methods to contribute to total species richness data.

3.3.4 Species identification

All the species were identified on the basis of morphological characteristics and photographs. Species were identified with the help of standard literature and the keys used in (Schleich and Kastle, 2002; Shah and Tiwari, 2004; Whitaker and Captain, 2004; Schleich and Rai, 2012a, 2012b, 2012c; Kastle *et al*., 2013). Online data base of http://www.reptile-database.org/ and http://www.indiansnakes.org/ was also followed to identify reptilian species. Any collection and preservation of species were not performed. Photographs of unidentified and doubtful species were discussed with senior herpetologist of Nepal.

3.4 Data analysis

Data was processed from Excel 2007. Shannon diversity index were performed from excel to measure the diversity of herpetofauna community. Other analyses were:

3.4.1 Simple linear regression

Simple linear regression (Sanders *et al*., 2003) was used to determine the species richness and abundance pattern along the elevation gradient. Regression was performed separately for species richness and abundance. Elevation was taken as Independent variable for both the cases and either species richness or abundance was taken as dependent variable in each case. Minitab (version 16.1.1) was used to perform Simple linear regression.

3.4.2 ANOVA

One way ANOVA (Malonza, 2015) was performed to determine the distribution of herpetofauna in different habitat types. During ANOVA test, habitat type was considered as independent variables and species richness and abundance were considered as dependent variable. Minitab (version 16.1.1) was used to perform ANOVA.

3.4.3 t-Test

Paired t test was used in statistic software R Console (version 3.4.3) to test the seasonal variation in herpetofauna. Pre monsoonal and post monsoonal abundance and species richness were compared with the analysis of paired t-test (McCain, 2010).

3.4.4 Generalized linear model (GLM)

Generalized linear model (Khatiwada *et al*., 2016) was applied to investigate the effect of environmental variables (canopy cover, leaf litter cover, shrub cover, Distance to water sources, Distance to settlement and Distance to road) on species richness. Species richness was taken as response variable and all other environmental variable was considered as predictor. GLM was performed in R Console (version 3.4.3) with vegan community ecology package.

3.4.5 Variation partitioning analyses (VPA)

Variation partitioning analyses (VPA) were conducted in R console (version 3.4.3) using the function "varpart" in the package ''vegan". VPA is a multiple regression analysis which is used to identify common and unique contributions of independent variables (predictor) to species richness (respond model) (Borcard *et al*., 1992). For VPA, elevation, canopy cover, shrub cover, leaf litter cover, distance to water, distance to road and distance to settlement

were taken as independent variable or explanatory variable (predictor) and species richness of herpetofauna is taken as dependent variable. Four explanatory matrix were fitted to explain the species richness, first matrix was elevation, second was the combination of canopy cover, shrub cover and leaf litter cover which explains the habitat character, third matrix explains the disturbance which include the distance to road and to settlement, forth matrix represent distance to water sources.

4 RESULTS

4.1 Species composition and abundance of herpetofauna:

Six hundred and sixty two individuals of Twenty five species of herpetofauna belonging to nine family and 21 genera were recorded (Table 2). All the species of herpetofauna belongs to two order- Anura and Squamata. The Shannon Diversity Index (H') shows high diversity of herpetofauna (H' = 2.38) in Ghandruk. The diversity was remarkably dominated by the order Anura (H' = 1.964) upon order squamata (H' = 1.63).

Table 2: Record of herpetofauna in Ghandruk (A- Agricultural land, W-Wetland, S-Settlement, G-Grassland, F-Forest, B-Barren land)

Name	Family	Habitat	Abundance
Amphibians:			
Duttaphrynus melanostictus (Schneider, 1799)	Bufonidae	A, G, S, W, F	13.27%
Duttaphrynus himalayanus (Günther, 1864)	Bufonidae	A, G, S, W, F	14.02%
Megophrys parva (Boulenger, 1893	Megophryidae	A, G, W, F	4.49%
Amolops marmoratus (Blyth, 1855)	Ranidae	W	0.56%
Amolops formosus (Günther, 1876)	Ranidae	W	1.68%
Nanorana liebigii (Günther, 1860)	Dicroglossidae	W	4.86%
Nanorana ercepeae (Dubois, 1974)	Dicroglossidae	W	0.93%
Nanorana blanfordii (Boulenger, 1882)	Dicroglossidae	W, F	1.87%
Zakerana syhadrensis (Annandale, 1919)	Dicroglossidae	W, F	2.99%
Fejervarya nepalensis (Dubois, 1975)	Dicroglossidae	W, F, A	24.49%
Euphlyctis cyanophlyctis (Schneider, 1799)	Dicroglossidae	W, F	27.48%
Ombrana sikimensis (Jerdon, 1870)	Dicroglossidae	W, G	3.36%
Reptiles:			
Laudakia tuberculata (Gray, 1827)	Agamidae	B, G, F	33.07%
Japalura tricarinata (Blyth, 1853)	Agamidae	F	2.36%
Calotes versicolor (Daudin, 1802)	Agamidae	G	2.36%
Asymblepharus sikimmensis (Blyth, 1854)	Scincidae	G, F, S, W	40.94%
Orthriophis hodgsoni (Günther, 1860)	Colubridae	S	0.79%
Pseudoxenodon macrops (Blyth, 1854)	Colubridae	F	0.79%
Herpetoreas platyceps (Blyth, 1854)	Colubridae	B, G, F,S, W, A	7.87%
Ovophis monticola (Günther, 1864)	Viperidae	G, A, F	3.94%
Lycodon aulicus (Linnaeus, 1758)	Colubridae	A	0.79%
Ptyas mucosa (Linnaeus, 1758)	Colubridae	G, S	2.36%
Xenochrophis piscator (Schneider, 1799)	Colubridae	S, W	2.36%
Ophiophagus hannah (Cantor, 1836)	Elapidae	S	0.79%
Oligodon erythrogaster Boulenger, 1907	Colubridae	F	1.57%

4.1.1 Amphibians

A total number of 535 individuals of 12 species of amphibians belonging to single order Anura were encountered during the field survey (Table 2). The Shannon Diversity Index (H') of Amphibian was 1.964 and all of these amphibians belongs to single order- Anura, four families and eight genera. Dicroglossidae was the most abundant amphibian family, comprising 58.33% of total number of species (seven species) recorded and 65.98% of total individual observed. Other amphibian families are Ranidae (two species), Bufonidae (two species) and Megophryidae (one species). *Euphlyctis cyanophlyctis* (27.47%) was most abundant amphibian species followed by *Fejervarya nepalensis* (24.48%), *Duttaphrynus himalayanus* (14.01%), *Duttaphrynus melanostictus* (13.27%), *Nanorana liebigii* (4.85%), *Megophrys parva* (4.48%), *Ombrana sikimensis (*3.36%), *Zakerana syhadrensis* (2.99%), *Nanorana blanfordii* (1.86%), *Amolops formosus* (1.68%), *Nanorana ercepeae* (0.96%) *and Amolops marmoratus* (0.6%) was least abundant among the amphibian species.

4.1.2 Reptiles

A total number of 127 individuals of 13 different species of reptiles were observed during the field survey (Table 2). The Shannon Diversity Index (H') of Reptile was 1.63 in study area. All of these reptiles belong to order squamata and five families and 13 genera (Table 2). Herpetofauna of Nine families were recorded during the survey among them Bufonidae, Megophryidae, Ranidae and Dicroglossidae belongs to amphibian and family Agamidae, Scincidae, Colubridae, Viperidae and Elapidae belongs to reptiles.
Asymblepharus sikimmensis (40.94 %) were mostly found species followed by *Laudakia tuberculata* (33.07%), *Herpetoreas platyceps* (7.87%), *Ovophis monticola* (5.94%), *Ptyas mucosa* (2.36%), *Xenochrophis piscator* (2.36%), *Japalura tricarinata* (2.36%), *Calotes versicolor* (2.36%), *Oligodon erythrogaster* (1.57%), *Orthriophis hodgsoni* (0.79%), *Pseudoxenodon macrops* (0.79%), *Lycodon aulicus* (0.79%) and *Ophiophagus hannah* (0.79%).

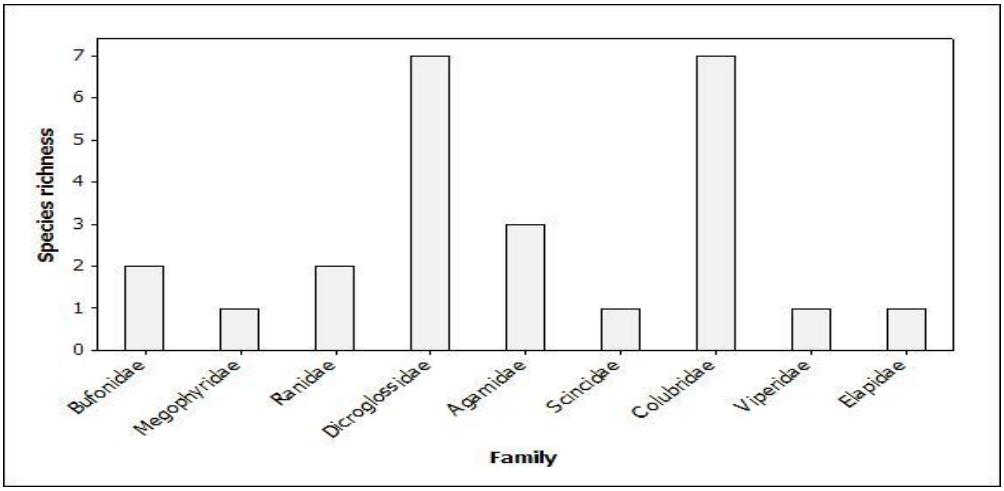


Figure 4: Family wise species richness of Herpetofauna, in Ghandruk, 2017.

Six hundred and sixty two individuals of herpetofauna were recorded among them Colubridae had the highest number of species (Eight species) followed by Dicroglossidae (Seven species), Agamidae (Three species), Bufonidae (Two species), Ranidae (Two species), Megophryidae (one species), Scincidae (one species), Elapidae (one species) and Viperidae (one species) (Figure 4).

