DIVERSITY AND ABUNDANCE OF HERPETOFAUNA IN KOLE WETLANDS, THRISSUR

By

SREEHARI, V.S

(2009-17-109)

THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Forestry

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF WILDLIFE SCIENCES
COLLEGE OF FORESTRY
VELLANIKKARA, THRISSUR – 680 656
KERALA, INDIA

2011

DECLARATION

I hereby declare that the thesis entitled **"Diversity and Abundance of Herpetofauna in Kole Wetlands, Thrissur"** is a bonafide record of research done by me during the course of research and that this thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara **Sreehari, V.S**

12-03-2012 **(2009-17-109)**

CERTIFICATE

I do here by certify that this dissertation entitled **"Diversity and Abundance of Herpetofauna in Kole Wetlands, Thrissur"** is a record of research work done independently by **Mr. Sreehari, V.S (2009-17-109),** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellanikkara

Dr. P.O. Nameer
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. Sreehari, V.S (2009-17-109),** a candidate for the degree of **Master of Science in Forestry,** agree that this thesis entitled **"Diversity and Abundance of Herpetofauna in Kole Wetlands, Thrissur"** may be submitted by him in partial fulfillment of the requirement for the degree.

Dr. P. O. Nameer
Associate Professor & Head
Department of Wildlife Sciences
College of Forestry
Kerala Agricultural University
Vellanikkara, Thrissur
(Chairman)

Dr. E. V. Anoop
Associate Professor & Head
Dept. of Wood Science
College of Forestry
Kerala Agricultural University
Vellanikkara, Thrissur
(Member)

Dr. A. V. Santhoshkumar
Associate Professor & Head
Dept. of Treephysiology and Breeding
College of Forestry
Kerala Agricultural University
Vellanikkara, Thrissur
(Member)

Dr. T.K. Kunhamu
Associate Professor
Department of Silviculture and Agroforestry
College of Forestry
Kerala Agricultural University
Vellanikkara, Thrissur
(Member)

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

With deep respect I express my heartfelt gratitude and unforgettable indebtness to my advisor ***Dr. P.O Nameer****, Associate Professor and Head, Department of Wildlife Sciences, College of Forestry, whose pragmatic suggestions, erudite guidance, unstinted mental support, friendly cooperation, constant evaluation and comments throughout the study period made my thesis work an easy task. He continually and convincingly conveyed a spirit of adventure and positive energy with regard to research and field work which I can't forget in my whole lifetime. I express my heartfelt and sincere thanks to him. Without his guidance and persistent help, this thesis would not have become a reality.*

I take this opportunity to place on record my sincere gratitude to ***Dr. B. Mohankumar,*** *Associate dean of College of Forestry for extending the available facilities in the college for the present study. I also extend my deep sense of gratitude to* ***Kerala Agricultural University*** *for the financial and technical support for pursuance of my study and research.*

I am deeply indebted to my advisory committee members ***Dr. E. V. Anoop****, Assoc. Prof. and Head, Dept. of Wood science,* ***Dr. A. V. Santhoshkumar****, Assoc. Prof. and Head, Dept. of Tree Physiology and Breeding, and* ***Dr. T.K. Kunhamu****, Assoc. Prof., Dept. of Silviculture and Agroforestry, and* ***Mr. S. Gopakumar****, Asst. Prof., Dept. of Forest Management and Utilisation for their constant encouragement and constructive suggestions throughout the study period, and also for the critical evaluation of the manuscript.*

Words cannot really express the true friendship that I relished from my friends ***Bahu, Kutti, Jobin.K , Vyepu, Jithu, Krish, Kiru*** *and* ***Akru*** *for their heartfelt help and timely suggestions and for accompanying me to the field, discussing the matter at length and being there with me throughout the study. I heartfully thank my junior buddies-* ***Jinjo, Hasi, Joboda*** *and* ***Kinnan,*** *for their immense support and care. The uninhibited moral support and love rendered by my friends and well-wishers is gratefully remembered. Let me place on record my heartiest thanks and love to my dearest* ***Chinnumol, Achumma, Anjuttan*** *and* ***Lechu*** *and my dear bro* ***Anoob*** *for their friendly help, unparalleled love and care and great support and back-up which gave me enough mental strength and courage to get through all mind-numbing circumstances during the course of my work. At this juncture, I extend my heartfelt respect and love for my* ***family*** *where I come from and the source of my pride. I can't forget my* ***father*** *who would always encourage me to follow my heart and take responsibility for my gifts and talents and my* ***mother*** *who is my constant inspiration. The love, care, support and encouragement given by my soul mate* ***Chinna*** *was in the end what made this thesis possible. I acknowledge them for helping me accomplish all my dreams in life, as in the case of this project.*

I would also like to thank the countless others whose hints I may have forgotten which nevertheless may have led to some major findings during the research schedule. Many thanks to all the ***contributors*** *who provided constructive criticism during the preparation of this thesis and thanks to* ***Orion Group*** *for being with me.*

*Above all I bow my head before the God, '****ALMIGHTY****' whose blessings enabled me to undertake this venture successfully.*

Sreehari, V.S

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Dedicated to

my Amma & Chinna

Introduction

INTRODUCTION

India has a very fascinating flora and fauna, not only are the large and spectacular animals, but small and less attractive animals like herpetofauna as well. Herpetofauna include the amphibians and reptiles. The term is derived from Greek word “herpeton” which means creeping animal. They are poikilothermic (vernacular "cold-blooded") tetrapods which means that their internal temperature varies along with that of the ambient environmental temperature. They are dependent on environmental heat sources and have relatively low metabolic rates. For example, many of them regulate their body temperature by basking in the sun by which they warm their bodies by absorbing heat from the surroundings. The herpetofauna consist of mainly two classes- Class Amphibia and Class Reptilia.

Class Amphibia (amphibians, from Amphi- meaning "on both sides" and bios meaning "life"), such as frogs, salamanders, and caecilians, are ectothermic (or cold-blooded) animals that metamorphose from a juvenile water-breathing form called tadpole, either to an adult air-breathing form, or to a paedomorph that retains some juvenile characteristics. The three modern orders of amphibians are Anura (frogs and toads), Caudata (salamanders and newts), and Gymnophiona (caecilians, limbless amphibians that resemble snakes), and in total they number approximately 6,500 species. Like the fish they evolved from, most amphibians lay eggs in water. Amphibians are superficially similar to reptiles, but reptiles are amniotes, along with mammals and birds. Amphibians evolved in the Devonian period and were top predators in the Carboniferous and Permian periods, but many lineages were wiped out during the Permian–Triassic extinction. Amphibians are excellent ecological indicators and in recent decades there has been a dramatic decline in amphibian populations around the globe. Many species are now threatened or extinct.

There are 311 species of amphibians in India (Dinesh et al., 2010a). Indian amphibians have a very high representation of endemics. Nearly sixty-three percent (63%) of the amphibians are endemic to India, of which 87 endemic

taxa are threatened (IUCN, 1997). Seventy eight percent of the amphibians reported from Western Ghats are endemic to Western Ghats and 44% are endemic to Kerala. The Western Ghats is the richest in terms of amphibians (Easa, 2003).

Class Reptilia are characterized by breathing air, laying shelled eggs, and having skin covered in scales and/or scutes. Reptiles are classically viewed as having a "cold-blooded" metabolism. They are tetrapods (either having four limbs or being descended from four-limbed ancestors). Modern reptiles inhabit every continent with the exception of Antarctica, and four living orders are currently recognized: Crocodilia (crocodiles, gavials, caimans, and alligators), Sphenodontia (tuataras only in New Zealand), Squamata (lizards, snakes, and worm lizards) and Testudines (turtles and tortoises). Contrary to amphibians, reptiles do not have an aquatic larval stage. As a rule, reptiles are oviparous (egg-laying), although certain species of squamates are capable of giving live birth. This is achieved by either ovoviviparity (egg retention) or viviparity (birth of offspring without the development of calcified eggs). Many of the viviparous species feed their fetuses through various forms of placenta analogous to those of mammals, with some providing initial care for their hatchlings.

There are 448 species of reptiles in India (IUCN, 1998). Nearly forty-four percent (44%) of the assessed reptiles are endemic to India. Western Ghats is the richest region in India with respect to endemic reptiles also. Sixty two percent of the reptiles of Western Ghats are endemic, while 42% of the reptiles are endemic to Kerala (Easa and Ramachandran, 2004). 173 species are reported from Kerala (Palot and Radhakrishnan, 2011).

Very few studies and researches are done in amphibians and reptiles of India. Amphibian studies in India are still at its infancy stage since much more information regarding distribution, population dynamics and threats are required (IUCN, 1997). Also, Reptiles are poorly studied group since information regarding distribution, population dynamics and threats are incomplete and most of the information available is from only a few well studied locations (IUCN,

1998). Most of the recent studies done in India in this field are concentrated to particular areas and the complete information about them are lacking, particularly in wetlands.

Wetlands are ecotones or transitional zones that occupy an intermediate position between dry land and open water. Wetland ecosystems are dominated by the influence of water; they possess characteristics of both terrestrial and aquatic ecosystems and properties that are uniquely of their own.

Wetlands support a wide array of flora and fauna and deliver many ecological, climatic and societal functions. Scientists often refer to wetlands as the kidneys of the earth and forests as the lungs of the earth. India by virtue of its extensive geographical stretch and varied terrain and climate, supports a rich diversity of inland and coastal wetlands.

Kerala is well known for its wetlands. These wetlands provided livelihood to the residents in the area in the forms of agricultural produce, fish, fuel, fiber, fodder, and a host of other day-to-day necessities. As long as human intervention remained minimal, the ecosystem, through its all-encompassing balancing nature, was self-cleansing. But the development demands that determine the choice of the paths upset the natural harmony. Infrastructure development in the form of roads, railways, and other lines of communication fragmented the contiguity of the wetlands, and destroyed extensive tracts of coastal vegetation thereby upsetting the entire complex ecology (GOI, 2007).

Kole wetlands are having the highest biodiversity with respect to flora and fauna among the wetlands of Kerala. However, despite this high level of endemicity and the biogeographical significance of the region, relatively few studies have been done in the herpetofauna of the wetlands in Kerala. Except for some studies on biodiversity, conducted in the late 1990s, there appears to be no systematic study of the biodiversity of the lake ecosystem in the recent past (Johnkutty and Venugopal, 1993). While Water bird count is being done on an annual basis, information on other flora and fauna of the lake is scanty and

unauthentic. Amphibians and reptiles are important components of biodiversity which are often under-represented in conservation planning. The present study is expected to provide a baseline data on the herpetofaunal diversity of the Kole wetlands. Herpetofauna could be the best indicators for an evaluation of the area for conservation, so such information would be of great use in the effective management of the wetland.

The present objective of the study is to understand the status, distribution and abundance of amphibians and reptiles (Herpetofauna) in Kole wetlands in Thrissur district.

Review of Literature

REVIEW OF LITERATURE

2.1 Wetlands

Wetlands are the lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water. This includes three attributes that help to delineate a wetland: (i) the area must be permanently or periodically inundated or water must be present for at least seven successive days during the growing season, (ii) the area must support hydrophytic vegetation and (iii) the substrate is predominantly hydric soils that are saturated or flooded for a sufficiently long period to become anaerobic in their upper layers. They are both lentic (pond) and lotic (stream) habitats that are either permanent or temporary (Cowardin et al., 1979). From the utilitarian point, wetlands can be defined as transitional areas between permanently flooded deep water environments and well drained uplands that contribute a wide array of biological, social and economic benefits (Watzin and Gozzelink, 1992).

The Ramsar Bureau has coined a Ramsar Classification System for Wetland type as approved by recommendation 4.7 and amended by resolution VI.5 of the Conference of the Contracting Parties (COP), in which the wetlands are broadly divided into three viz. I. Marine/Coastal wetlands, II. Inland Wetlands and III. Man-made wetlands and their subdivisions (Ramsar Convention Secretariat, 2006). According to Ministry of Environment & Forests, Government of India, wetlands are broadly divided into Inland wetlands and Coastal wetlands and each class is further divided into different types (GOI, 2007).

Geomorphologically, the wetlands in Kerala may be divided among five major systems at the broadest level as marine, estuarine, riverine, and lacustrine and palustrine (CED, 2003). Due to the unique physical characteristics Kerala endows, like backwater systems and a diverse terrain of high land, midland and low land within a thin strip of landmass of about 38864 sq km, there exists much

ambiguity in the classification of wetlands. Thus, major classes and types of wetlands are redefined keeping the MoEF classification system as the standard. Accordingly the following major wetland classification system compiled by the detailed study on wetlands of Kerala by Nameer (2010) and Ramsar Convention Secretariat (2006), and is given in Table 1.

Table 1. Classification Scheme for Wetlands of Kerala (Ramsar Convention Secretariat, 2006, Nameer, 2010)

Wetland Classes	
Shallow sea	Depth of water <6m
Rocky sea coast and sea cliffs	
Sea beaches	Sand pebbles
Freshwater ponds	Palustrine
Freshwater lakes	lacustrine
Estuaries and backwaters	
Reservoirs of dams	
Rice fields	
Swamp forests	
Mangrove forests	

The Ministry of Environment and Forests, Government of India estimated that different types of wetlands occupies 4.7 million ha, of which 1.5 million ha are natural, 2.6 million ha are manmade and 0.6 million ha are mangrove vegetation. The results of the nationwide wetland inventory (Garg et al., 1998) reveals that there are 27,403 wetland units in the country occupying 7.6 million ha, of which coastal Wetlands are 3959 units with 4.0 million ha, whereas inland wetlands are 23,444 units with 3.6 million ha. So far, India has designated 25 wetland sites as Ramsar sites of International importance, of which Vembanad-Kole Backwater system was declared on August 2002 (GOI, 2007).