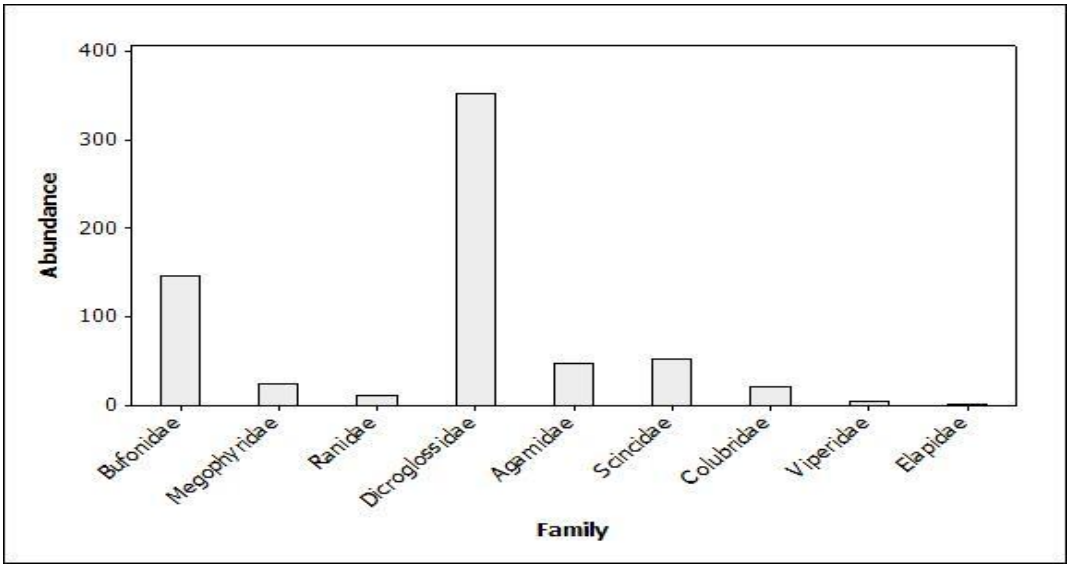


Figure 5: Family wise abundance of Herpetofauna.

Abundance of Dicroglossidae was highest followed by Bufonidae, Scincidae, Agamidae, Colubridae, Megophryidae, Ranidae, Viperidae and Elapidae (Figure 5).

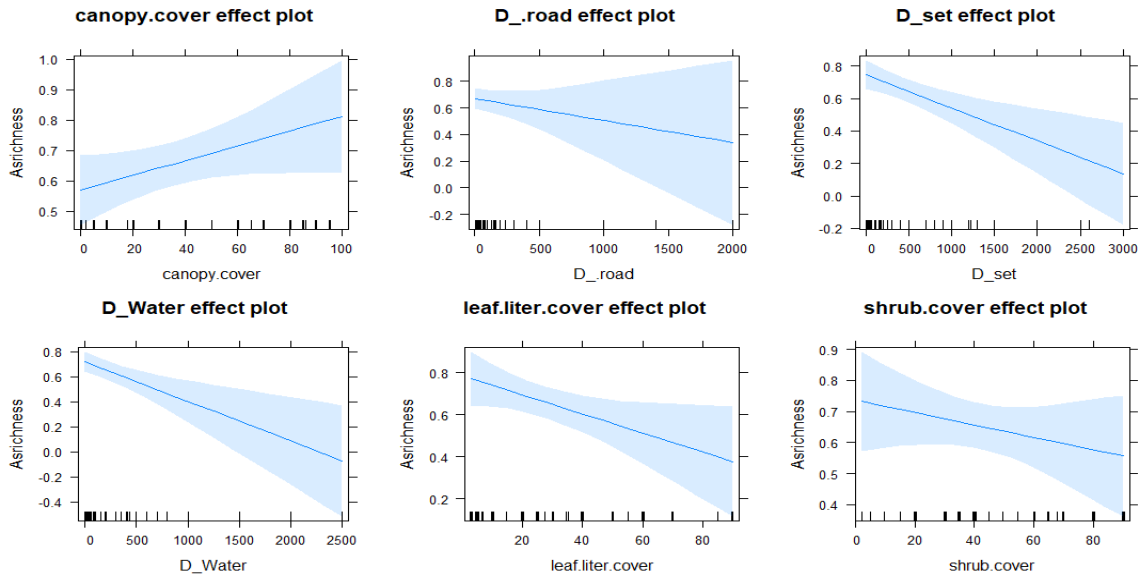
4.1.3 Effect of environmental factors on species richness

Species richness of Amphibian was influence by different factors. Amphibian diversity was significantly related with explanatory variables like distance to water, settlement and Leaf litter cover (Table 3). GLM does not predict any significant relation between amphibian diversity with canopy cover, distance from road and shrub cover.

Table 3: GLM result of Amphibian species richness with different environmental factors

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.95609322	0.09503386	10.061	2.00E-16
Canopy cover	0.00242145	0.00132526	1.827	0.06994.
Distance from road	-0.00016615	0.00016329	-1.017	0.31079
Distance from settlement	-0.00020415	0.00006086	-3.355	0.00104
Distance from Water	-0.00031732	0.00009699	-3.272	0.00136
Leaf litter cover	-0.00454638	0.00208399	-2.182	0.0309
Shrub cover	-0.0019991	0.00187262	-1.068	0.28767

Species richness of amphibians showed significant negative association with distance to distance to human settlement, distance to water bodies and leaf litter cover (Table 3). Though Species richness of amphibians found negatively associated with distance to road and Shrub cover (Figure 6) but their role on species richness was not found significant. It was found that canopy cover was only positively associated with species richness of amphibian but its role was also insignificant.



(ASrichness= Amphibian species richness)

Figure 6: Effect plot of Canopy cover, Distance from road, Distance from settelment, Distance from water, Leaf litter cover and Shrub cover on Species richness of amphibian.

Role of different explanatory variables on species richness of reptiles was tested through GLM. It was found that Species richness of reptiles was significantly associated with leaf litter cover, distance of water, distance of settelment and canopy cover (Table 4).

Table 4: GLM result of species richness of reptile with different environmental variables.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.089564	0.094822	0.945	0.34662
Shrub cover	0.001989	0.001868	1.065	0.28902
Leaf litter cover	0.005063	0.002079	2.435	0.01623
Distance from Water	0.000274	9.68E-05	2.827	0.00543
Distance from settlement	0.000264	6.07E-05	4.345	0.0000275
Distance from road	0.000132	0.000163	0.808	0.42075
Canopy cover	-0.00374	0.001322	-2.831	0.00537

Species richness of reptiles showed significant positive association with Leaf liter cover, Distance from Water, Distance from settlement and significant negative association with canopy cover (Table 4). Though Species richness of reptile found positively associated with distance to road and shrub cover (Figure 7) their role on species richness was not found significant.

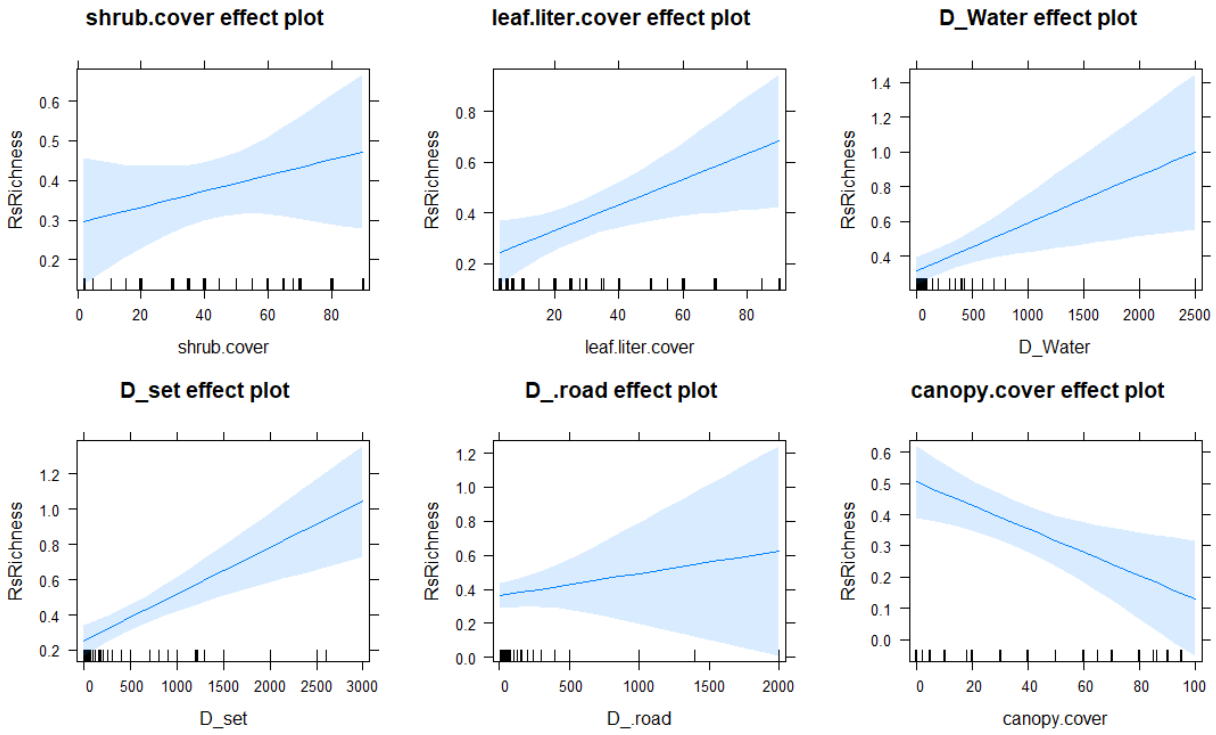


Figure 7: Effect plot of Shrub cover, Leaf litter cover, Distance from water, Distance from settelment, Distance from road and Canopy cover on Species richness of reptiles.

Variation partitioning was performed to evaluate the combinational effect of different environmental variables on total species richness of herpetofauna. Explanatory factors like Elevation, habitat character, disturbance and water distance together contribute three percent, nine percent, forty percent and thirty five percent on species richness of herpetofauna (Figure 8). Habitat character like canopy cover, shrub cover and leaf litter explains only five percent for species richness. Combinational effect of habitat character and disturbance contribute another two percentage effects on species richness. Water distance has second highest contribution on variation of species richness its single contribution was 34%. Combination of water distance and habitat character has contribution of one percent on species richness. Water distance alone had significant effect on richness but its combine effect with elevation and habitat character was not found on species richness.

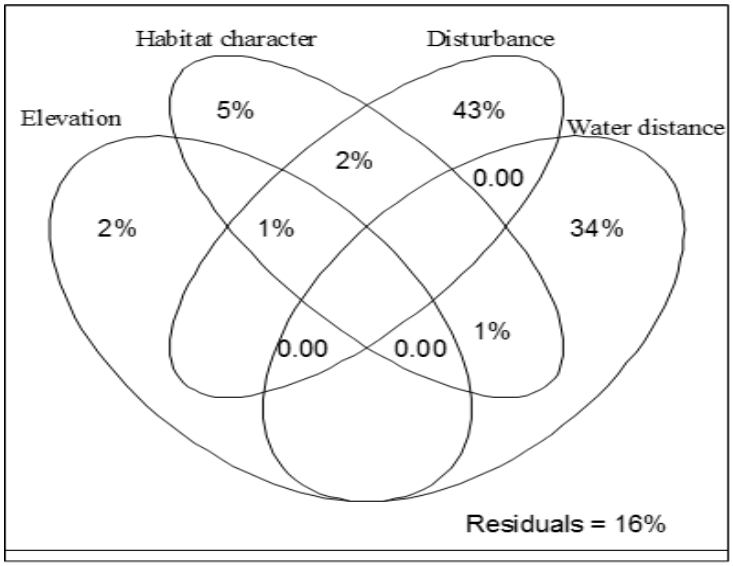


Figure 8: Variation partition analysis showing the relative influence of different variables on the species richness of herpetofaunal.

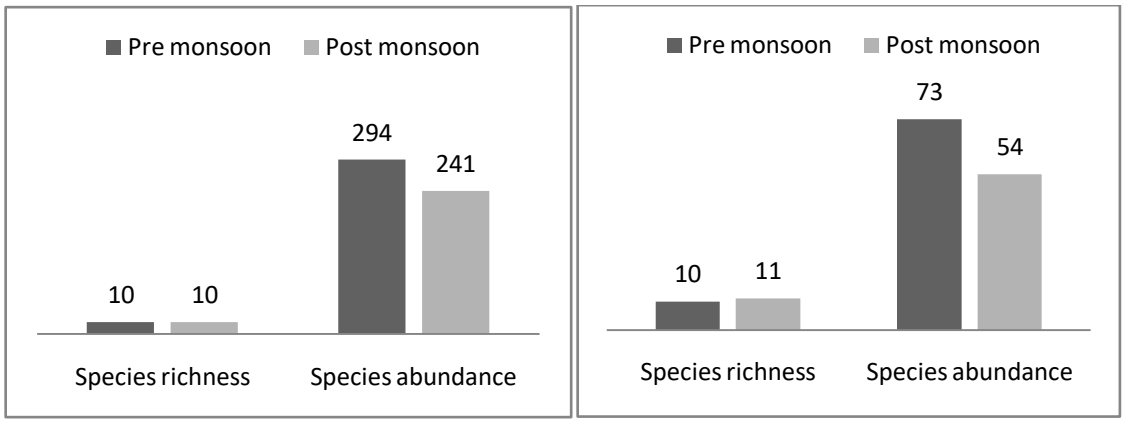
Disturbance factor like distance to road and settlement explains highest variance (43%) for species richness (Table 5). In case of disturbance also combinational effect of disturbance with distance to water was not seen on species richness. Elevation alone found to have only two percent effect on variation of species richness of total species but its combination with habitat character and disturbance contribute another one percent on richness. However there was no any combinational effect of elevation with habitat character, disturbance and distance to water on species richness. Similarly combination of habitat character, disturbance and water distance also had no any effect on species richness.

Table 5: Explanatory tables of Variation partition analysis:

Explanatory variable	No of variables	R square	Contribution
Elevation	1	0.02331	2%
Habitat characters (Canopy cover, Shrub cover, Leaf litter cover)	3	0.14272	5%
Disturbance (Distance to Road, Distance to settlement)	2	0.44392	43%
Distance to water	1	0.35441	34%
Elevation + Habitat character	4	0.15495	0%
Elevation + Disturbance	3	0.4675	0%
Elevation + Distance to water	2	0.37409	0%
Habitat character + Disturbance	5	0.54609	2%
Habitat character + Distance to water	4	0.47036	1%
Disturbance + Distance to water	3	0.78502	0%
Elevation + Habitat character + Disturbance	6	0.5657	1%
Elevation + Habitat character + Distance to water	5	0.48061	0%
Elevation + Disturbance + Distance to water	4	0.80614	0%
Habitat character + Disturbance + Distance to water	6	0.84606	0%
Elevation +Habitat character + Disturbance + Distance to water	7	0.86657	0%

4.2 Seasonal variation of herpetofauna

Paired t test was performed to compare mean differences of species richness and abundance of herpetofauna between pre monsoon and post monsoon season. There was no any significant difference in species richness (t-value = -1.30, P-Value = 0.220) and abundance (t-value = 0.73, P-Value = 0.478) in between pre monsoon and post monsoon season. Shannon diversity index (H') shows that diversity of herpetofauna was slightly higher in post monsoon (H'=2.26) than pre monsoon (H'=2.19). It was found that species richness of herpetofauna was high at post monsoon but abundance was found higher at pre monsoon season. Among 25 herpetofauna species recorded, 20 species were found during pre-monsoon season and 21 species were found on post monsoon season. Equal amphibian species were recorded in both pre monsoon and post monsoon season however there was difference in species compositions. In case of reptiles there were 10 species in pre monsoon and 11 were present in post monsoon season (Figure 9A). In both season species composition was different. During pre-monsoon season 367 individuals of herpetofauna was recorded among them 294 were amphibians and 73 were reptiles (Figure 9). During post monsoon season 295 individuals of herpetofauna were recorded among them 241 were amphibians and 54 were reptiles. *Ophiophagus hannah, Ptyas mucosa, Lycodon aulicus, Ombrana sikimensis* and *Amolops marmoratus* were absent during pre monsoon season and *Nanorana ercepeae, Zakerana syhadrensis, Orthriophis hodgsoni* and *Pseudoxenodon macrops* were absent during post monsoon season.



A B

Figure 9: Seasonal pattern of species richness and abundance of amphibian (A) and reptiles (B) respectively.

Sixty four percent of species were recorded consistently during both the season and those species were *Duttaphrynus melanostictus, Duttaphrynus himalayanus, Megophrys parva, Amolops formosus, Nanorana liebigii, Nanorana blanfordii, Fejervarya nepalensis and Euphlyctis cyanophlyctis, Laudakia tuberculata, Japalura tricarinata, Calotes versicolor, Asymblepharus sikimmensis, Herpetoreas platyceps, Ovophis monticola, Xenochrophis piscator* and *Oligodon erythrogaster. Euphlyctis cyanophlyctis* (41.49%) was most abundant amphibian species during pre monsoon season. Similarly In post monsoon season *Fejervarya nepalensis* (40.66%) was most abundant amphibian species (Figure 10). *Asymblepharus sikimmensis* was abundant among reptile species (Figure 11) in both pre monsoon (43.83%) and post monsoon season (37.03%).

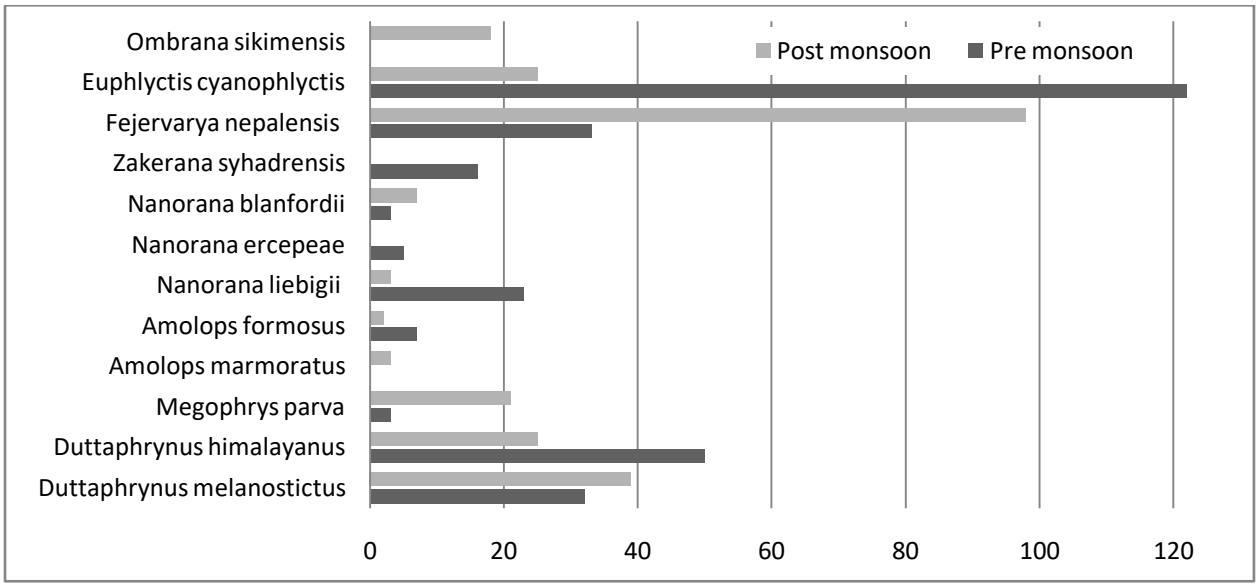


Figure 10: Comparison of Amphibian abundance in Pre monsoon and Post monsoon, 2017.

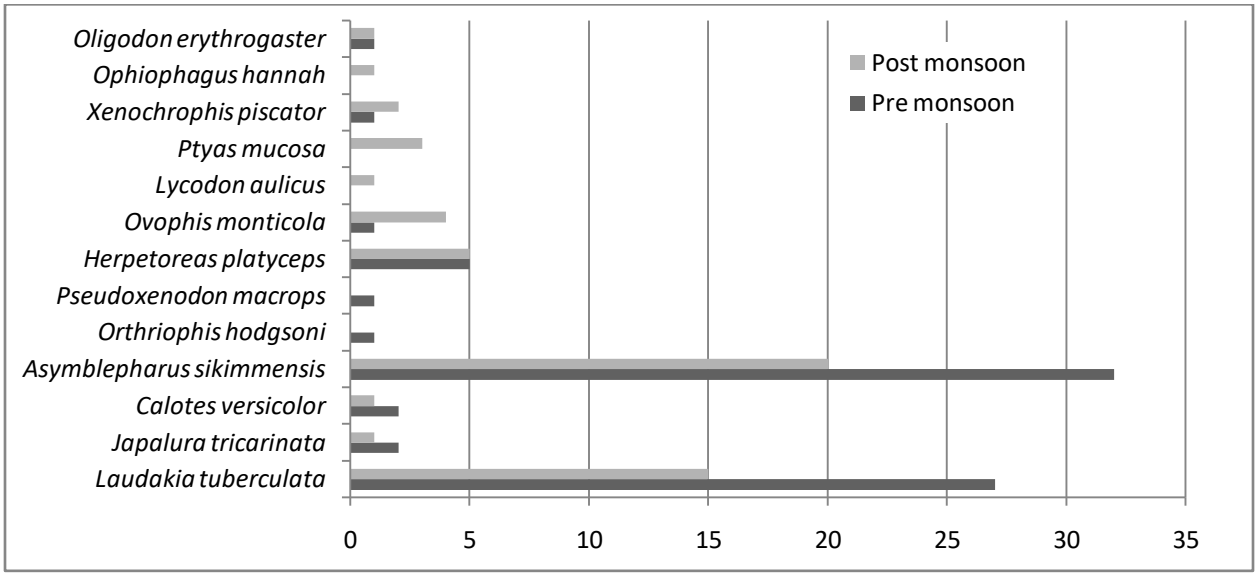


Figure 11: Comparison of Reptilian abundance in Pre monsoon and Post monsoon, 2017.