The wetlands in Kerala are currently subjected to acute pressure owing to rapid developmental activities and indiscriminate utilization of land and water. As a result, the system is being degraded, especially in the tropics or taking about Kerala specifically, at an alarming rate of around one percent per year. Though there were no quantitative estimates on the rate of destruction of wetlands in Kerala, the qualitative degradation of the ecosystem is, more or less, well understood. The degradation of the major wetlands of Kerala has been driven by various direct and indirect forces. The major driving forces of wetland degradation are: (i) population/households growth and urbanization, (ii) industries, (iii) infrastructure, (iv) agriculture, (v) aquaculture, (vi) fishing, (vii) poaching, (viii) mining, (ix) deforestation, (x) services, (xi) water transport and (xii) tourism (GOI, 2007). One of the major difficulties in economic valuation of a wetland is the insufficient information available on important ecological and hydrological processes, on the basis of which such values are generated by wetlands (Barbier et al. 1997).

2.1.1 Kole Wetlands

The coasts of Kerala are remarkable for the presence of a string of backwaters, estuaries, and lagoon barrier complexes. Kole lands lie between Bharathapuzha in the north and Chalakudy River in the south. It is located between 10^{o} 20’ and 10^{o} 40’ north latitudes and 75^{o} 58’ and 76^{o} 11’ east longitudes (Johnkutty and Venugopal 1993). Kole wetlands is a Ramsar site since 2002 (Ramsar Convention Secretariat, 2006 and Islam and Rahmani, 2008), Important Bird Area, since 2004 (Islam and Rahmani, 2004) and a High Value Biodiversity Area since 2009 (MoEF, 2009). Karuvannur and Kecheri rivers drain the Kole lands and finally discharge into the Arabian Sea. Kole lands are divided into two divisions namely the Thrissur Kole and the Ponnani Kole. The Karuvannur River divides the Thrissur Kole land in to North and South Kole. It also acts as the flood basin for these rivers. Water level rises up to 5.5 meters during the southwest monsoon. The wetland area comes under the administration of civil authorities of Mukundapuram, Chavakkad, Thrissur and Thalappilly

taluks of Thrissur district and Ponnani taluk of Malappuram district (Johnkutty and Venugopal, 1993).

The Kole land is a flat saucer shaped low-lying area, flanked by lateritic hills on the eastern and western margins. The Kole land runs parallel to the sea and are low-lying tracts located 0.5 to 1 meter below the mean sea level. The floodwater from the rivers used to bring enormous quantities of nutrient rich alluvium, which gets deposited in the Kole lands (Thomas et al., 2003). Though wetland system is extensively rich in biodiversity, there hasn't been any comprehensive study on its flora and fauna (GOI, 2007). Table 2 is a summary of the available data.

Table 2. Biodiversity of Vembanad- Kole wetland (GOI, 2007; Nameer, 2010)

Groups	**No. of species**
Flora	
Phytoplanktons	67
Herbs, Shrubs, Climbers	308
Trees	26
Fauna	
Zooplanktons	32
Fishes	43
Insects	26
Birds	243
Mammals	20

The wetlands support diverse fauna, including a large variety of fish, prawns and clams, amphibians, reptiles and birds and provide a habitat for both anadromous and catadromous fish species. The avifauna of this area requires special mention. During the winter months, the Vembanad Kole supports the third largest population of more than 20,000 waterfowls in India. The birds come from different region and stay here for breeding and feeding. Kole lands provide a

congenial habitat for a wide variety of birds including the waterfowls (GOI, 2007). A total of 243 species of birds, belonging to 16 orders and 39 families were recorded from the Kole wetlands. Among them, 81 species are wetland birds, 53 species were winter visitors. Kole wetland is an abode of many passerine species also (Sivaperuman and Jayson, 2000).

2.1.2 Threats to Wetlands

Among all wetlands of Kerala, Vembanad- Kole is the most affected one as a result of urbanization and population growth, industrial development, agriculture and aquaculture, water transport, tourism etc. The Vembanad estuary receives effluents from chemical and engineering industries, food and drug manufacturing industries and also from paper, rayon, rubber, textiles and plywood industries (GOI, 2007). The annual fertilizer consumption in Kuttanad alone is estimated as 20,000 tons. Agriculture and aquaculture practices prevalent in the drainage basins are also partly responsible for eutrophication through deposition of eroded top soil and agrochemicals and pesticides (CWRDM, 1995). Many factors, which threaten the Kole wetland ecosystem are poaching, heavy use of pesticides, and unregulated fishing from the canals laid in Kole land to drain excess water. Pesticides and herbicides of 15 different brands were used in the paddy fields for the protection of paddy (Sivaperuman and Jayson, 2000).

Aquatic ecosystems and wetlands are usually looked down upon as wastelands and are being reclaimed for various developmental needs, bringing several taxa, which would be of great potential value in medicine and other industrial uses on the verge of extinction. The encroachment, mining and reclamation in many locations lead to loss of biodiversity and make changes in the ecosystem functioning. Loss of wild species including endemic species is a phenomenon associated with ecosystem changes. In the backwaters, the stake net method of fishing removes a wide array of non-target organisms, which are functionally important to the aquatic environment. Other destructive type of fishing and pollution has also impact on the ecology. Excessive weed growth and

algal blooms caused by eutrophication also causes ecosystem changes. The cumulative deposition of macrophytic biomass is bringing out a gradual alteration in the estuarine benthic communities due to the disturbance in the food chain. The plastic wastes dumped into the system cause blockage, water stagnation and related problems in the system leading to biodiversity loss (GOI, 2007).

2.2 Herpetofaunal Studies in India

Herpetofauna have a very high species richness and endemism in India. There are two major centres of distribution of amphibians and reptiles in India i.e. North East India and the Western Ghats (Jayaram, 1974). There are 311 sp. of Indian amphibians (Dinesh et al., 2010a) and 448 sp of Indian reptiles (IUCN, 1997). In India, the majority of herpetofaunal surveys have largely reported cumulative species lists, and studies attempting to estimate density or relative abundance are uncommon (Pawar and Birand, 2001).

2.2.1 Amphibian Studies

Studies on Indian amphibians are comparatively few and have not equalled with the progress made on other vertebrate groups (Shaji and Easa, 1999). The studies date back to fauna volumes published by Boulenger (1882, 1890) and Smith (1935, 1943). Ferguson (1904) listed the batrachians of Travancore. Myers(1942a, b) described new species from Anamalai hills and Travancore. It was then after a long gap till Daniel (1963) and Daniel and Shekhar (1989) published a field guide for the identification of amphibians of western India along with details on the distribution. But their study was based on museum specimens and the food and feeding habits of a few tropical anuran species have been studied. A fair amount of literature is available on the diet of Indian bull frog *Rana tigerina* (Mullan, 1912; Iswar, 1953; Abdullai, 1962; Wadekar, 1963; Joshee, 1968; Issac and Rege, 1975; Nigam, 1979). Geographical distribution of Indian amphibians was earlier studied by Inger and Dutta (1986), Tilak and Ray (1990) and Sekar (1991). Range extension in South Indian amphibians was studied by Daniels (1992). Chanda (1990, 1992) has reported the altitudinal

distribution of *Rana hexadactyla* in the North-East India. The stomach contents of many species of anura have been examined to ascertain their diets and also to determine their role in an ecosystem. Studies on the testicular cycle of tropical amphibians are scarce. Such studies in Indian anurans are limited to a few Rana species (Saidapur and Nadkarni, 1975; Srivastava, 1987). Daniels (1997a,b,c) published a field guide for identifying frogs and toads by collecting live specimens. A complete field guide on the Caecilians of the Western Ghats was prepared by Bhatta (1998).

Daniel (1963a, b; 1975), and Daniel and Sekar (1989) published field guides for the identification of the amphibians of Western India along with the details on their distribution. However, since the study was based on the museum specimens, its scope was rather limited. Daniels (1997a,b,c) published field guides for the identification of frogs and toads in the Western Ghats.

2.2.1.1 Recent Studies in Amphibians of Kerala

Many new species were discovered in the eighties and nineties. Pillai (1978; 1981) described new species from Wayanad and Silent Valley National Park. Inger et al. (1984a, b) documented the amphibians of Silent Valley and Ponmudi in southern part of Kerala respectively. Radhakrishnan (1996a, b) enlisted the amphibians in Aralam and Parambikulam Wildlife Sanctuaries. In addition to this, Radhakrishnan et al., (1996) made a taxonomic study on the amphibians in Eravikulam National Park. Zacharias and Bhardwaj (1996) made a preliminary study on the amphibians of Periyar Tiger Reserve. Easa (1998) made a study on the herpetofauna in Kerala part of Nilgiri Biosphere Reserve documenting the amphibians along with their microhabitat preferences and abundance. The updated list of Dutta (1992; 1997) has amphibians of Kerala along with their distribution records. In general, studies on the amphibians of Kerala are scanty and limited to documentation in Protected Areas (Shaji and Easa, 1999).

After 2000, many new species were discovered in amphibians. A new genus and species of Ranidae from south Western Ghats, *Minervarya sahyadris* was discovered in 2001(Dubois et al., 2001). Many Philautus species were discovered recently viz. *Philautus ponmudi* from Ponmudi hills. It can be distinguished from all other members of the genus by the combination of its rather robust body, relatively large snout–vent length, rounded snout, protruding eyes, and vermiculated coloration of the posterior surface of the tibia. It is one of the largest species of the genus in the Western Ghats (adult males of type series up to 38.9 mm). It is currently known only from the type locality, where it is essentially an inhabitant of the canopy (Biju and Bossuyt, 2005a). Two new Philautus, *P. bobingeri*, *P. graminirupes* was discovered in the same year from South Western Ghats (Biju and Bossuyt, 2005b).

Of all these discoveries, the discovery of *Nasikabatrachus sahyadrensis* was a major breakthrough. It is commonly known as purple frog. Phylogenetic analyses designate this frog as the sister taxon of Sooglossidae, a family exclusively occurring on two granitic islands of the Seychelles archipelago. The discovery discloses a lineage that may have been more diverse on Indo-Madagascar in the Cretaceous period, but now only comprises four species on the Seychelles and a sole survivor in India. Because of its very distinct morphology and an inferred origin that is earlier than several neobatrachian families, this frog is recognized as a new family Neobatrachidae (Biju and Bossuyt, 2003). In 2007, a new nightfrog, *Nyctibatrachus minimus* coming under the family Nyctibatrachidae was discovered from Kurichiyarmala of Wayanad district. It is the smallest frog from India. It's most distinctive feature is the small adult snout-vent length, averaging only 12.3mm in adult males, making it the smallest known frog from India (Biju et al., 2007).

A new species of the oriental shrub frog *Philautus ochlandrae* is described from Kakkayam Reserve Forest of Calicut district, Kerala, in the southern Western Ghats. These frogs reside in the hollow tube of internodal region of *Ochlandra setigera* reed brake (Gururaja et al., 2007).

Another major study in 2009 rediscovered a lost species‟ Travancore bush frog" (*Philautus travancoricus*) was considered extinct since it was last reported more than a 100 years back (Biju and Bossuyt, 2009). The species was rediscovered from a highly degraded environment in its original locality. Twelve new species were discovered in the same study and it was the first publication to describe a dozen new species of vertebrates from India after independence. A total of 25 frogs have been discovered by Biju and his collaborators since 2003. Biju and Bossuyt have added another 18 new species within four years from 2005 to 2008.

One of the latest studies in April 2010 was the discovery of a new ground-dwelling rhacophorid frog *Raorchestes resplendens* from Eravikulam National Park. The species is morphologically dissimilar from any known member of this family in having a bright orange to reddish colouration, multiple macro glands on the body and extremely short limbs. Phylogenetic analyses of mitochondrial genes indicate that this new frog is nested in a radiation of shrub frogs that had its origin on the Indian subcontinent, and which is here recognized as a distinct genus, Raorchestes. The new species, *Raorchestes resplendens* is likely restricted to less than 3 sq. km on the summit of Anamudi, and deserves immediate conservation priority (Biju et al., 2010). The earlier checklist of amphibians in Kerala consists of only 87 species (Andrews et al., 2005a). The new checklist of amphibians of Kerala includes 104 species including 92 species of frogs and 12 species of caecilians (Dinesh et al., 2010b). A new species of the genus Polypedates under the family Rhacophoridae is described from Western Ghats, India. The new species is compared with *Polypedates maculatus, P. pseudocruciger* and *P.occidentalis,* in Western Ghats and found to be a new species and named as *Polypedates bijui* (Zachariah et al., 2011a). In another study, nine new species of frogs of the genus Raorchestes are described from the hill ranges of southern Western Ghats. Four species are described from Bonacaud estate, Thiruvananthapuram district, Kerala; two from Kadalar estate, Idukki, Kerala; one from Gavi, Pathanamthitta district, Kerala; one from Ooty, Nilgiri,

Tamil Nadu and one from Naduvattam, Nilgiri, Tamil Nadu. Of the nine species described, six are bush frogs, one is a canopy frog and two species are associated with reeds. They are *Raorchestes agasthyaensis, Raorchestes crustai, Raorchestes johnceei, Raorchestes kadalarensis, Raorchestes manohari, Raorchestes ravii, Raorchestes theuerkaufi, Raorchestes thodai* and *Raorchestes uthamani* (Zachariah et al., 2011b).

2.2.2 Reptilian Studies

The studies on Indian reptiles started with Russell in 18th century, who made an elaborate inventory of reptiles in south India. Gunther (1864) published the most valuable account on Indian herpetology based on the collections in the British Museum. The book 'The reptiles of India' by Gunther has accounts of 180 species of snakes. Beddome (1863a, b, 1870, 1876, 1886) named several new snakes from Kerala. Systematics of Herpetology gained much momentum when Boulenger (1890) published several volumes on reptiles and batrachians. He was the first to develop a 'satisfactory' key for identification of snakes. Boulenger (1894, 1896, 1907) described several new species of reptiles from different parts of Kerala. Ferguson (1895, 1903, 1907) reported on the snakes and tortoises of Travancore.

Wall worked for 30 years in different parts of India studying the natural history of snakes. He published 88 papers in the Journal of Bombay Natural history Society. His papers on reptiles include snakes of Kannur (Wall, 1905) and Nilgiris and Wayanad (Wall, 1918). A landmark in indian Ophidiology was the publication of Fauna volume on reptiles by Smith (1933, 1935, 1943).

Among the snakes, uropeltids is the least studied group due to the subterranean life. The earlier workers missed to present it well due to the non-availability of specimens. Rajendran (1977) filled this gap with his extensive survey in the Western Ghats especially in the southern parts of Kerala. The information on the status and distribution of the reptilian species were collected by the CAMP workshop on Indian reptiles (IUCN, 1998).

2.2.2.1 Recent Studies in Reptiles of Kerala

The focus on Kerala part of Western Ghats was by Murthy (1972a, b) of Zoological Survey of India, who published his report on the snakes of Anamalais and Cardamom hills. Murthy (1978a, b), later documented the lizards of New Amarambalam, reptiles of Silent Valley and New Amarambalam (Murthy, 1981). Murthy (1974) and Murthy and Sundarsingh (1975) published the results of the survey of uropeltids in Anamalais, Palnis and Thenmalai in Kerala.

Henderson (1912) described the forest cane turtle from Chalakudy, which was later rediscovered by Vijaya (1982). Radhakrishnan (1999) reported its range of extension further south. Documentation of reptiles by Inger et al. (1984a, b), Radhakrishnan (1997, 1999), Zacharias and Bhardwaj (1996), Thomas and Easa (1997a, b, c), Thomas *et al.* (1998) and Abraham *et al.* (1999) added to the information on the reptiles of Kerala. Easa and Ramachandran (2004) documented the reptile species recorded from Kerala through the survey of literature pertaining to the distribution of animals in the group and new description from the state. The most recent study is an updated checklist of the reptiles of Kerala (Jafer Palot and Radhakrishnan, 2011).

2.3 Major Threats towards Herpetofauna

The herpetofauna are facing various threats including habitat destruction, habitat fragmentation, agricultural operations, road mortality, poaching, killing etc. Assessments based on the revised IUCN criteria showed that nearly 57% of the amphibians in India are threatened, with the Western Ghats having the highest number (49) of the threatened species (Kumar et al., 1998).

2.3.1 Habitat Destruction

The Western Ghats have witnessed widespread logging and clear felling for plantations of timber, tea, coffee, agriculture etc. (Chandran, 1997). Although clear felling and logging were stopped in the early 1980s, most of the forest areas, including those in PAs continue to be under various extractive and non-extractive uses by human communities living within and close to the forest (Daniels et al., 1995; Karanth et al., 2006). These reasons ultimately resulted in the complete conversion to human use of a species' entire distributional range. Habitat destruction cause restricted and patchy distributions of several amphibian species in the Western Ghats (Vasudevan et al., 2001). Species richness of herpetofauna, particularly of forest species are negatively affected by factors such as decreasing area and increased disturbance of forest fragments (Kumar et al., 2002).

2.3.2 Habitat Fragmentation

Habitat fragmentation affects herpetofaunal biodiversity very seriously. Mainly, the isolation of species is due to the construction of roads and canals across the habitats. Due to habitat fragmentation and high human densities, the Western Ghats is considered one of the eight most threatened biodiversity hot spots of the world (Kumar et al., 2002). The location of dams and reservoirs within the protected areas has led to the destruction of habitats of amphibians in many WLS like Neyyar, Peppara, Shenduruni, Idukki, Peechi-Vazhani, Chimmini, Parambikulam and Periyar. It has also resulted in the scarcity of water downstream, which poses problems to existence of several riparian species of amphibians during the summer period (Andrews et al., 2005b).

2.3.3 Agricultural Operations

Agricultural operations are also a serious threat to amphibians and reptiles in our state. The agricultural practices which are carried out in large areas within or in the neighbourhood of some protected areas like Wayanad, Aralam, and

Agasthyavanam Biological Park is a serious threat to them (Andrews et al., 2005b). The indiscriminate use of pesticides in plantations is causing environmental pollution harmful to amphibians. Seven of the 12 new species were found only in areas which were forests some time back, are now plantations (Biju and Bossuyt, 2009).

2.3.4 Road Mortality

Roads have become one of the growing threats to animal and plant populations (Trombulak and Frissell, 2000). It can affect in two ways. One is by direct mortality by vehicles and the second is indirect effect by the modification of aquatic and terrestrial habitats by exhaust (Turtle, 2000). Roads are known to cause forest fragmentation (Reed et al., 1996). The Western Ghats have experienced large-scale changes over the last century because of expansion of plantations and townships (Nair, 1991).The road mortality studies are but lacking in Kerala. Only major study in road kill of herpetofauna in Western Ghats was done in Anamalai hills (Vijayakumar et al., 2001).

2.3.5 Poaching

Poaching is mainly done for food (frogs, Varanus sp, Python), for costly products like star tortoise, snake skin, snake venom etc, for fat and flesh, for ornamental trophies, for studies (in large quantity), for exhibition, for illegal specimen collection etc. *Crocodylus palustris*, the only crocodile family member seen in the western coast of India, their numbers have dwindled due to poaching (Srinivasulu and Das, 2008).

2.3.6 Killing

Particularly reptiles are killed and this is due to the fear of getting harmed or unknowingly or as a hobby. The fear and resentment aroused due to snake-bites results in malicious killing of many non-venomous snakes on sight. Direct human killing has been identified as an important cause of population decline in

snakes. A large number of kills of the non-venomous Travancore wolf snake *Lycodon travancoricus* had been reported in Nilambur, Kerala due to its similarity to the Indian krait, the most deadly venomous terrestrial snake in India. (Balakrishnan, 2010). A recent study in Kerala about the major threats impacting amphibians in Kerala shows that in our state, the major threat to amphibians is due to habitat loss. About 88% threat is due to habitat loss only. The habitat loss is followed by pollution (31%), utilization, natural disasters, human disturbances, fire etc. and the least (only 1%) is by animal diseases (Biju, 2001).

2.4 Conservation Challenges

There are many conservation challenges with respect to herpetofauna. The patchy distribution of herpetofauna has important conservation implications. The protected areas in the Western Ghats need to enclose ecological gradients and drainage systems in order to conserve them completely. Even forest fragments are likely to contain several undescribed species. Patchy fragments in Western Ghats still retain a considerable number of endemics. Conservation should depend on taxa and their habitat. But many forest fragments are privately owned and managed for production of cash crops under natural shade, conservation of many endemics is difficult. Taxonomic uncertainties are another major handicap in the studies on amphibians and reptiles (Kumar et al., 2002).

The turnover of species should also be taken into consideration while planning for the conservation of amphibians. A dedicated effort involving diverse stakeholders is urgently required to restore and conserve the threatened habitats in the Western Ghats and the biodiversity within them (Mudappa and Raman, 2003). Unlike mammals and birds, which show very little patchiness in distribution, amphibians in the Western Ghats seem to be highly patchily distributed. “A few large protected areas”, which is the conservation model for mammals and birds, may not provide adequate coverage for many species of amphibians. What we require instead may be a network of protected areas that cover different drainage systems (Vasudevan et al., 2006).

2.5 Need for Focus on Herpetofauna

IUCN Global Amphibian Assessment has recorded that we have lost 200 amphibian species since 1980. The Global Amphibian Assessment revealed 99 amphibian species that are adversely impacted by exploitation for the international trade, including 35 species that are globally threatened. Currently, only 36 of these species (16 of the globally threatened species) are listed on Appendices I or II of CITES (IUCN, 2004). One in three among surviving amphibian species are on the verge of extinction. Complete information about the herpetofauna in Kerala is lacking except some location centric studies done individually (Biju, 2001). Amphibians and reptiles have the highest level of endemism among vertebrates in the Western Ghats hotspot. It is a mega hotspot for reptilian fauna, having over 50% endemic species and a number of these endemic species being in the IUCN 'threatened' category. But nothing has been done for their conservation (Nihara et al., 2007). The studies about herpetofauna of wetlands are scarce in India and in Kerala and this inadequacy of knowledge and information of these animals warrants immediate attention on the studies of them in this wetland region and hence the study.

Materials and Methods

MATERIALS AND METHODS

3.1 Study Area

3.1.1 Name, Location and Extent

Kole lands lie between Bharathapuzha in the north and Chalakudy River in the south. It is located between 10^{o} 20' and 10^{o} 40' N latitudes and 75^{o} 58' and 76^{o} 11' E longitudes. Karuvannur and Kechery rivers drain the Kole lands and finally discharge into the Arabian Sea. Kole lands are divided into two divisions namely the Thrissur Kole and the Ponnani Kole. The Karuvannur River divides the Thrissur Kole land in to North and South Kole. It also acts as the flood basin for these rivers. Water level rises up to 5.5 meters during the southwest monsoon. The wetland area comes under the administration of civil authorities of Mukundapuram, Chavakkad, Thrissur and Thalappilly taluks of Thrissur district and Ponnani taluk of Malappuram district (Johnkutty and Venugopal, 1993).

The 'Kole lands', which is spread into Thrissur and Malappuram remains as one of the major fresh water wetlands of Kerala state. This is said to be the rice granary of these districts at par with Kuttanad the 'Rice Bowl' of Kerala. Rice cultivation in Kole lands is said to have started way back in the eighteenth century. However, earliest record on rice cultivation in Trichur Kole lands dates back to 1916.

The Kole land runs parallel to the sea and are low-lying tracts located 0.5 to 1 meter below the mean sea level. The floodwater from the rivers used to bring enormous quantities of nutrient rich alluvium, which gets deposited in the Kol lands. The cyclical nutrient recharging of the wetland during the flood season rendered the area as one of the most fertile soils of Kerala. This is indicated by the fact that 'while the average productivity of rice in the state is less than two tonnes per hectare, Kole lands yielded 4-5 tonnes of rice per hectare. Seven to eight tonnes per hectare are also not uncommon (Johnkutty and Venugopal 1993). The bumper yield under favourable condition and total loss in case of breaching

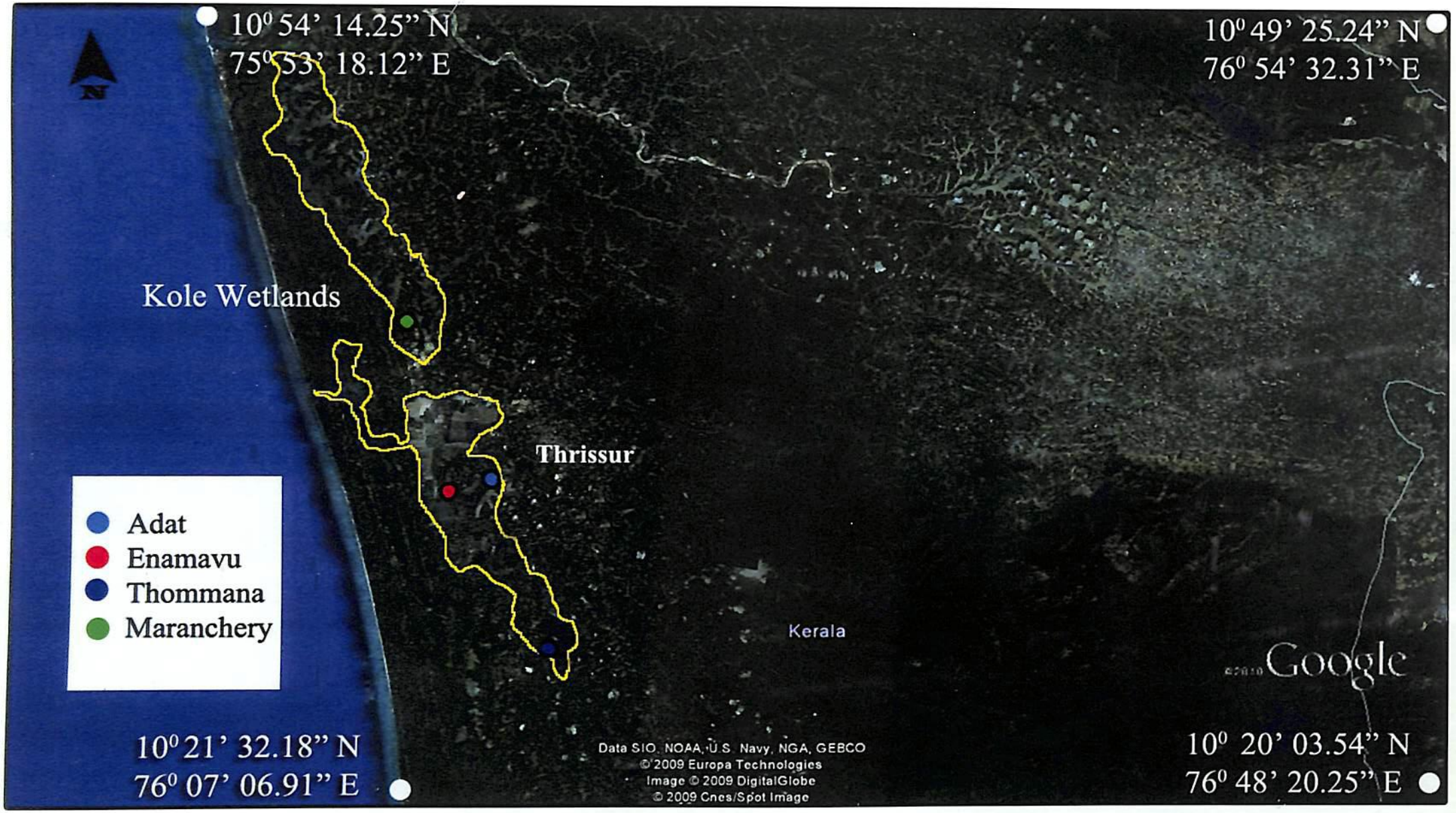


Fig. 1 Map of Kole Wetlands showing the study locations (using Google Earth and Diva GIS)

of the earthen bunds made farming a gambling. Hence, these rice fields came to be called as ‘Kole lands’ signifying bumper crop in Malayalam.