On comparing species abundance between pre monsoon and post monsoon season Abundance of *Duttaphrynus melanostictus, Megophrys parva, Amolops marmoratus, Nanorana blanfordii, Fejervarya nepalensis, Ombrana sikimensis, Ovophis monticola, Lycodon aulicus, Ptyas mucosa, Xenochrophis piscator* and *Ophiophagus hannah* increases at post monsoon season. However abundance of *Duttaphrynus himalayanus, Amolops formosus, Nanorana liebigii, Nanorana ercepeae, Zakerana syhadrensis, Euphlyctis cyanophlyctis, Laudakia tuberculata, Japalura tricarinata, Calotes versicolor, Asymblepharus sikimmensis, Orthriophis hodgsoni, Pseudoxenodon macrops* decreases at post monsoon. In both the season abundance of *Herpetoreas platyceps* and *Oligodon erythrogaster* were unchanged with abundance of one and five respectively.

4.3 Distribution pattern of herpetofauna along elevational gradient

Survey was conducted from 1,000 m up to 2,700m and species were categorized under 100m each band in the study area. Highest species richness (13 species) was recorded from elevation range of 1900m and least species richness (1 species) was recorded from 1,300 m elevation bands. From 1900m species like *Duttaphrynus melanostictus, Duttaphrynus himalayanus, Megophrys parva, Nanorana liebigii, Nanorana blanfordii were recorded, Zakerana syhadrensis, Fejervarya nepalensis, Ombrana sikimmensis, Laudakia tuberculata, Asymblepharus sikimmensis, Orthriophis hodgsoni, Herpetoreas platyceps* and *Ovophis monticola* were recorded. *Duttaphrynus melanostictus* was the single species recorded at the elevation of 1300m.

There was a declining trend in species richness and abundance with increase in altitude (Figure 12). Elevation was negatively correlated with species richness, but their linear

relationship was not significant (r^2 = 0.009018, p= 0.9256). But in case of species abundance, simple regression analysis clearly shows significant linear pattern of abundance with altitude (r^2 = 0.09321, p < 0.05).

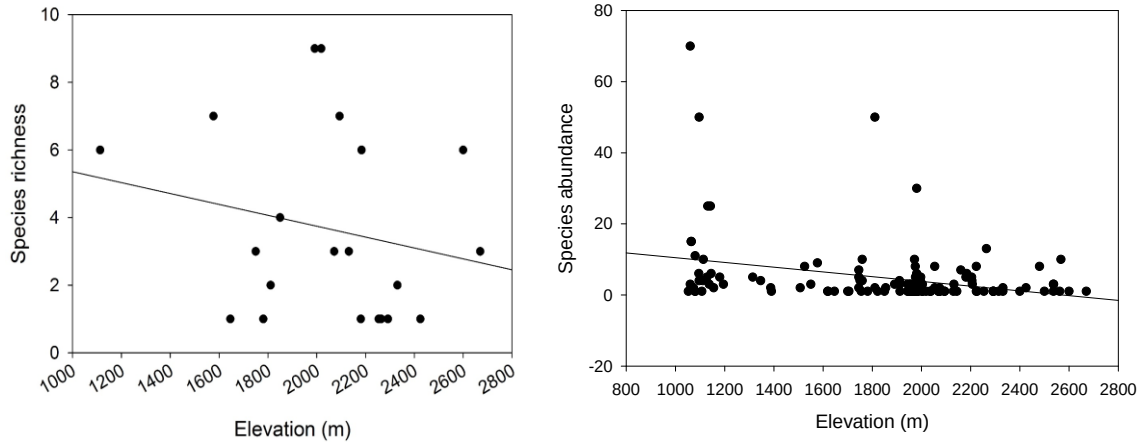


Figure 12: Linear regression model showing the effect of elevation on Herpetofaunal species richness and abundance.

There was irregular distribution pattern of herpetofauna along with elevation gradient (Figure 13). Highest species abundance was found at 1,000 m elevation where species richness was seven but both richness and abundance dropped to zero at 1,200 m and 1,400m. Gradually from an elevation of 1,600m both richness and abundance goes increasing and get sharp pick up at 1,900m where richness and abundance were 13 and 176 respectively. There was sharp fall in richness and abundance from 1,900 m to 2,100 m and with some slight fluctuation on 2,200 m richness shows decreasing trend up to 2,600m.

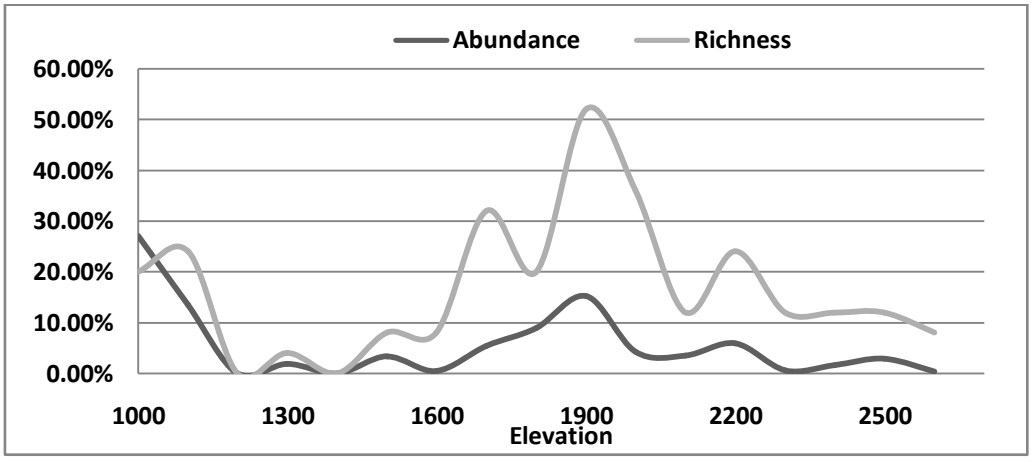


Figure 13: Species richness and abundance pattern of herpetofauna along elevation gradient.

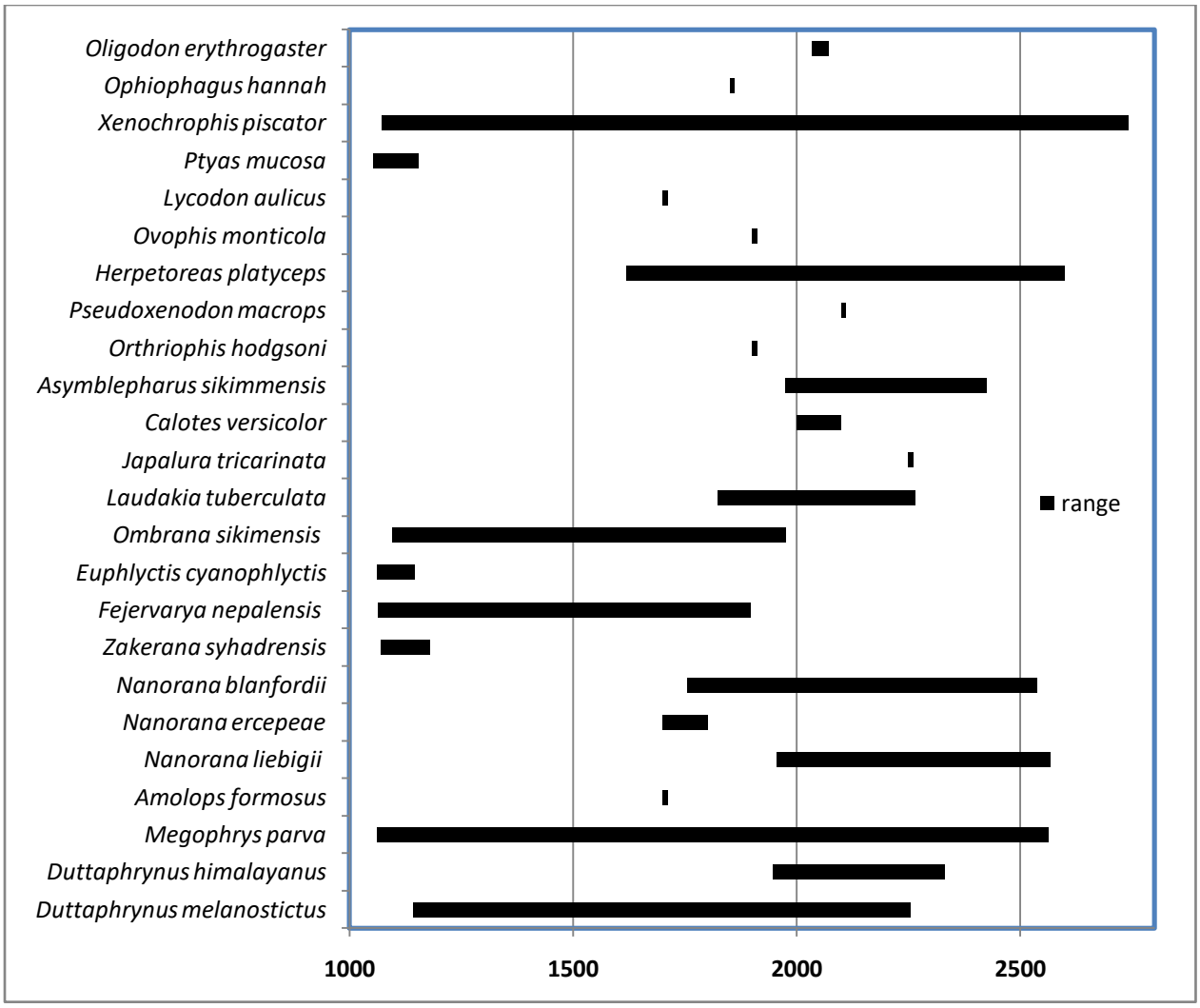


Figure 14: Elevational range of species at Ghandruk, 2017.

Among amphibian species *Nanorana liebigii* were found from the highest elevation (2,567m) and *Euphlyctis cyanophlyctis* were found from lowest elevation (1,058m). In case of reptiles *Ptyas mucosa* was recorded at the lowest elevation (1,052m) and *Xenochrophis piscator* was recorded at the highest elevation (2,670 m). Many species were distributed on large elevation range. *Megophrys parva* and *Xenochrophis piscator* was amphibian and reptilian species shows high elevation range (Figure 14).

4.4 Distribution of herpetofauna on different Habitat type

Herpetofauna was not uniformly distributed among different habitat type (Figure 15). There was significant difference ($F=3.42$, $P<0.01$) in species richness of herpetofauna in different habitat types (Table 6).

Table 6**:** One-way ANOVA table between species richness of herpetofauna and different habitat types

Source	DF	SS	MS	F-value	P-value	Remarks
Factor	5	3.633	0.727	3.42	0.006	significant
Error	144	30.640	0.213			

Herpetofaunal species richness was found highest (52%) at forest followed by wetland (48%), grassland (48%), agriculture (28%), settlement (28%) and least at barren habitat (8%). But herpetofaunal abundance was found highest at wetland (43.2%) followed by agriculture (20.84%), grassland (15.25%), forest (11.17%), barren (5.43%) and least at settlement (4.07%).

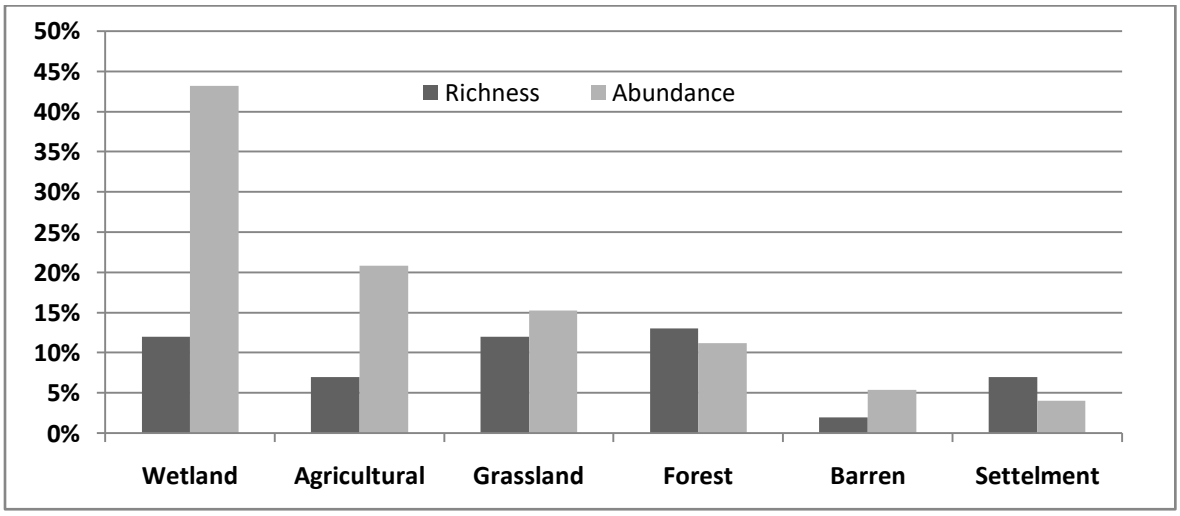


Figure 15: Distribution of herpetofauna on different habitat type of Ghandruk, 2017.

However, herpetofaunal abundance was not found significantly different ($F= 1.78$, $P>0.05$) in different habitat type (Table7).

Table 7: One-way ANOVA table between abundance of herpetofauna and different habitat types

Source	DF	SS	MS	F-value	P-value	Remarks
Factor	5	1820	364	1.78	0.12	Not significant
Error	144	29380	204			

One way ANOVA also shows that amphibian species richness differ significantly with habitat types ($F = 6.26$, $P < 0.001$). Most of the amphibian species (91.67%) were found on wetland habitat followed by grassland (50%), forest (41.67%), agriculture (33.33%), settlement (25%) and none of the amphibian species were found on the barren habitat (Figure 15).

Table 8: One-way ANOVA table between abundance and richness of amphibian and reptile in different habitat types

	F-value	P-value	Remarks
Amphibian abundance	2.72	0.027	Significant
Amphibian richness	6.26	0.001	Highly significant
Reptile abundance	0.83	0.534	Not significant
Reptile richness	2.69	0.028	Significant

Similarly, Species richness of reptile was also found significantly different in different habitat type ($F=2.69$, $p<0.05$).In forest habitat, 61.54% species were found followed by grassland (46.15%), settlement (30.77%), agricultural (23.07%), barren (15.38%) and only 7.6% species were found on wetland habitat (Figure 16).

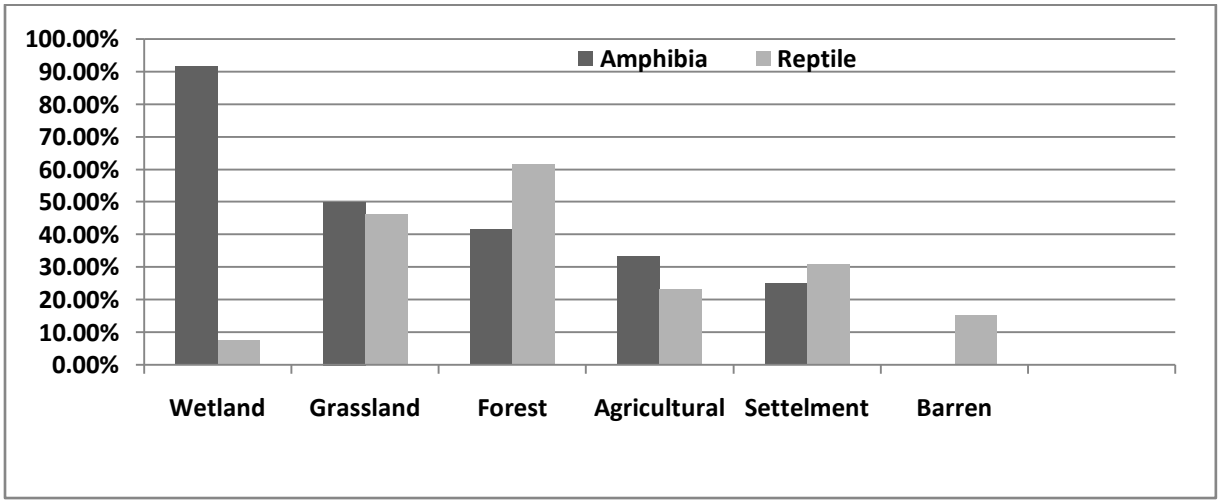


Figure 16: Species richness of amphibian and reptiles on different habitat type, 2017.

Nanorana ercepeae and *Ombrana sikimensis* were recorded from single habitat type, *Nanorana liebigii* and *Zakerana syhadrensis* were recorded from two different type of habitat. Similarly *Fejervarya nepalensis, Nanorana blanfordii* and *Amolops marmoratus* were recorded from three different type of habitat. *Duttaphrynus himalayanus* and *Duttaphrynus melanostictus* were recorded from four different habitat and *Megophrys parva* was recorded from five different habitat types. There was no any common amphibian species for all six habitat type.

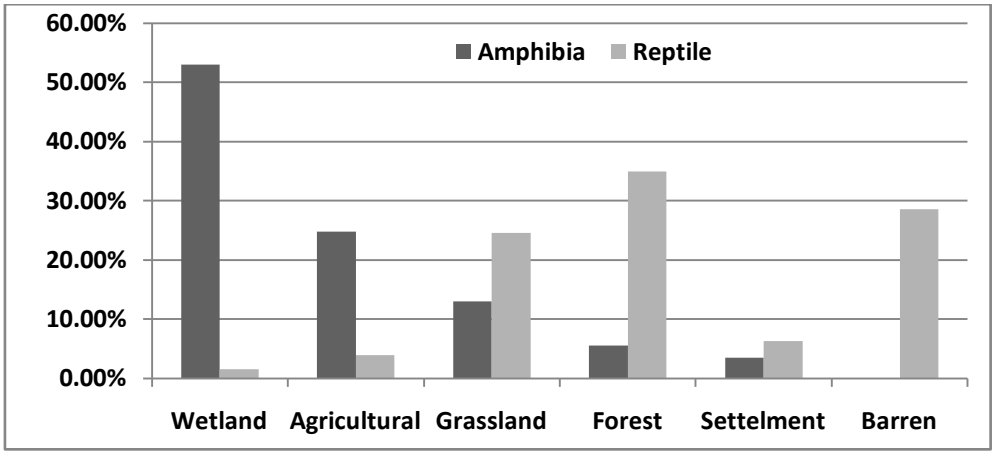


Figure 17: Abundance of amphibian and reptiles on different habitat type, 2017.

Though there was difference in abundance of reptiles and amphibian in different habitat type, amphibian abundance was only found significantly different (Table 8). Thirty four percent of Reptile abundance was found at forest (34.92%) followed by barren (28.57%), grassland (24.60%), settlement (6.35%), agricultural (3.97%) and least at wetland (7.6%) (Figure17). *Lycodon aulicus, Ptyas mucosa, Oligodon erythrogaster, Ophiophagus Hannah, Pseudoxenodon macrops, Orthriophis hodgsoni, Calotes* versicolor and *Japalura tricarinata* were recorded from single habitat type. *Xenochrophis piscator* and *Ovophis monticola* were recorded from two different habitats. *Laudakia tuberculata* and *Asymblepharus sikimmensis* were recorded from three different habitat type and *Herpetoreas platyceps* were found on all six type of habitat.

5. DISCUSSION

5.1 Species composition and abundance

Twenty five species of herpetofauna belonging to nine family and 21 genera were recorded from study site. Of which 12 species were amphibian species which belongs to four families and eight genera and 13 were reptilian species belonging to five families and 13 genera. Abundance of amphibian was 536 and a reptile was 126, Shannon index also shows high diversity of amphibian than reptiles. According to available literatures there were three herpetofaunal studies on this Annapurna region. First research was performed by (Nanhoe and Ouboter, 1987) on entire range of Dhaulagiri-Annapurna Mountain, later (Shah, 2001) perform another study on southern Annapurna region and recently (Giri, 2013) performed amphibian survey on ACA. During the research (Nanhoe and Ouboter, 1987) reported 53 species of herpetofauna off which 21 were amphibian and 32 were reptiles, (Shah, 2001) recorded 40 species of herpetofauna among them 16 were amphibians and 24 were reptiles, later (Giri, 2013) recorded 22 species of amphibians from ACAP region. Kastle *et al*. (2013) listed 50 species of herpetofauna from this Conservation area and (Shah and Tiwari, 2004) listed 66 herpetofauna from kaski district on which Ghandruk lies.