For the present study, four random areas from the wetlands are selected viz. Adat, Enamavu, Thommana and Maranchery so that the areas represent the whole of the Kole wetlands (Fig. 1).

3.1.2 Geology, Rock and Soil

It is believed that Kole lands along with the Vembanad estuarine areas have been formed by an upheaval of the shoreline subsequent to the regression and transgression of the coastal waters in the past. The Kole land area is a submerged plain land representing piedmont type of deposits, silted up with alluvium brought down by Karuvannur and Kechery rivers. Texturally the material ranges from fine to coarse clastic particles derived from lateritic hills surrounding the area. Black carbonaceous clay with a lot of large decomposed tree trunks is often seen in the Kole indicating that fluvio-estuarine deposition process have played a major role in the formation of Kole lands.

The presence of deep sand layers seen in several areas provide evidence that the area might have been under the sea in the recent geological past (Kurup and Varadachar, 1975). The western margin of the Kole lands has an expanse of sedimentary rocks including sandstone and clay of Varkala formation. The coastal alluvium seen in the western extremities probably represents a sand bar extending north-south parallel to the coast. The eastern border of the Kole land is characterized by low-lying hills, which is essentially a crystalline terrain. The differential weathering of crystalline rocks such as biotite gneiss and charnockite results in heterogeneous laterite (Thomas et al., 2003).

Hameed (1975) investigated the chemical characteristics of Kole land soil and reported that the organic matter content of the soil is very high. In the surface level it varies from 2.07 - 4.16%. A lesser amount of organic matter is seen in the subsurface layer (1.37-9.70%). However, in certain parts the subsurface

accumulation of peat was observed and the organic content varied between 28.91-69.91%. Chemically the soil is acidic with pH 2.6 to 6.3 and the pH decreases with increasing depth. The total nutrient content of the soil throughout the Kole land is 0.14 – 0.57% Nitrogen, 0.2-0.24 % P_2O_5, and 0.09 –0.60 % of K_2O. CaO levels also are reported to be very high. Based on the textural analysis Kole land soil has been classified into clay, sandy loam, sandy clay loam, and clay loam (Sheela, 1988).

3.1.3 Climate

3.1.3.1 Rainfall pattern and Distribution

As in other areas of the state, Kole lands also receive two well-defined rainy seasons, the southwest and North-west Monsoons. Johnkutty and Venugopal (1993) reported that the mean annual rainfall recorded in the Kole lands is 2757 mm out of which 67.3% is received during SW monsoon and 18% during NE monsoon. The phenomenon of depression rains which is noted during October - November is also another source of water for the Kole lands.

3.1.3.2 Temperature

Moderate climatic conditions are experienced in the Kole land area. The area has a recorded minimum temperature of 21^{o} C and a maximum of 38^{o}C. Air is humid (85-95% during June -September and 70% during January). Mean pan evaporation in the Kole tract is 5.8 mm/day (Johnkutty and Venugopal 1993).

3.1.4 Drainage

The combined drainage area of the Kechery and Karuvanuur Rivers is 1685 km^2 with the monsoon flow of 2265 mm^3 and total flow is 2388 mm^3. The Karuvanuur has two tributaries Manali and Kurumali. Peechi River and its tributaries feed the Manali River. Kurumali River originates at the confluence of

Chimmony Puzha and Mupply Puzha. All these rivers take their origin from the Western Ghats.

Kechery River, which originates from the Machad hills drains the north Kole and release the water into the Enamackal estuary. The 'North Kole' stretches from Kechery River in the north to Karuvanuur River in the south. The area extending from south bank of Karuvannur River to Vellangalur region in the south is called as 'South Kole'. A network of main and cross canals connects the different regions of the Kole to the rivers and it facilitates good drainage. Thuppan thodu and Nedum thodu are the two major drainage canals of the south Kole. From the Muriyad area, Thamaravalayam canal drains into the Karuvannur River during monsoon and convey irrigation water from the river to the Kole lands during summer crop periods.

The main exit for the water collected in the south Kole is the Enamakkal regulator and that of the North Kole the Idiyanchira regulator. These regulators also control the salt-water intrusion into the paddy fields (Johnkutty and Venugopal 1993). The summer irrigation needs of about 80,000 ha of Trichur Kole lands are met from three dams constructed across the tributaries of Karuvannur River i.e., Peechi in Manali river and Chimmoni and Mupply across the tributaries of Kurumali river (Thomas et al., 2003).

3.2 Methods

3.2.1 Period of Observation

The field study was carried out from July 2010 to June 2011. Seasonal observations were taken during these periods. Though the time frame represented the retreating south-west monsoon, the north-east monsoon, winter, hot summer and the south-west monsoon, these were grouped into two seasons namely the wet season (June to October) and dry season (November to May), since the change in seasons was not distinguishable.

3.2.2 Site Selection

The site selected for this study was Kole lands, which are mainly composed of paddy fields and some wetlands. General study was carried out in the Kole lands of which Adat, Thommana, Enamavu and Maranchery of Thrissur district were selected as the representative plots for the whole Kole lands in this study. Visual encounter survey was basically carried out in these study areas.

3.2.3 Visual Encounter Survey

This is the direct method by which the herpetofauna is noted by direct sightings and from the calls. The survey was done along the existing paths where there are high chances of encountering amphibian life forms like along the canals, on the bunds, paddy fields etc. These surveys were done in the morning and evening hours. Daytime searches in the morning hours were between 07.00 to 11.00 hrs. Lizards and snakes are basking or active in this period while evening searches were from 18.00 to 22.00 hrs, when both diurnal and nocturnal species are active. Amphibians and reptiles were caught, identified, measured, photographed and released. Unidentified amphibians were caught and kept in the bags, and were taken to the lab and identified using published field keys and original descriptions of the species. Stream surveys were also done as streams are a very important microhabitat for many amphibians, especially for breeding, and subject to high seasonal variations due to monsoons.

3.3 Data Analysis

The species richness can be expressed by various indices that show how that species is related to a particular habitat. In the present study species richness, species diversity, abundance and seasonal variations are computed and similarities in herpetofaunal population in these areas were found. The following indices which are commonly used for measuring species richness, diversity, abundance and similarity were used to analyse the population of herpetofauna in the study area.

3.3.1 Margalef species richness index

Margalef index is calculated by the formula given below,

$$DMg = \frac{S-1}{\ln N}$$

Where, S is the total number of species recorded and N is the total number of individuals summed over all S species (Magurran, 1988).

3.3.2 Diversity indices

3.3.2.1 *Simpson's index, λ*

Simpson (1949) proposed the first diversity index used in ecology as

$$D = \Sigma p_i^2$$

where, pi is the proportional abundance of the 'i' th species given by

$$p_i = \frac{n_i}{N}$$

Where, i = 1, 2, 3, 4, …..S, n_i is the number of individuals of the i^{th} species and N is the total known individuals for all S species in the population. Simpsons index, which varies from 0 – 1, gives the probability that two individuals drawn at random from a population belong to the same species. Simply stated, if the probability is high that both individual belong to the species, then the diversity of the community sample is low (Ludwig and Reynolds, 1988). Here 1-D is taken for the Simpson Index.

3.3.2.2 *Shannon-Wiener index, H'*

The Shannon-Wiener index (Shannon and Wiener, 1963) is a measure of the average degree of "uncertainty" in predicting to what species an individual chosen at random from a collection of S species and N individuals will belong.

This average uncertainty increases and as the distribution of individuals among the species becomes even. Thus H' has two properties that have made it a popular measure of species diversity: (1) H'=0 if and only if there is only one species in the sample, (2) H' is maximum only when all S species are represented by the same number of individuals, that is, a perfectly even distribution of abundance (Ludwig and Reynolds, 1988).

The equation of the Shannon function, which uses natural logarithm (ln), is

$$H' = \Sigma (p_i . \ln p_i)$$

Where H' is the average uncertainty per species in the infinite community made up of S species with known proportional abundance p_1, p_2, p_3,…….p_s.

3.3.2.3. Pielou's evenness index

In the present study evenness index was calculated using the Pielou's Evenness Index (Pielou, 1975).

$$J' = \frac{H'}{\ln S}$$

Where H' is Shannon-Weiner diversity index and S is the species richness. J' expresses H' relative to the maximum value that H' can obtain when all of the species in sample are perfectly even with one individual per species.

3.3.3 Similarity indices

The similarity of the group of animals concerned between the study sites were worked out using Bray Curtis Cluster Analysis.

3.3.3.1 Bray Curtis Cluster Analysis

The similarity of the group of animals concerned between the study sites were worked out using Bray Curtis Cluster Analysis. Cluster analysis is a

multivariate analysis technique and is not as much a typical statistical test as it is a collection of different algorithms that put objects into clusters. The clusters formed with this family of methods should be highly internally homogeneous (member are similar to one another) and highly externally heterogeneous (members are not like members of other cluster).

Unlike many other statistical procedures, cluster analysis methods are mostly used when there are no prior hypotheses, but where research is still in an explanatory phase. A dendrogram (tree like diagram) is produced, which summarises the process of clustering. Similar cases are joined by links whose position in the diagram is determined by the level of similarity between the cases (Aldenderfer and Blashfield, 1984).

3.3.4 Diversity t test

Diversity t test is done for comparing Shannon diversities in two samples of abundance data with the assumption of equal sampling conditions. Two columns of abundance data with taxa down the rows are needed for the test. The p value determines whether there is a difference in the diversity with the two samples. If p value is less than 0.01, it is significant at 1% level, if p value is between 0.01 and 0.05, it is significant at 5% level and if p value is greater than 0.05, then it is non-significant (Poole, 1974).

3.3.5 Statistical analysis

Various statistical packages including the Microsoft Office Excel (Version 2010), SPSS (Version 17), Biodiversity Pro (McAleece et al., 1997), and PAST (Hammer et al., 2001) were used for statistical analysis of the data collected.

Results

RESULTS

4.1 Species Composition of Herpetofauna from Kole Wetlands

There were 25 species of herpetofauna in the Kole Wetlands recorded from the four study areas at Adat, Thommana, Enamavu and Maranchery (Table 3). This includes eight species of amphibians and 17 species of reptiles of which seven species of amphibians and five species of reptiles were recorded during the study period and the rest reported earlier. The species reported from the four study sites in the wet and dry seasons are included in Table 4. Each of these groups is explained in detail below.

4.1.1 Amphibians of Kole Wetlands

Seven species of amphibians were recorded during the study. The seven species include Common Indian Toad (*Duttaphrynus melanostictus*), Skittering Frog (*Euphlyctis cyanophlyctis*), Cricket Frog (*Fejervarya sp.*), Indian Bull Frog (*Hoplobatrachus tigerinus*), Golden Frog (*Hylarana aurantiaca*), Fungoid Frog (*Hylarana malabarica*) and Kani Bush Frog (*Pseudophilautus kani*). Paddy Field Frog (*Fejervarya limnocharis)* was earlier reported from the wetlands. The amphibians of Kole Wetlands are represented in the families such as Dicroglossidae with three species, Ranidae with two species and Bufonidae and Rhacophoridae with one species each. The list of amphibians identified along with their taxonomic position is given in Table 3.

4.1.2 Reptiles of Kole wetlands

Five species of reptiles were recorded in the present study. They include Common Green Forest Lizard (*Calotes calotes*), Indian Garden Lizard (*Calotes versicolor*), Brook's gecko (*Hemidactylus brookii*), Common rat snake (*Ptyas mucosus*) and Checkered keelback (*Xenochrophis piscator*). They are represented by the families Agamidae with two members, Colubridae with two members and Gekkonidae with a single member. The other species observed earlier from the

Kole lands are Common Keeled Skink (*Eutropis carinata*), Indian Rock Python (*Python molurus*), Indian Cobra (*Naja naja*), Russels Viper (*Daboia russelii*), Green Vine Snake (*Ahaetulla nasuta*), Common Bronzeback Snake (*Dendrelaphis tristis*), Common Wolf Snake (*Lycodon aulicus*), Common Sand Boa (*Gongylophis conicus*), Indian Flapshell turtle (*Lissemys punctata*), Indian black turtle (*Melanochelys trijuga*), Asian giant softshell turtle (*Pelochelys cantorii*) and Common Indian Monitor (*Varanus bengalensis*) represented in the families Scincidae, Pythonidae, Elapidae, Viperidae, Colubridae, Colubridae, Boidae, Trionychidae, Bataguridae and Varanidae (Table 3).