In this study, Species richness of herpetofauna was less than previous studies because this study was performed on Ghandruk region of ACA only. This could be the region for low species diversity and survey was carried on mid hill of Ghandruk region. *Nanorana ercepeae* is the new species record for ACAP; this species is endemic amphibian species of Nepal. Dubois discovered it for the first time from Jiuligad, Bajhang in 1974. Till 2011, it was thought as an endemic species of western Nepal but later it was also recorded in Illam district of eastern Nepal (Khambu, 2011). Shah and Tiwari (2004) and Kastle *et al*. (2013) describe this species from western Nepal only. *Duttaphrynus melanostictus, Duttaphrynus himalayanus, Amolops formosus, Amolops marmoratus, Chaparana sikkimensis, Euphlyctis cyanophlyctis, Limnonectes syhadrensis, Fejervarya nepalensis, Nanorana liebigii, Nanorana blanfordii and Megophrys parva* are other amphibian species of the study area. Presences of these species in study site coincide with the list of amphibian of (Nanhoe and Ouboter, 1987; Shah, 2001; Giri, 2013). Shah and Tiwari (2004) and Kastle *et al*. (2013) also support the presence of these amphibian species on study area. Shrestha (2001) also explains the presence of *Duttaphrynus himalayanus, Amolops formosus, Amolops marmoratus, Nanorana liebigii* and *Megophrys parva* from ACA.

Among 13 species of reptile species *Ophiophagus hannah, Elaphe hodgsoni, Xenochrophis piscator* were rerecorded after 30 years in this locality. Presence of these species was noted by (Nanhoe and Ouboter, 1987) for the first time in Annapurna region but these species were not recorded in the study of (Shah, 2001). Shah and Tiwari (2004) and Schleich *et al*. (2013) also explain the presence of these species which makes this finding stronger and reliable. *Oligodon erythrogaster* was not listed on the findings of (Nanhoe and Ouboter, 1987) but

this research recorded two individuals of this species on Ghandruk which resembles with the results of (Shah, 2001). Other reptilian species are *Asymblepharus sikimmensis, Calotes versicolor, Herpetoreas platyceps, Japalura tricarinata, Laudakia tuberculata, Lycodon aulicus, Ovophis monticola, Pseudoxenodon macrops* and *Ptyas mucosa.* Several studies by (Nanhoe and Ouboter, 1987; Shah, 2001; Shah and Tiwari, 2004; Schleich *et al*., 2013) also support the presence of these species at this region. Shrestha (2001) also reported *Japalura tricarinata, Laudakia tuberculata* and *Asymblepharus sikimmensis* from Annapurna region.

Nanhoe and Ouboter (1987) listed the presence of three gecko species *Hemidactylus brookii, Hemidactylus flaviviridis* and *Hemidactylus garnotii* in Annapurna Dhaulagiri region. Shah and Tiwari (2004) also indicate the occurrence of *Hemidactylus brookii* but in this study no any Gecko species were recorded from Ghandruk. Absence of gecko species is supported by the result of (Shah, 2001), he also has not mention any gecko species from Southern Annapurna region in his study.

Schleich and Kastle (2002) reported *Duttaphrynus melanostictus* as the most common frog in Nepal. Though *Duttaphrynus* spp were common they were third abundant amphibian species in Ghandruk but (Pokhrel and Thakuri, 2016; Shrestha and Shah,2017) found *Duttaphrynus* spp as most abundant amphibian species from Manaslu Conservation Area. High abundance of *Duttaphrynus* spp might be due to dry climatic condition in MCA. In this study *Euphlyctis cyanophlyctis* had the highest relative abundance among the 12 species of amphibian recorded. Aryal *et al*. (2015) also support the findings of Ghandruk; they also found *Euphlyctis cyanophlyctis* as abundant species in Kathmandu valley. Thapa (2016) also identified this species as an abundant amphibian species in Palpa district. Pal *et al*. (2012) also noted *Euphlyctis cyanophlyctis* as abundant amphibian species in west Bangal. *Euphlyctis cyanophlyctis* reproduce throughout the year; this might be the cause of high abundance of this frog in its distributional range.

Shan and Tiwari (2004) stated *Amolops marmortus* as a common frog species of Nepal, (Khatiwoda, 2011) also ranked this species as second abundant species in Chitwan but in ghandruk this species had lowest relative abundance and it was found on single site only during post monsoon season. Similarly, (Pokhrel *et al*., 2011) found *Megophrys parva* as abundant amphibian species in Nagarjun forest of SNNP but abundance this species was not good in Ghandruk. Major cause of decline in number of these species is due to high exploitation for food and medicinal purposes (Shah and Tiwari, 2004).

In Ghandruk *Laudakia tuberculata* was the most abundant reptile species. Similar result was found by (Shrestha and Shah, 2017) and (Pokhrel and Thakuri, 2016) in MCA, they also represent this species as abundant reptile species. Shah and Tiwari (2004) also explain this lizard as common species of reptiles. This species is herbivore, adapted on settlements and disturbed area and have fast movement these characters of *Laudakia tuberculata* helps them

to flourish in mid hill of Nepal. But (Lamsal, 2014; Thapa, 2016) found*Calotes versicolor* as abundant species from Chitwan and Palpa respectively. *Pseudoxenodon macrops* and *Ophiophagus hannah* were least abundant reptile species in Ghandruk. *Ophiophagus hannah*is an rare species (Shah and Tiwari, 2004) and generally distributed on lowland of Nepal this could be the region for small population at Mid land. Shah and Tiwari (2004) and Kastle *et al* (2013) describes *Orthriophis hodgsoni* and *Lycodon aulicus* as common species but they were least abundant reptile species and only single individuals were observed throughout the study period. Both the species live near the human settlement (Whitaker and Captain, 2004; Kastle *et al*., 2013) and people misidentify snakes (eg*Lycodon aulicus* as krait) and results into indiscriminate killing of snake (Sharma *et al*., 2013) at a sight. Beside these types of undisciplined killing other threats like illegal capture by snake charmers and illegal collection for medicines and food (Shah *et al*., 2011) could also be the cause of population decline of snakes in Ghandruk.

Species richness of amphibian and reptiles was not influenced equally by same factors. Both Amphibian and reptile diversity was significantly influenced by distance of water, distance of settlement and Leaf litter cover. Water distance shows both independent as well as combines effect on diversity of herpetofauna. Amphibian diversity was found higher near water sources but in case of reptiles its diversity was found least. Settlement was positively significant with reptile richness where as it was negatively significant with amphibian richness. Giaretta *et al.* (1997) also found influence of leaf litter on anuran composition. Species richness of Amphibian shows positive relation with canopy cover but effects of canopy on amphibian communities was not found significant. Though reptile was only significantly associated with canopy cover but its independent influence was found very high on species richness of herpetofauna. There was no significant relation of Road distance and shrub cover species richness of herpetofauna.

5.2 Seasonal variation of herpetofauna

Paired t test was performed to test the mean differences in abundance and species richness of herpetofauna. There were no significant differences in mean species richness and abundance of herpetofauna in pre monsoon and post monsoon season. This finding contradicted with (Chan, 2007), he found seasonal significant differences in both species richness and abundance of herpetofauna in United States of America. Katuwal (2013) also found significant difference in species richness of bird in pre-monsoon and post-monsoon. Though Species richness of herpetofauna was not significant different their relatively richness was higher in post monsoon season. Similar result was obtained by (Krishnamurthy, 1996) in amphibian's species richness in Western Ghats and (Katuwal, 2013) also found high richness of bird in post monsoon than pre monsoon. Beside herpetofauna and birds, diversity of butterfly was also found higher at post monsoon season in India (Borkar and Komarpant,

2004). According to (Zug and Mitchell, 1995) due to drought in pre monsoon season activities of herpetofauna remains suppressed; this could be main region for record of low herpetofauna during pre monsoon season. However, (Pal *et al*., 2012) and (Vasanthi *et al*., 2014) reported high species richness of herpetofauna during pre monsoon than post monsoon in India. Sathianeson and Wesley (2012) and Ghosh *et al*.(2012) also found more biomass of seaweed and diversity of phytoplankton community in Pre monsoon than of post monsoon respectively in India. Difference in monsoon pattern, micro climate between India and Nepal can be the region for such differences in species richness in same season.

Though species abundance was not significantly different in two seasons, 367 individuals of herpetofauna were recorded in pre monsoon season and 295 were only recorded in post monsoon season. Similar result was obtained by (Chan, 2007); he also reported high abundance of herpetofauna during pre monsoon season. Singh and Banyal (2014) also supports high abundance of species during pre monsoon, they explain high number of *Laudakia tuberculata* in pre monsoon from Himachal Pradesh. But (Chandramouli *et al*., 2015) recorded high abundance of species during post monsoon season from India. Abundance of amphibian reptile species was decreased by 50% and 46.15% respectively during post monsoon season. Abundance of *Duttaphrynus himalayanus, Amolops formosus, Nanorana ercepeae, Zakerana syhadrensis, Fejervarya nepalensis, Euphlyctis cyanophlyctis, Laudakia tuberculata, Japalura tricarinata, Calotes versicolor, Asymblepharus sikimmensis, Orthriophis hodgsoni* and *Pseudoxenodon macrops* were found decreased during post monsoon season.

Most of the herpetofauna starts breeding from early monsoon (Shah and Tiwari, 2004) and environmental factors such as rainfall and temperature plays important factor on Breeding of herpetofauna (Gauthreaux, 1980; Sexton *et al*., 1990). During breeding time there would be high movement, foraging and mating activity such activities expose them, and this could be the cause for record of high species abundance during pre-monsoon season. During field survey in may many of amphibian species were found showing courtship behavior near permanent water sources. Copulation of D*uttaphrynus melanostictus, Duttaphrynus himalayanus, Amolops formosus, Euphlyctis cyanophlyctis* and *Megophrys parva* was observed in the pre monsoon field.