Table 3. Checklist of herpetofauna (amphibians and reptiles) of the Kole wetlands

Sl. no.	**Common Name**	**Scientific Name**	**Family**
I	**Amphibians**		
1	Common Indian Toad	*Duttaphrynus melanostictus*	Bufonidae
2	Skittering Frog	*Euphlyctis cyanophlyctis*	Dicroglossidae
3	Cricket Frog sp.	*Fejervarya sp.*	Dicroglossidae
4	Indian Bull Frog	*Hoplobatrachus tigerinus*	Dicroglossidae
5	Golden Frog	*Hylarana aurantiaca*	Ranidae
6	Fungoid Frog	*Hylarana malabarica*	Ranidae
7	Kani Bush Frog	*Pseudophilautus kani*	Rhacophoridae
8	Paddy Field Frog*	*Fejervarya limnocharis*	Dicroglossidae
II	**Reptiles**		
9	Common Green Forest Lizard	*Calotes calotes*	Agamidae
10	Indian Garden Lizard	*Calotes versicolor*	Agamidae
11	Brook's Gecko	*Hemidactylus brookii*	Gekkonidae
12	Indian Rat Snake	*Ptyas mucosa*	Colubridae
13	Checkered Keelback	*Xenochrophis piscator*	Colubridae
14	Common Keeled Skink*	*Eutropis carinata*	Scincidae
15	Indian Rock Python*	*Python molurus*	Pythonidae

16	Indian Cobra*	*Naja naja*	Elapidae
17	Russels Viper*	*Daboia russelii*	Viperidae
18	Green Vine Snake*	*Ahaetulla nasuta*	Colubridae
19	Common Bronzeback Snake*	*Dendrelaphis tristis*	Colubridae
20	Common Wolf Snake*	*Lycodon aulicus*	Colubridae
21	Common Sand Boa*	*Gongylophis conicus*	Boidae
22	Indian Flapshell turtle*	*Lissemys punctata*	Trionychidae
23	Indian black turtle*	*Melanochelys trijuga*	Bataguridae
24	Asian giant softshell turtle*	*Pelochelys cantorii*	Trionychidae
25	Common Indian Monitor*	*Varanus bengalensis*	Varanidae

[* fields indicate earlier observed species from Kole Wetlands (Nameer, 2010)]

4.1.3 Herpetofauna recorded in the four study sites in Kole Wetlands during wet and dry seasons

In the Adat region, of the eight species recorded, *Calotes versicolor, Duttaphrynus melanostictus* and *Hylarana malabarica* were seen only in the wet season. The most recorded species from Adat was *Fejervarya sp.*in wet season and *Hoplobatrachus tigerinus* in the dry season (Table 4, Fig. 2). In Enamavu, of the nine species recorded, *Calotes calotes, Duttaphrynus melanostictus, Fejervarya sp* and *Pseudophilautus kani* were absent in the dry season and *Ptyas mucosus* was absent in the wet season. *Euphlyctis cyanophlyctis* was the most abundant species in the wet season and *Hoplobatrachus tigerinus* was the abundant one in the dry season (Table 4, Fig. 3). Of the six species from Maranchery, *Calotes versicolor, Hylarana aurantiaca* and *Xenochrophis piscator* was not seen in the dry season and *Fejervarya sp.*was not seen in the wet season. *Hylarana aurantiaca* was the abundant species in the wet season and *Hoplobatrachus tigerinus* was seen most in dry season (Table 4, Fig. 4). Similarly, in Thommana, *Xenochrophis piscator, Hemidactylus brookii* and *Calotes versicolor* were absent in the dry season. *Hylarana aurantiaca* was the

abundant species in the wet season and *Euphlyctis cyanophlyctis* was the most abundant in the dry season. *Hemidactylus brookii* was reported only from the Thommana region (Table 4, Fig. 5).

Table 4. Herpetofauna recorded during the study period in the four sites in Kole Wetlands during wet and dry seasons

Species	**Adat (No.of individuals)**		**Enamavu (No.of individuals)**		**Maranchery (No.of individuals)**		**Thommana (No.of individuals)**	
	wet	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**
Calotes versicolor	3	0	0	0	9	0	2	0
Calotes calotes	0	0	3	0	0	0	0	0
Hemidactylus brookii	0	0	0	0	0	0	8	0
Duttaphrynus melanostictus	1	0	1	0	0	0	0	0
Euphlyctis cyanophlyctis	17	24	20	17	27	21	23	35
Fejervarya sp.	33	21	16	0	0	36	5	18
Hoplobatrachus tigerinus	25	35	18	33	23	43	22	24
Hylarana aurantiaca	1	6	19	0	32	0	28	6
Hylarana malabarica	13	0	8	33	0	0	1	6
Pseudophilautus kani	0	0	7	0	0	0	9	12
Ptyas mucosus	0	0	0	17	0	0	0	0
Xenochrophis piscator	6	15	0	0	9	0	2	0

Fig 2. Herpetofauna recorded during the study period in Adat during wet and dry seasons

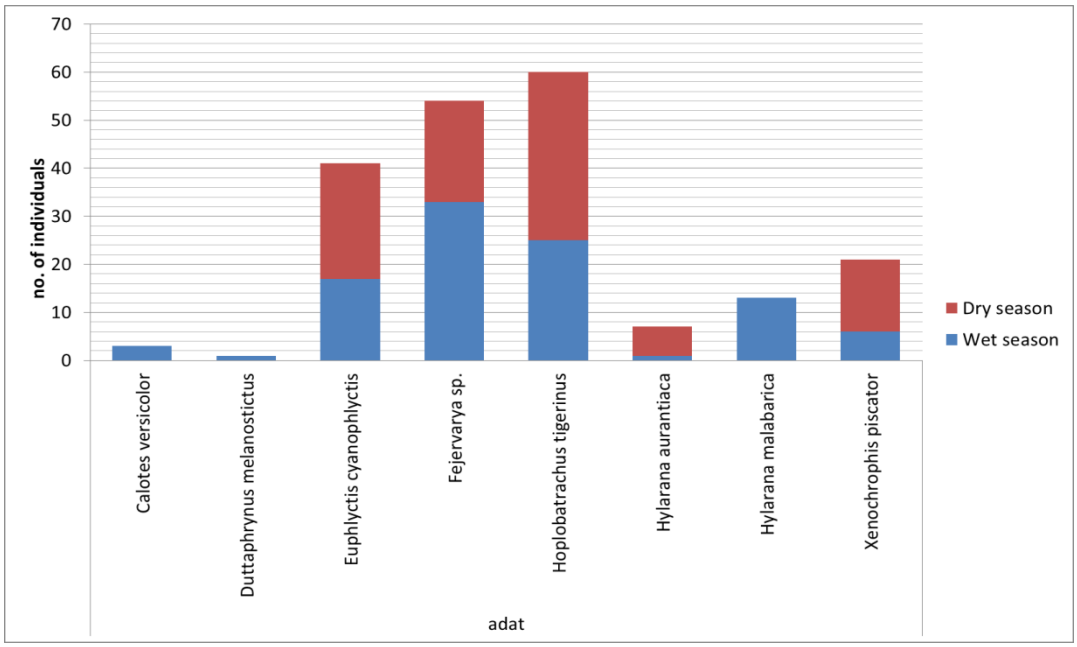


Fig 3. Herpetofauna recorded during the study period in Enamavu during wet and dry seasons

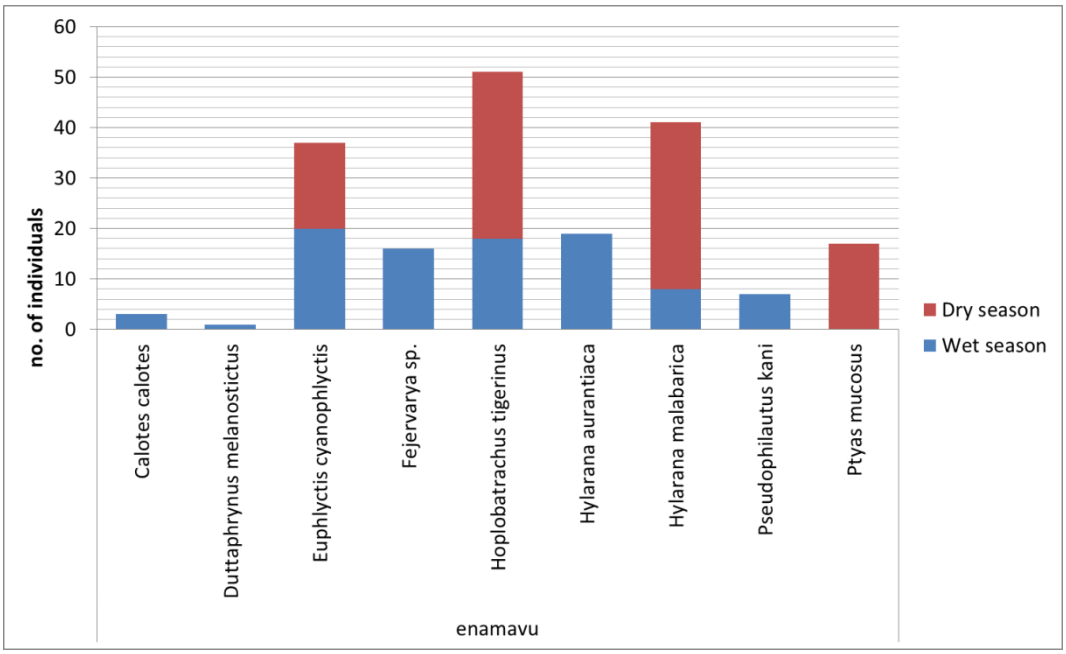


Fig 4. Herpetofauna recorded during the study period in Maranchery during wet and dry seasons

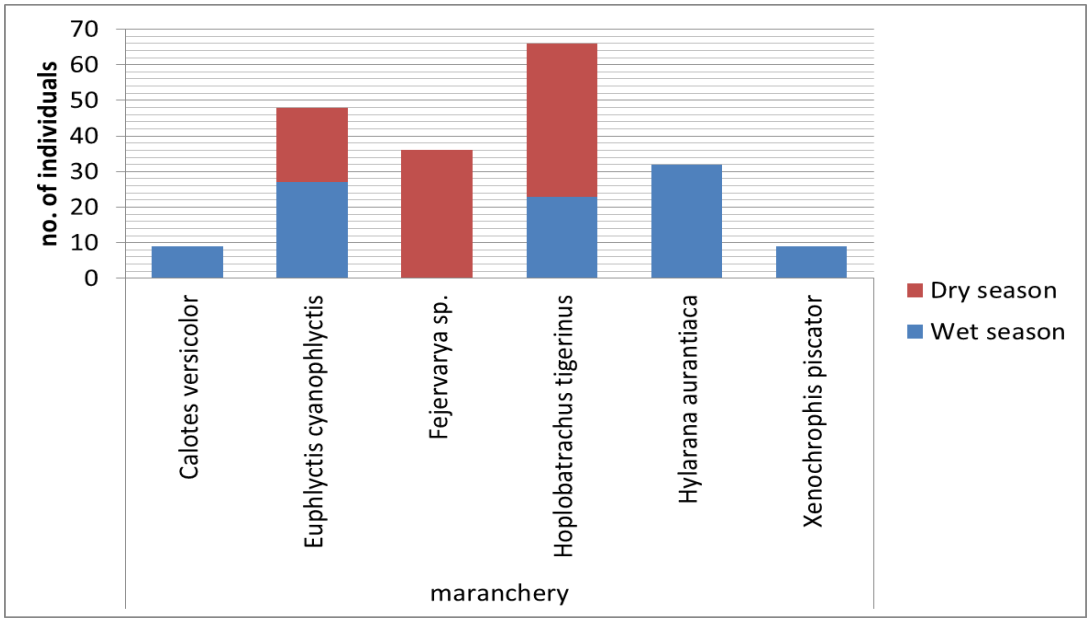
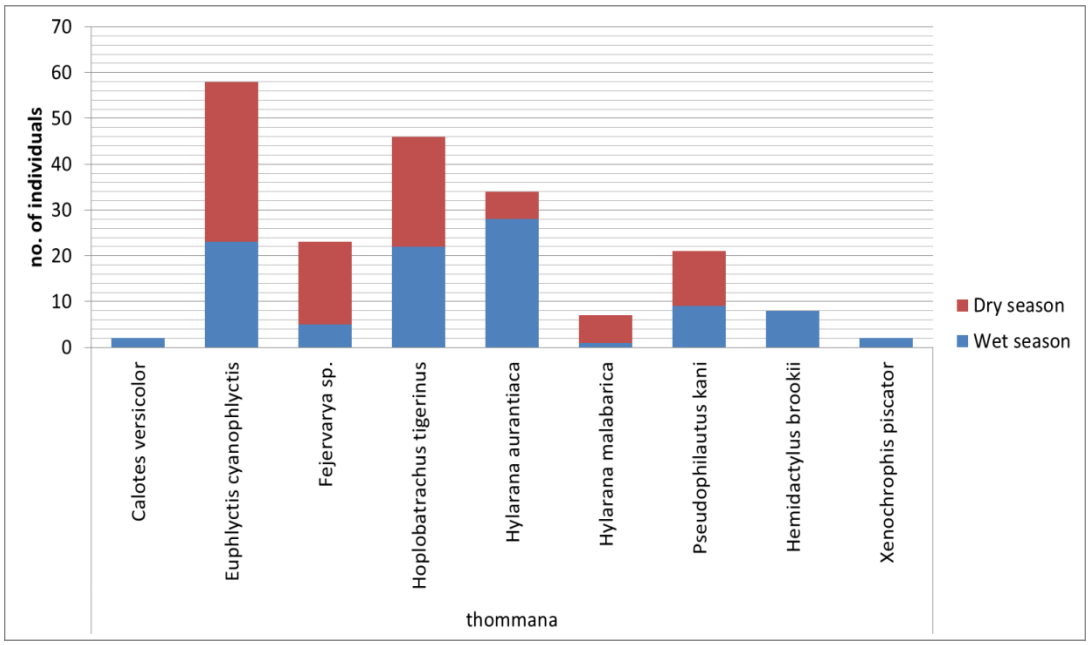


Fig 5. Herpetofauna recorded during the study period in Thommana during wet and dry seasons



4.2 Seasonal Variation in the Herpetofauna of the Kole Wetlands

The herpetofauna of the Kole Wetlands were studied during the Wet (June to October) and dry (November to May) seasons. The details on the amphibian and reptilian diversity during the wet and dry seasons are explained below.

4.2.1 Seasonal Variation in the Amphibians of the Kole Wetlands

The details on the amphibian diversity during the wet season are given in Table 5. In the wet season, the highest number of species of amphibians was recorded from Enamavu with seven species and lowest from Maranchery with three species. However, the maximum number of individuals was recorded from Thommana with 55 individuals and lowest is from Maranchery with only 10 individuals (Table 5).

Table 5. The summary statistics of the amphibians in the different study sites of Kole Wetlands during wet season

Sample (wet season)	Total Species	Total Individuals	Mean Individuals	Variance	Standard Deviation	Standard Error
Adat	6	21	3	6.33	2.52	0.95
Enamavu	7	41	5.86	17.14	4.14	1.56
Maranchery	3	10	1.43	3.29	1.81	0.68
Thommana	6	55	7.86	45.81	6.77	2.56

The details on the amphibian diversity during the dry season are given in Table 6. In the dry season, the highest number of species of amphibians was recorded from Thommana with six species and lowest from Maranchery and Enamavu with three species. However, the maximum number of individuals was recorded from Adat with 26 individuals and lowest is from Enamavu with only 5 individuals (Table 6).

Table 6. The summary statistics of the amphibians in the different study sites of Kole Wetlands during dry season

Sample (dry season)	Total Species	Total Individuals	Mean Individuals	Variance	Standard Deviation	Standard Error
Adat	4	26	4.33	21.87	4.68	1.91
Enamavu	3	5	0.83	0.97	0.98	0.40
Maranchery	3	11	1.83	5.77	2.40	0.98
Thommana	6	14	2.33	1.87	1.37	0.56

4.2.1 Seasonal Variation in the Reptiles of the Kole Wetlands

The details on the reptilian diversity during the wet season are given in Table 7. In the wet season, the highest number of species of reptiles was recorded from Thommana with three species and all others areas with two species each. However, the number of individuals recorded from Enamavu was nine whereas it was three from Maranchery (Table 7).

Table 7. The summary statistics of the reptiles in the different study sites of Kole Wetlands during wet season

Sample (wet season)	Total Species	Total Individuals	Mean Individuals	Variance	Standard Deviation	Standard Error
Adat	2	5	1.25	3.58	1.89	0.95
Enamavu	2	9	2.25	10.92	3.30	1.65
Maranchery	2	3	0.75	0.92	0.96	0.48
Thommana	3	7	1.75	1.58	1.26	0.63

The details on the reptilian diversity during the dry season are given in Table 8. In the dry season, only one species was reported from Adat and Enamavu each. No reptiles were seen from Maranchery or Thommana in the dry seasons. 5 individuals were recorded from Adat alone and one individual was recorded from Enamavu (Table 8).

Table 8. The summary statistics of the reptiles in the different study sites of Kole Wetlands during dry season

Sample (dry season)	Total Species	Total Individuals	Mean Individuals	Variance	Standard Deviation	Standard Error
Adat	1	5	2.5	12.5	3.54	2.5
Enamavu	1	1	0.5	0.5	0.71	0.5

4.2 Species Diversity Analysis

The species richness and diversity of herpetofauna was calculated for the four locations in study area for two seasons generally taken as wet and dry seasons. The species richness and diversity details of the herpetofauna of Kole Wetlands in the wet and the dry seasons are given in Table 9 and 10 respectively.

4.2.1 Species richness and diversity of herpetofauna during wet season in Kole wetlands

The highest number of species was recorded from Enamavu and Thommana in wet season i.e. nine species, followed by Adat and least in Maranchery. In the case of number of individuals recorded, the maximum is from Thommana with 62, followed by Enamavu, Adat and the least from Maranchery with 13 individuals (Table 9). The dominance value is high in Thommana and Maranchery as the total individuals seen are less compared to the number of species and the dominance value is least in Enamavu as the number of species and individuals are comparatively high. Simpson index (1-D) shows that the diversity is high in Enamavu region having nine species when compared with the number of species and the total individuals sighted, followed by Adat with eight species. Thommana also have nine species but the total individuals are more thus making them less diverse as per the index (Table 9, Fig. 6). Similarly Shannon index also shows that the diversity is high in Enamavu, followed by Adat, Thommana and Maranchery (Table 9, Fig. 7).

Pielou's evenness index shows the Shannon index, the maximum value it can obtain when all the species in sample are perfectly even with one individual per species. In that way, Adat and Enamavu are having same evenness index as the dominance in these areas are similar relating to the number of species and total individuals (Table 9). Margalef index shows the species richness relating to the total number of species recorded and the total number of individuals summed over all species. Here, it is very clear that the species richness index is high in Adat as eight species were reported from just 26 individuals, followed by Enamavu, Thommana and Maranchery in wet season (Table 9).

Table 9. Species richness and diversity of herpetofauna in wet season in Kole Wetlands

	Adat	**Enamavu**	**Maranchery**	**Thommana**
Taxa	8	9	5	9
Individuals	26	50	13	62
Dominance	0.14	0.14	0.17	0.17
Simpson index	0.83	0.84	0.77	0.81
Shannon index	0.81	0.86	0.66	0.80
Evenness index	0.81	0.81	0.92	0.72
Margalef index	2.15	2.05	1.56	1.94

Fig. 6. Herpetofaunal diversity (Simpson Index) in the four study locations during wet season in Kole Wetlands

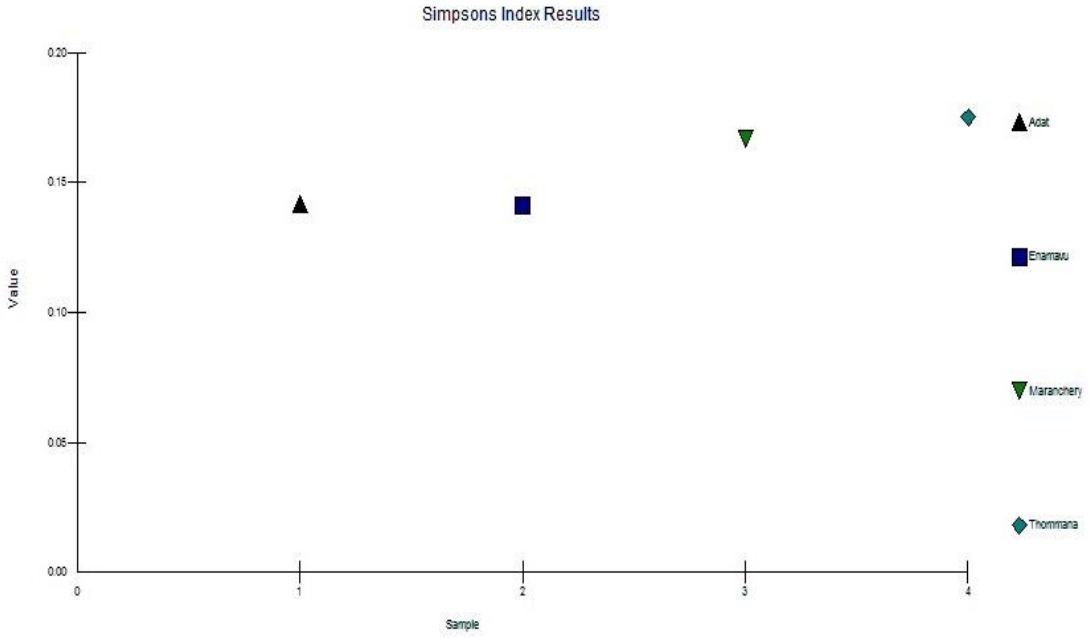
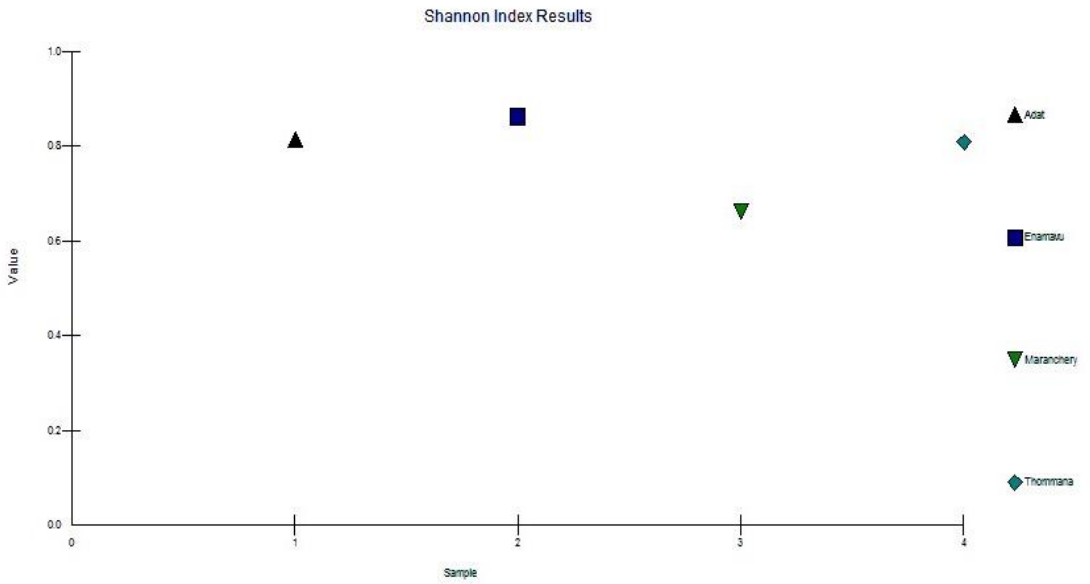


Fig. 7. Herpetofaunal diversity (Shannon Index) in the four study locations during wet season in Kole Wetlands



4.2.1 Species richness and diversity of herpetofauna during dry season in Kole wetlands

The maximum number of species was recorded from Thommana followed by Adat in dry season i.e. six species, followed by five and least in Maranchery with only three species. In the case of number of individuals recorded, the maximum is from Adat with 31, followed by Thommana and Maranchery and the least from Enamavu with only six individuals (Table 10). The dominance value is high in Maranchery in dry season too, as the total individuals seen are less compared to the number of species and the dominance value is least in Enamavu as the number of species is four from just six individuals sighted there in total (Table 10). Simpson index (1-D) shows that the diversity is high in Thommana region having six species comparing the number of species and the total individuals sighted, followed by Adat with five species and Enamavu and Maranchery follows (Table 10, Fig. 8). Similarly Shannon index also shows that the diversity is high in Thommana, followed by Adat, Enamavu and Maranchery (Table 10, Fig. 9).

Pielou's evenness index shows that way, Enamavu and Maranchery are almost having same evenness index as the dominance in these areas are similar relating to the number of species and total individuals (Table 10). Margalef index shows that the species richness index is high in Thommana as six species were reported from just 14 individuals, followed by Enamavu, Adat and Maranchery in dry season (Table 10).

Table 10. Species richness and diversity of herpetofauna in dry season in Kole Wetlands

	Adat	**Enamavu**	**Maranchery**	**Thommana**
Taxa	5	4	3	6
Individuals	31	6	11	14
Dominance	0.23	0.13	0.35	0.15

Simpson index	0.74	0.72	0.60	0.79
Shannon index	0.64	0.58	0.43	0.72
Evenness index	0.87	0.94	0.90	0.87
Margalef index	1.17	1.67	0.83	1.90

4.2.2 Similarity of herpetofauna among different habitats in wet season in Kole wetlands

Bray-Curtis cluster analysis of similarity of herpetofauna in wet season in the four study locations of Kole wetlands showed that there is a greater degree of similarity between the herps of Thommana and Enamavu. The least similarity was for Maranchery compared to others (Fig. 10).

4.2.3 Similarity of herpetofauna among different habitats in dry season in Kole wetlands

Bray-Curtis cluster analysis of similarity of herpetofauna in dry season in the four study locations of Kole wetlands showed that there is a greater degree of similarity between the herps of Thommana and Maranchery. The least similarity was for Enamavu compared to others (Fig. 11).