5.3 Distribution pattern of herpetofauna along elevational gradients

There was decreasing trend of species richness and abundance of herpetofauna with increase in altitude. Declining species richness with increasing elevation was observed on many taxa and this relation is widely accepted as a general pattern (Rahbek, 1995). Khatiwada and Haugaasen (2015) and Kastle *et al*. (2013) also support decreases in Nepalese herpetofauna with increase in altitude. Several studies (Brown and Alcala, 1961; Scott, 1976; Navas, 2006) also documented decline in herpetofaunal species richness with increasing elevation. Graham (1990) also found inverse relation of elevation with species richness of bats and birds.

Multiple factors like Climatic, biological, geographical and historical factors causes variation in species richness along elevational gradients (Rahbek 1995; Whittaker *et al*., 2001). McCain (2010) and Navas (2006) consider temperature as the strongest single factor influencing elevational richness patterns of reptiles. Chettri *et al*. (2010) believes rainfall and temperature as an important limiting factor in distribution of snake in Himalaya. In case of amphibian elevation richness patterns environmental stressors like Water pH and intensity of UV radiation is taken as more important affecting factor than temperature (Navas, 2006).

Though herpetofauna declines with increase in altitude but there was no significant linear relation between species richness and elevation. In Chitwan, (Khatiwada and Haugaasen, 2015) also did not found significant relation between species richness and elevation. Similar result was obtained by (Fauth *et al*., 1989) in Costa Rica, there was inverse relation between elevation and species richness but their relation was also non linear. Naniwadekar and Vasudevan (2007) also did not found any significant linear relation of elevation with species richness. Similar result was obtained by (Katuwal, 2013), he did not found any significant relation of altitude with species richness of bird in Manaslu. However abundance shows significant linear relation with elevation in this study. This findings match with the result of (Khatiwada and Haugaasen, 2015) there was also significant linear relation between abundance and elevation.

In this study there was mid elevation peak in species richness pattern of herpetofauna with altitude. Sanders (2002) also found mid-elevations peak effect of species richness of ant with elevation. A mid-domain peak in richness is due to overlap of species ranges toward the center of the domain. The ‘‘ends are bad’’ hypothesis explain the cause of mid elevation peak in species richness. According to this hypothesis distribution at upper elevations are limited by climatic severity and reduced availability of resources and at lower elevations by climatic severity and predation (McCoy, 1990). McCain (2010) also explained similar mid-elevation peaks of reptile diversity from Eastern-hemisphere (Nepal, India and other Asian countries). But (Naniwadekar and Vasudevan, 2007) did not found peak anuran richness at middle elevation. Chettri *et al*. (2010) found more or less monotonic decline in species richness of reptiles along with elevation in India.

Most of the species shows wide distribution range, *Xenochrophis piscator* and *Megophrys parva* were the reptile and amphibian species having highest distribution range. Species like *Amolops marmoratus, Amolops formosus, Nanorana ercepeae, Japalura tricarinata, Orthriophis hodgsoni, Pseudoxenodon macrops, Ovophis monticola, Lycodon aulicus* and *Ophiophagus Hannah* were recorded from single site only. So their elevational range remains unknown in Ghandruk. Except *Xenochrophis piscator, Herpetoreas platyceps* and *Asymblepharus sikimmensis* reptiles did not shows wider elevation range. Many of the reptile species are specialized for particular microhabitat, they have narrow tolerance to climatic variations and due to this region they might be confined to narrow elevation zone (Chettri *et*

al., 2010). Most of the amphibians show wide range of distribution but they did not follow Rapoport's rule. According to Rapoport's rule, Range size tends to decrease with decreasing latitude and decreasing elevation and with increase of latitude and altitude the species tend to increase their range size (Brown *et al*., 1996; Stevens, 1992). Taxa inhibiting in higher elevations have comparatively large climatic tolerances due to this region they have greater elevational range.

Table 9: Comparative review on elevation range of Herpetofauna of Ghandruk

Name	Present study (2017)	Shah and Tiwari (2004)	Kastle et al., (2013)	Rai (2003)	Nanhoe and Ouboter (1987)	Thapa (2016)
Duttaphrynus melanostictus	1142-2254	< 2250m	<1800	56-1000	800-2250	391-1448
Duttaphrynus himalayanus	1947-2331	1300-2744	1300-2700	2500-4000	1300-265	-
Megophrys parva	1060-2562	970-2440	970-2480	1000-3000	1230-2440	973
Amolops marmoratus	1100	840-2896	1000-1900	-	1040-1840	-
Amolops formosus	1700	1190-2896	-	1000-3000	1800-2650	-
Nanorana liebigii	1955-2567	1525-3360	1500-3360	2200-2800	1560-2930	-
*Nanorana ercepeae**	1700	2200-2650	2200-2659	2300	-	-
*Nanorana blanfordii**	1755-2537	1800-2920	1830-3000	2900-4000	-	-
Zakerana syhadrensis	1064-1456	< 1980	150-1980	56-1000	1500	-
*Fejervarya nepalensis**	1080-1912	1350-1580	1350-1580	56-1000	1500	462-1387
Euphlyctis cyanophlyctis	1060-1145	<2000	<2000	56-1000	760-1660	572-1387
*Ombrana sikimmensis**	1096-1976	1210-2500	1200-2500	3660	1210-1770	-
Laudakia tuberculata	1822-2264	790-3400	310-3400	1000-3000	790-3400	-
Japalura tricarinata	2200	1830-2896	1650-2896	-	1830-2850	-
Calotes versicolor	2000-2100	100-3200	< 2300	< 2040	880-1660	462-1461
Asymblepharus sikimmensis	1975-2425	100-3200	150-3200	1000-4000	1340-3200	373-1269
Orthriophis hodgsoni	1900	1000-3200	1000-3000	1000-3000	2740-3200	1172-1272
Pseudoxenodon macrops	2200	1200-2360	< 1800	-	2000-2360	-
Herpetoreas platyceps	1619-2600	1040-3657	1500-3600	1000-3000	1040-3100	900-1265
Ovophis monticola	1900	1320-2680	1320-2250	1000-3000	1550-1900	1800
Lycodon aulicus	1700	100-2130	150-2100	1000-3000	914-2130	389-706
Ptyas mucosa	1052-1155	100-1750	< 3000	-	800-1750	385-1387
*Xenochrophis piscator**	1073-2670	100-700	<700	56-1000	960-1500	392-1387
Ophiophagus hannah	1800	100-3500	150-1530	-	-	593-663
Oligodon erythrogaster	2035-2072	1525-2600	1525-2000	-	-	1500-2000

*New record of distribution

Among 25 herpetofauna species, five species were recorded beyond their previously known elevational range (Table 9). *Nanorana blanfordii*, *Nanorana ercepeae* and *Ombrana sikimmensis* were recorded below previously described elevation range. Whereas *Fejervarya nepalensis* and *Xenochrophis piscator* was recorded above previously known elevational range. Before this study Nanorana *blanfordii* was not reported below 1800 (Shah and Tiwari, 2004; Kastle *et al*., 2013; Rai, 2002) in Nepal but it was recorded from 1755m in Ghandruk. *Nanorana ercepeae* was also believed to be distributed above 2200m from Bajhang district (Shah and Tiwari, 2004; Kastle *et al*., 2013) and 2300m from eastern Nepal (Rai, 2003; Khambhu, 2011). From Ghandruk, *Nanorana ercepeae* was recorded at an elevation of 1700m. After this study, distribution of this species confirmed from east to west between 1700-2700m. Similarly, *Ombrana sikimmensis* was recorded from 1096m during this study, before it was only recorded above 1200m (Shah and Tiwari, 2004; Kastle *et al*., 2013; Rai, 2003; Nanhoe and Ouboter, 1987; Khambhu, 2011). *Fejervarya nepalensis* were not reported above 1580 m but during this study it was recorded up to 1912 m. Both Fejervarya *nepalensis* and *Xenochrophis piscator was* well described as low land species of Nepal (Pandey, 2012; Bhattarai *et al*., 2017b; Khatiwada *et al*., 2016; Zug and Mitchell, 1995) their distribution was not known above 1600m (Shah and Tiwari, 2004; Kastle *et al*., 2013; Rai, 2003; Nanhoe and Ouboter, 1987; Khambhu, 2011; Thapa, 2016). In this study *nepalensis* and *Xenochrophis piscator* are recorded up to 1912 and 2670m respectively.

5.4 Distribution of herpetofauna on different habitat

Diversity and distribution of Herpetofauna was not uniform in different habitat. There was significant difference in species richness of herpetofauna in different habitat types. Species richness of herpetofauna was highest in forest followed by wetland, grassland, agricultural land, settlement area and barren land. Ramesh *et al*. (2013) also recorded high diversity from forest habitat from southern India. Thapa (2016) explained different scenario from Palpa, he reported highest diversity of herpetofauna from agricultural land and least from forest.

Habitat use pattern of amphibian and reptile was found different in Ghandruk. It was found that amphibian richness was found highest at wetland followed by grassland, forest, agriculture and least at settlement. Different studies also support high species richness of amphibian in Wetland (Krishnamurthy, 1996; Dutta and Mukhopadhyay, 2013; Bawaskar and Bawaskar, 2016; Thapa, 2016). In Palpa, (Thapa, 2016) did not classify grassland as separate habitat and recorded more species from agricultural land than forest which was different from Ghandruk. Vasanthi (2014) expressed equal contribution of forest and cultivable land as a habitat for amphibian species. No any amphibian species was recorded from barren land.

High richness of reptile was found from forest followed by grassland, settlement, agricultural land, barren land and least from wetland. Similar result was documented by (Rao *et al*., 2005) but (Thapa, 2016) disagree with these findings; Thapa recorded highest reptilian species from settlement area. Only one species of reptile was recorded from wetland in Ghandruk. Bawaskar and Bawaskar, (2016), Rao et al. (2005) and Thapa (2016) also agree on least species richness of reptile in wetland.

In case of abundance of herpetofauna, high abundance was recorded from wetland followed by agriculture, grassland, forest, barren and least at settlement. Many reptiles and amphibians depend on wetland for some part of their life cycles, due to this region they spend some time on wetland (Gibbons, 2003). Reptile need terrestrial habitat for nesting, hibernating, aestivating, foraging, adult residency, and terrestrial dispersal. Like species richness, abundance of amphibian and reptile was also higher at wetland and forest. Though only two reptile species were recorded from Barren land, second high abundance of reptiles was found from this habitat. *Laudakia tuberculata* were the second abundant reptile species which was highly distributed on barren land.

Most of the herpetofauna were recorded from more than one type of habitat. Species like *Amolops marmoratus, Amolops formosus, Nanorana liebigii, Nanorana ercepeae, Ombrana sikimmensis, Oligodon erythrogaster, Ophiophagus Hannah, Ptyas mucosa, Lycodon aulicus, Pseudoxenodon macrops, Orthriophis hodgsoni, Calotes versicolor* and *Japalura tricarinata* are recorded from single habitat type.

6. CONCLUSION AND RECOMMENDATIONS

Value of Shannon diversity index (H' = 2.38) revealed that Ghandruk is an important site for herpetofauna. Twenty five species of herpetofauna belonging to nine family and 21 genera were recorded from study site. *Nanorana ercepeae* were recorded for the first time in Ghandruk as well as from western Nepal. Similarly *Ophiophagus hannah*, *Elaphe hodgsoni* and *Xenochrophis piscator* were re-recorded in Ghandruk after 30 years. *Euphlyctis cyanophlyctis* showed its dominance over all herpetofaunal population abundance (*Pi* = 0.222). Amphibian diversity was significantly related with explanatory variables like water, settlement and Leaf litter cover. Whereas reptiles were significantly affected by leaf litter cover, Distance of water, Distance of Settelment and canopy cover.

Mean difference in species richness and abundance of herpetofauna was not significant in pre monsoon and post monsoon season. There was decreasing trend of species richness and abundance of herpetofauna with increase in altitude. There was no significant linear relation between species richness and elevation but abundance shows significant linear relation with elevation. Mid elevation peak in species richness pattern of herpetofauna with altitude was seen in Ghandruk. There was significant difference in species richness of herpetofauna in different habitat types. Habitat use pattern of amphibian and reptile was found different.

Based on the results of this study following recommendations have been made

- This study is based on pre monsoon and post monsoon survey and study was performed up to 2700m only. More detailed study is necessary to understand the seasonal and altitudinal distribution of herpetofauna of the region.
- Exploitation of Paha frog species by local people was seen during the survey period, effective conservation awareness programs should be conducted.
- Species richness of herpetofauna was found higher in Wetland and Agricultural lands. Uses of pesticides should be reduced to improvise the health of wetland and agricultural land.

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Annex 1: Shannon's Diversity Index of herpetofauna in Ghandruk, 2017

Name	Number	Pi	ln(pi)	Pi*ln(pi)
Duttaphrynus melanostictus	71	0.107250755	-2.232585679	-0.2394465
Duttaphrynus himalayanus	75	0.113293051	-2.177777442	-0.2467271
Megophrys parva	24	0.036253776	-3.317211726	-0.1202615
Amolops marmoratus	3	0.004531722	-5.396653267	-0.0244561
Amolops formosus	9	0.013595166	-4.298040979	-0.0584326
Nanorana liebigii	26	0.039274924	-3.237169018	-0.1271396
Nanorana ercepeae	5	0.00755287	-4.885827644	-0.036902
Nanorana blanfordii	10	0.01510574	-4.192680463	-0.0633335
Zakerana syhadrensis	16	0.024169184	-3.722676834	-0.0899741
Fejervarya nepalensis	131	0.197885196	-1.620068233	-0.3205875
Euphlyctis cyanophlyctis	147	0.222054381	-1.504832969	-0.3341548
Ombrana sikkimensis	18	0.027190332	-3.604893798	-0.0980183
Laudakia tuberculata	42	0.063444109	-2.757595938	-0.1749532
Japalura tricarinata	3	0.004531722	-5.396653267	-0.0244561
Calotes versicolor	3	0.004531722	-5.396653267	-0.0244561
Asymblepharus sikimmensis	52	0.078549849	-2.544021837	-0.1998325
Orthriophis hodgsoni	1	0.001510574	-6.495265556	-0.0098116
Pseudoxenodon macrops	1	0.001510574	-6.495265556	-0.0098116
Herpetoreas platyceps	10	0.01510574	-4.192680463	-0.0633335
Ovophis monticola	5	0.00755287	-4.885827644	-0.036902
Lycodon aulicus	1	0.001510574	-6.495265556	-0.0098116
Ptyas mucosa	3	0.004531722	-5.396653267	-0.0244561
Xenochrophis piscator	3	0.004531722	-5.396653267	-0.0244561
Ophiophagus hannah	1	0.001510574	-6.495265556	-0.0098116
Oligodon erythrogaster	2	0.003021148	-5.802118375	-0.0175291
H^i				2.38905466

Annex 2: Shannon index of herpetofauna in pre monsoon and post monsoon.

Name	Pre monsoon				Post monsoon			
	No.	**pi**	**ln**	**ln*pi**	**No**	**pi**	**ln**	**ln*pi**
Duttaphrynus melanostictus	32	0.087193	-2.43963	-0.21272	39	0.132203	-2.02341	-0.2675
Duttaphrynus himalayanus	50	0.13624	-1.99334	-0.27157	25	0.084746	-2.4681	-0.20916
Megophrys parva	3	0.008174	-4.80675	-0.03929	21	0.071186	-2.64245	-0.18811
Amolops marmoratus	0	0	0	0	3	0.010169	-4.58836	-0.04666
Amolops formosus	7	0.019074	-3.95945	-0.07552	2	0.00678	-4.99383	-0.03386
Nanorana liebigii	23	0.06267	-2.76987	-0.17359	3	0.010169	-4.58836	-0.04666
Nanorana ercepeae	5	0.013624	-4.29592	-0.05853	0	0	0	0
Nanorana blanfordii	3	0.008174	-4.80675	-0.03929	7	0.023729	-3.74107	-0.08877
Zakerana syhadrensis	16	0.043597	-3.13277	-0.13658	0	0	0	0
Fejervarya nepalensis	33	0.089918	-2.40885	-0.2166	98	0.332203	-1.10201	-0.36609
Euphlyctis cyanophlyctis	122	0.332425	-1.10134	-0.36611	25	0.084746	-2.4681	-0.20916
ombrana sikkimensis	0	0	0	0	18	0.061017	-2.7966	-0.17064
Laudakia tuberculata	27	0.073569	-2.60952	-0.19198	15	0.050847	-2.97893	-0.15147
Japalura tricarinata	2	0.00545	-5.21221	-0.0284	1	0.00339	-5.68698	-0.01928
Calotes versicolor	2	0.00545	-5.21221	-0.0284	1	0.00339	-5.68698	-0.01928
Asymblepharus sikimmensis	32	0.087193	-2.43963	-0.21272	20	0.067797	-2.69124	-0.18246
Orthriophis hodgsoni	1	0.002725	-5.90536	-0.01609	0	0	0	0
Pseudoxenodon macrops	1	0.002725	-5.90536	-0.01609	0	0	0	0
Herpetoreas platyceps	5	0.013624	-4.29592	-0.05853	5	0.016949	-4.07754	-0.06911
Ovophis monticola	1	0.002725	-5.90536	-0.01609	4	0.013559	-4.30068	-0.05831
Lycodon aulicus	0	0	0	0	1	0.00339	-5.68698	-0.01928
Ptyas mucosa	0	0	0	0	3	0.010169	-4.58836	-0.04666
Xenochrophis piscator	1	0.002725	-5.90536	-0.01609	2	0.00678	-4.99383	-0.03386
Ophiophagus hannah	0	0	0	0	1	0.00339	-5.68698	-0.01928
Oligodon erythrogaster	1	0.002725	-5.90536	-0.01609	1	0.00339	-5.68698	-0.01928
			H'	2.19			**H'**	2.26

Annex 3: Elevational range of herpetofauna in Ghandruk, 2017

Name	Lower elevation	Higher elevation	Elevational Range
Megophrys parva	1060	2562	1502
Duttaphrynus melanostictus	1142	2254	1112
Duttaphrynus himalayanus	1947	2331	384
Amolops marmoratus	1100	1200	100
Amolops formosus	1700	1800	100
Nanorana liebigii	1955	2567	612
Nanorana ercepeae	1700	1800	100
Nanorana blanfordii	1755	2537	782
Zakerana syhadrensis	1064	1456	392
Fejervarya nepalensis	1080	1912	832
Euphlyctis cyanophlyctis	1060	1145	85
Ombrana sikimensis	1096	1976	880
Laudakia tuberculata	1822	2264	442
Japalura tricarinata	2200	2300	100
Calotes versicolor	2000	2100	100
Asymblepharus sikimmensis	1975	2425	450
Orthriophis hodgsoni	1900	2000	100
Pseudoxenodon macrops	2200	2300	100
Herpetoreas platyceps	1619	2600	981
Ovophis monticola	1900	2000	100
Lycodon aulicus	1700	1800	100
Ptyas mucosa	1052	1155	103
Xenochrophis piscator	1073	2670	1597
Ophiophagus hannah	1800	1900	100
Oligodon erythrogaster	2035	2072	37

Annex 4: Distribution of herpetofauna in different habitat recorded in Ghandruk

Name	Agriculture	Barren	Forest	Grassland	Settlement	Wetland
Megophrys parva	3	0	4	6	3	8
Duttaphrynus melanostictus	36	0	1	25	0	9
Duttaphrynus himalayanus	37	0	16	7	15	0
Amolops marmoratus	0	0	0	0	0	3
Amolops formosus	0	0	0	0	0	9
Nanorana liebigii	0	0	0	1	0	25
Nanorana ercepeae	0	0	0	0	0	5
Nanorana blanfordii	0	0	8	0	1	15
Zakerana syhadrensis	0	0	1	0	0	15
Fejervarya nepalensis	57	0	0	25	0	50
Euphlyctis cyanophlyctis	0	0	0	6	0	141
Ombrana sikimensis	0	0	0	0	0	4
Laudakia tuberculata	0	34	4	3	0	0
Japalura tricarinata	0	0	3	0	0	0
Calotes versicolor	0	0	0	3	0	0
Asymblepharus sikimmensis	0	0	31	17	4	0
Orthriophis hodgsoni	0	0	0	0	1	0
Pseudoxenodon macrops	0	0	1	0	0	0
Herpetoreas platyceps	1	2	1	2	2	2
Ovophis monticola	0	0	1	4	0	0
Lycodon aulicus	1	0	0	0	0	0
Ptyas mucosa	3	0	0	0	0	0
Xenochrophis piscator	0	0	1	2	0	0
Ophiophagus hannah	0	0	0	0	1	0
Oligodon erythrogaster	0	0	2	0	0	0
Total	**138**	**36**	**74**	**101**	**27**	**286**

Annex 5: Data sheet during the field survey Ghandruk, 2017

Method/ number	Date	Lat.	Long.	Ele.	aspect	Habitat type	canopy cover	shrub cover	leaf liter cover	D.Water	D.Road	D.Set	Name of species and (n)