Fig. 8. Herpetofaunal diversity (Simpson Index) in the four study locations during dry season in Kole Wetlands

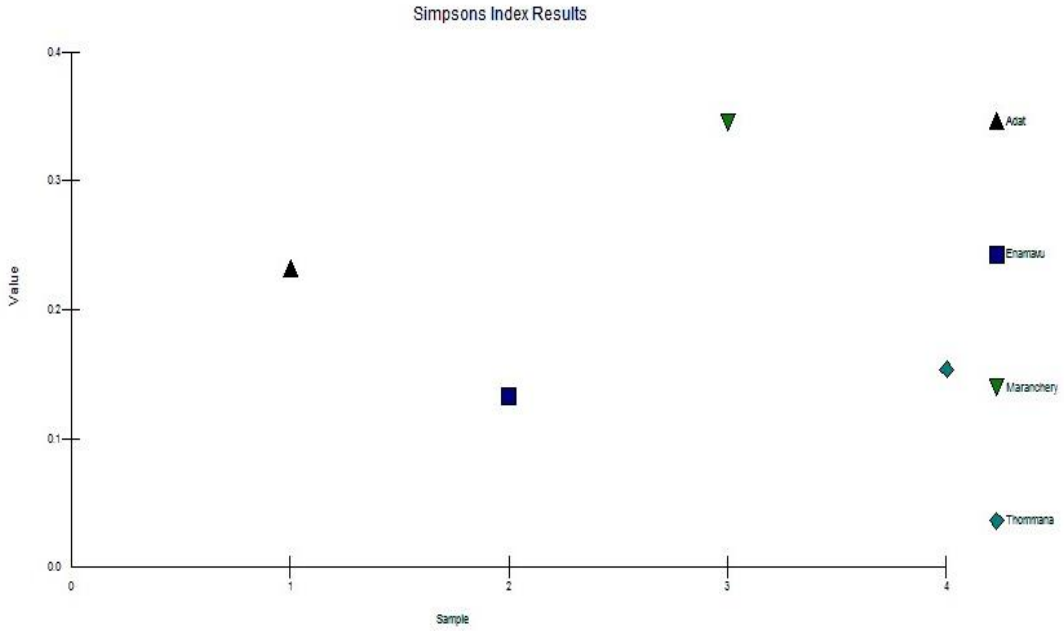


Fig. 9. Herpetofaunal diversity (Shannon Index) in the four study locations during dry season in Kole Wetlands

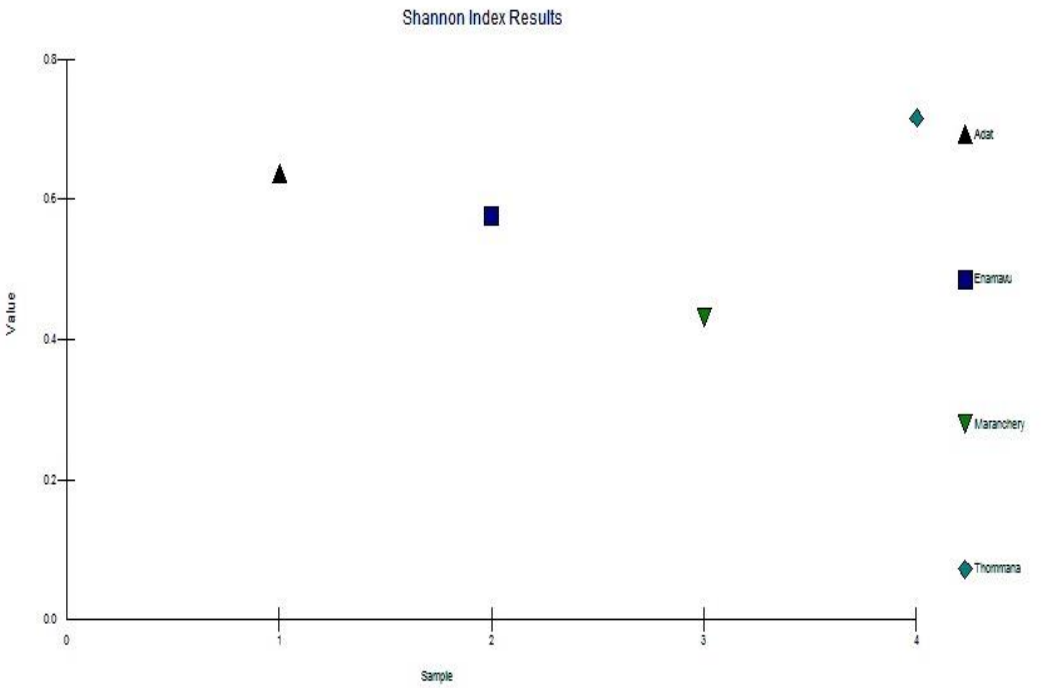


Fig. 10. Bray-Curtis Cluster Analysis of similarity of herpetofauna in wet season in the four study locations of Kole wetlands

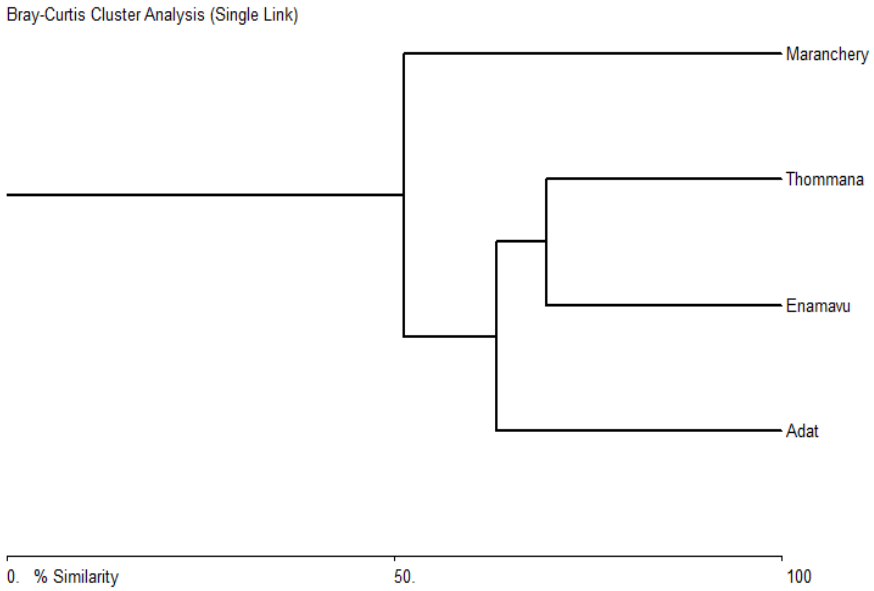
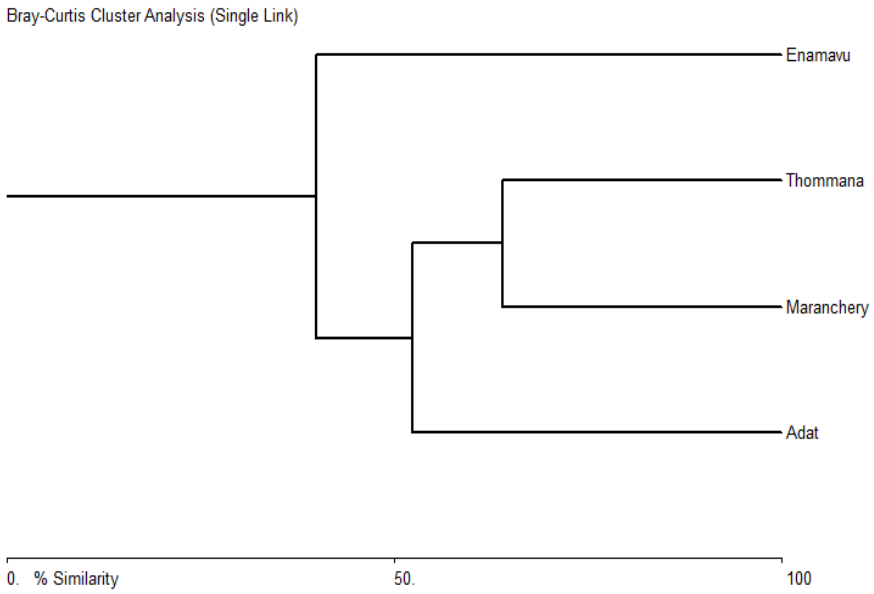


Fig. 11. Bray-Curtis Cluster Analysis of similarity of herpetofauna in dry season in the four study locations of Kole wetlands



4.3 Frequency and Relative Abundance of Herpetofauna in Kole Wetlands

The frequency and relative abundance of the herpetofauna in the four locations during wet and dry seasons are explained below from Table 11 to 14.

4.3.1 Frequency and Relative Abundance of herpetofauna in Adat during the wet and the dry seasons

Eight species of herpetofauna were recorded from the Adat region in total from both wet and dry seasons. In dry season, only five species were recorded. The most frequently seen species of amphibian was *Hoplobatrachus tigerinus* in both wet and dry seasons. It was the most abundant species in dry season but *Fejervarya sp.* was the most abundant in wet season. In reptiles, *Xenochrophis piscator* was the most frequently seen and most abundant species in both wet and dry seasons. *Hyalarana malabarica*, *Calotes versicolor* and *Duttaphrynus melanostictus* were absent in the dry season. The frequency and relative abundance of *Hoplobatrachus tigerinus, Xenochrophis piscator, Euphlyctis cyanophlyctis* and *Hylarana aurantiaca* were seen higher in dry periods (Table 11).

Table 11. Frequency and relative abundance of herpetofauna in Adat during the wet and the dry season

Sl. no	Species	Wet season		Dry season	
		Frequency	Relative Abundance	Frequency	Relative Abundance
1	*Hoplobatrachus tigerinus*	7	25	12	35
2	*Fejervarya sp.*	5	33	5	21
3	*Hylarana malabarica*	4	13	-	-
4	*Xenochrophis piscator*	4	6	5	15
5	*Euphlyctis cyanophlyctis*	3	17	7	24
6	*Calotes versicolor*	1	3	-	-
7	*Duttaphrynus melanostictus*	1	1	-	-
8	*Hylarana aurantiaca*	1	1	2	6

4.3.2 Frequency and Relative Abundance of herpetofauna in Enamavu during the wet and the dry seasons

Nine species of herpetofauna were recorded from the Enamavu region in total from both wet and dry seasons. In dry season, only four species were recorded. The most frequently seen species of amphibian was *Euphlyctis cyanophlyctis* in wet season, but *Hoplobatrachus tigerinus* and *Hylarana malabarica* were most frequent in dry season. *Euphlyctis cyanophlyctis* was the most abundant species in wet season but *Hoplobatrachus tigerinus* and *Hyalarana malabarica* were the most abundant in dry season. In reptiles, *Calotes calotes* was the only reptile seen in the wet season and *Ptyas mucosus* was the only reptile seen in the dry season. *Hylarana aurantiaca, Pseudophilautus kani, Fejervarya sp., Calotes calotes* and *Duttaphrynus melanostictus* were absent in the dry season. The frequency of herpetofauna were all low in the dry season, but relative abundance of *Hoplobatrachus tigerinus* and *Hylarana malabarica* were seen higher in dry periods (Table 12).

Table 12. Frequency and relative abundance of herpetofauna in Enamavu during the wet and the dry season

Sl. no.	Species	Wet season		Dry season	
		Frequency	Relative Abundance	Frequency	Relative Abundance
1	*Euphlyctis cyanophlyctis*	13	20	1	17
2	*Hoplobatrachus tigerinus*	9	18	2	33
3	*Hylarana aurantiaca*	7	19	-	-
4	*Pseudophilautus kani*	7	7	-	-
5	*Fejervarya sp.*	5	16	-	-
6	*Hylarana malabarica*	3	8	2	33
7	*Calotes calotes*	2	3	-	-
8	*Duttaphrynus melanostictus*	1	1	-	-
9	*Ptyas mucosus*	-	-	1	17

4.3.3 Frequency and Relative Abundance of herpetofauna in Maranchery during the wet and the dry seasons

Six species of herpetofauna were recorded from the Maranchery region in total from both wet and dry seasons. In dry season, only three species were recorded and five species in wet season. The most frequently seen species of amphibian was *Euphlyctis cyanophlyctis* in wet season, but *Hoplobatrachus tigerinus* was most frequent in dry season. *Hylarana aurantiaca* was the most abundant species in wet season but *Hoplobatrachus tigerinus* was the most abundant in dry season. In reptiles, the frequency of *Xenochrophis piscator* was higher than *Calotes versicolor*, but their abundance remains the same. No reptiles were seen in the dry season. *Hylarana aurantiaca*, *Xenochrophis piscator* and *Calotes versicolor* were absent in the dry season. The frequency and relative abundance of *Hoplobatrachus tigerinus* was seen higher in dry periods and *Fejervarya sp.* was not seen in the wet season. (Table 13).

Table 13. Frequency and relative abundance of herpetofauna in Maranchery during the wet and the dry season

SL no	**Species**	**Wet season**		**Dry season**	
		Frequency	**Relative Abundance**	**Frequency**	**Relative Abundance**
1	*Euphlyctis cyanophlyctis*	4	27	2	21
2	*Hoplobatrachus tigerinus*	3	23	6	43
3	*Hylarana aurantiaca*	3	32	-	-
4	*Xenochrophis piscator*	2	9	-	-
5	*Calotes versicolor*	1	9	-	-
6	*Fejervarya sp.*	-	-	3	36

4.3.4 Frequency and Relative Abundance of herpetofauna in Thommana during the wet and the dry seasons

Nine species of herpetofauna were recorded from the Thommana region in total from both wet and dry seasons. In dry season, only six species were

recorded. The most frequently seen species of amphibian was *Euphlyctis cyanophlyctis* in wet season, and *Euphlyctis cyanophlyctis* and *Hoplobatrachus tigerinus* was most frequent in dry season. *Hylarana aurantiaca* was the most abundant species in wet season but *Euphlyctis cyanophlyctis* was the most abundant in dry season. In reptiles, the frequency and relative abundance of *Hemidactylus brookii* was high in wet season, but none of the reptiles were seen in the dry season. *Hemidactylus brookii*, *Calotes versicolor* and *Xenochrophis piscator* were absent in the dry season. The relative abundance of *Hoplobatrachus tigerinus, Euphlyctis cyanophlyctis, Pseudophilautus kani, Fejervarya sp.* and *Hylarana malabarica* was seen higher in dry season (Table 14).

Table 14. Frequency and relative abundance of herpetofauna in Thommana during the wet and the dry season

SL no.	**Species**	**Wet season**		**Dry season**	
		Frequency	**Relative Abundance**	**Frequency**	**Relative Abundance**
1	*Euphlyctis cyanophlyctis*	19	23	4	35
2	*Hoplobatrachus tigerinus*	12	22	4	24
3	*Hylarana aurantiaca*	11	28	1	6
4	*Pseudophilautus kani*	8	9	2	12
5	*Fejervarya sp.*	4	5	2	18
6	*Hemidactylus brookii*	3	8	-	-
7	*Calotes versicolor*	2	2	-	-
8	*Xenochrophis piscator*	2	2	-	-
9	*Hylarana malabarica*	1	1	1	6

4.4 DIFFERENCE IN DIVERSITIES OF HERPEROFAUNA IN WET AND DRY SEASONS IN KOLE WETLANDS

To know whether there is a difference in the diversities seen in the herpetofauna according to the change in the season, a diversity t test was done for the four locations of Kole Wetlands for the two seasons viz. wet and dry. The values are given in the Table 15. The p value determines whether there is a

difference in the diversity with respect to the season. If p value is less than 0.01, it is significant at 1% level, if p value is between 0.01 and 0.05, it is significant at 5% level and if p value is greater than 0.05, then it is non-significant. Here, in Adat, the p value is greater than 0.05, so it is non-significant which means that there is no change in the diversity of herpetofauna with respect to the season. For Enamavu, the p value is less than 0.05, so it is significant at 5% level, i.e. there is a significant difference of the species with respect to the season up to 5% significant level. Similarly in Maranchery and Thommana, it is significant up to 5% significant level. None of them are significant at 1% significant level (Table 15).

Table 15. Diversity t test for the herpetofauna of Kole Wetlands in wet and dry seasons

	Adat		**Enamavu**		**Maranchery**		**Thommana**	
	wet	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**
No. of Species	8	5	9	4	5	3	9	6
Index	1.74	1.40	1.90	1.08	1.37	0.90	1.80	1.47
Variance	0.02	0.01	0.01	0.06	0.02	0.03	0.01	0.03
t-test statistic	1.99		3.16		2.11		1.63	
df	50.45		7.83		23.91		23.27	
p value	0.051		0.013		0.045		0.115	

4.4 MORTALITY OF HERPETOFAUNA IN KOLE WETLANDS

Mortality of the herpetofauna was noted for both seasons in Kole Wetlands during the study. Most of the mortality was due to the road kills. The recorded mortality of the species is shown in Table 16 and Fig. 12.

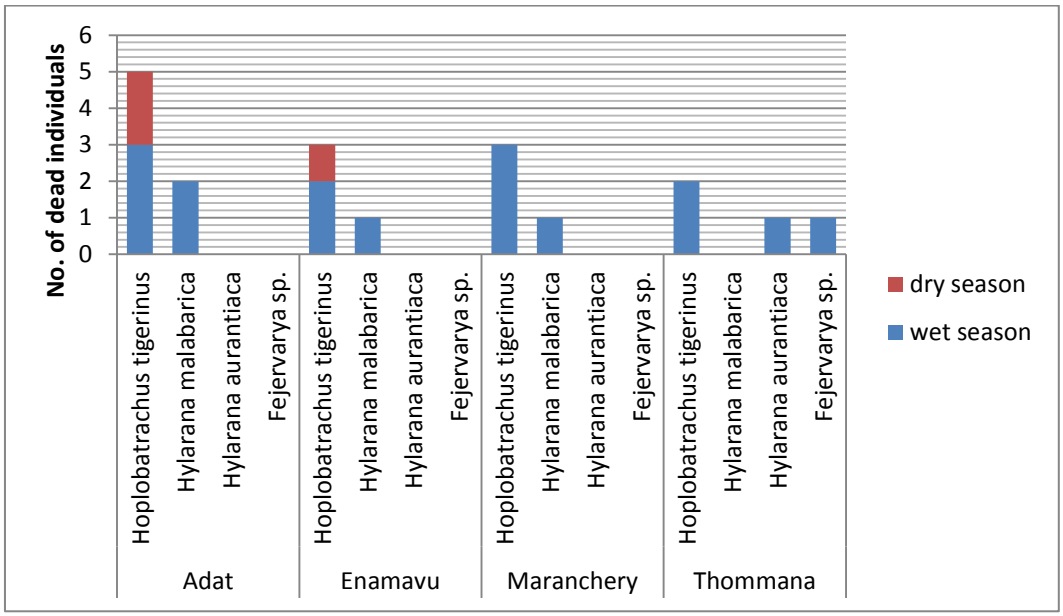
Most of them were seen killed in the rainy season as the herpetofauna, especially amphibians are seen very abundant on the roads in the rainy season. Most of the mortality was found from Adat and Thommana region in the wet

season and in Adat in the dry season. *Hoplobatrachus tigerinus* was the most killed species as they are big and are seen frequently in the roads. This species is also the most killed in the dry season. They are followed by *Hylarana malabarica.* No dead species were recorded in Thommana and Maranchery in dry season. None of the reptiles were seen killed in four locations both in wet and dry seasons (Table 16, Fig. 12).

Table 16. Mortality of Herpetofauna of Kole Wetlands in wet and dry seasons

Location	**species**	**season**	**no. of dead individuals**
Adat	*Hoplobatrachus tigerinus*	wet	2
	Hylarana malabarica	wet	1
	Hylarana malabarica	wet	1
	Hoplobatrachus tigerinus	wet	1
	Hoplobatrachus tigerinus	wet	1
Enamavu	*Hoplobatrachus tigerinus*	wet	1
	Hoplobatrachus tigerinus	wet	1
	Hylarana malabarica	wet	1
Thommana	*Hylarana aurantiaca*	wet	1
	Hoplobatrachus tigerinus	wet	1
	Hoplobatrachus tigerinus	wet	1
	Fejervarya sp.	wet	1
Maranchery	*Hoplobatrachus tigerinus*	wet	1
	Hylarana malabarica	wet	1
	Hoplobatrachus tigerinus	wet	1
	Hoplobatrachus tigerinus	wet	1
Adat	*Hoplobatrachus tigerinus*	dry	1
	Hoplobatrachus tigerinus	dry	1
Enamavu	*Hoplobatrachus tigerinus*	dry	1
Thommana	*none*	dry	0
Maranchery	*none*	dry	0

Fig 12. Mortality of Herpetofauna of Kole Wetlands in wet and dry seasons



Discussion

DISCUSSION

5.1 Species Composition of the Amphibians and Reptiles of Kole Wetlands

During the present study, a total of 12 species of herpetofauna were recorded from the four locations of Kole wetlands viz. Adat, Enamavu, Maranchery and Thommana. Out of the 12 species, seven species were amphibians and five species were reptiles. Each of them is explained below.

5.2 Amphibians of Kole Wetlands

The amphibians of Kole wetlands are represented in the families such as Dicroglossidae with three members, Ranidae with two members and Bufonidae and Rhacophoridae with a single member each under the order Anura. The various species of these families which were recorded from the wetland and their descriptions are given below.

5.2.1 Family Dicroglossidae

5.2.1.1 Skittering frog (*Euphlyctis cyanophlyctis*)

This species ranges throughout much of South Asia including southern Afghanistan and Sri Lanka. It extends from Thailand to Nepal, throughout India, Sri Lanka, almost throughout Pakistan below 1800m (Khan, 1997). The interorbital space is narrower than the upper eyelid; tympanum is distinct, about two third the size of the eye; fingers slender, pointed or slightly swollen at the tips, first not extending beyond second; toes are completely webbed; inner metatarsal tubercle long, conical much like a rudimentary toe; male with vocal slits under the lower jaw; dorsum with numerous scattered small smooth tubercles, sides of body rugose, ventrum smooth (Daniels, 2005).

Dorsum light gray, olivegreen or light brown, sometimes black in colour with irregular black spots. Thighs posteriorly dark with one or two yellow or

white irregular longitudinal stripes; ventrum white, immaculate or with dark speckling or reticulation; vocal sacs light brown. They are territorial and aggressive, inhabiting open wells and small stagnant ponds. It is one of the most adaptive of Indian amphibians that practically which are found in all water bodies including polluted ones. This was amongst the four species of Indian frogs that were harvested intensively to supply frog leg industry (Daniels, 2005). During the present study, *Euphlyctis cyanophlyctis* was one of the most abundant and frequently seen species in both wet and dry seasons. May be due to the high adaptability of the species, they are seen in paddy fields, bunds and stagnant waters in all the four locations of the wetland (Plate 1).

5.2.1.2 Cricket Frog (*Fejervarya limnocharis*)

This species is widely distributed in India, Pakistan and Sri Lanka, through South East Asia to China and Japan. In India, it is practically found everywhere except in deserts. This is a small to medium sized frog of the Indian wetlands, meadows and other damp ground. It is olive brown in colour with black spots and bands all over the upper surface. Most of the frogs that belong to this species have a white vertebral stripe and the underside is white. In breeding males, the throat is blackish. The males are much smaller than females. The skin on the back may bear folds and warts. The snout is pointed. The eardrum is large and about 2/3 diameter of the eye. The tip of the fingers and toes do not bear discs and the toes are about ½ webbed. The first finger is longer than the second. The males have external vocal sacs that are visible when they call (Daniels, 2005).

The paddy field frog is part of a large complex of very similar looking frogs. It has, therefore, often confused with a number of other species in the field due to its highly variable colouration, size and habitat choice (Daniels, 2005). During the present study, the recorded species was not confirmed as *limnocharis* species as there are many species in *Fejervarya* genus which have been recently described. It was also found to be a very common species in the Kole Wetlands (Plate 1).

5.2.1.3 Indian Bull Frog (*Hoplobatrachus tigerinus*)

The Indian bull frog is found in India, Sri Lanka, Nepal, Bangladesh and Pakistan. It has also been introduced into Madagascar. Within India, it is widely distributed throughout the peninsula. It is the most common frog in the Western Ghats. It is found from sea level to about 2000 m ASL, in the hill, rice plantations, irrigation channels, ponds, stream sides etc. The Indian Bull Frog is the largest frog in India. It is readily identified by its large size and the bold tiger like stripes and spots on the pale skin. The overall colouration is yellowish and some have traces of green on the sides. A broad white band runs along the side separating the dark coloured pattern of the back from the unmarked white belly. Almost all individuals bear a broad white-yellow vertebral stripe. The young show more green in their overall colouration. The breeding male turns bright lemon yellow. The ear drum is large and distinct. The vocal sacs are external and blue in colour. The toes are extensively webbed, though not fully. Owing to its large size the Indian Bull Frog occupied the prime position in the frog leg trade. Although formal trade has been banned in India locally the species is still harvested for food (Daniels, 2005).

During the present study, *Hoplobatrachus tigerinus*, was one of the commonly sighted species in all the four locations in the Kole wetlands. Interestingly, more number of the species was recorded in the dry season and also the majority of them were young ones. Poaching of these frogs was noted personally during the study period in the wetlands. Mortality rate of *H. tigerinus* was found to be high which can be attributed to the bulky size and slow moving nature of the species (Plate 1).

5.2.2 Family Bufonidae

5.2.2.1 Common Indian Toad (*Duttaphrynus melanostictus*)

The Common Indian Toad is one of the most widely distributed species in the genus *Duttaphrynus* (earlier *Bufo*). It is seen in variety of habitats from sea level to over 2000 m ASL in the hills of peninsular India. It is amongst the few species of amphibians that inhabit and breed close to the sea. Despite its preference for human modified habitats and homesteads it may be seen even along the forest edges in the Western Ghats. This species is found all over India and adjacent countries up to Indonesia. It is the most common of the Indian amphibians. It is also such a highly variable species, especially the juveniles, that it has often been confused with many other co-existing species throughout its range. It is identified by its medium to large sized numerous horny warts spread all over the body. Its colour is highly variable ranging from plain brick red to almost black. The hardened and the horny ridges on the head, like the numerous warts on tips of the fingers and toes are all black. The ventral side is whitish with fine black spots. The ear drum is as big as the eye or at least half its size and is very conspicuous. The poison glands in the ridges are very prominent. There are pimple like warts on sole and toes. Juvenile lacks warts and also often have an inconspicuous ear drum. They secrete toxin when handled that have a typical pungent odour and is milky in appearance (Daniels, 2005).

The present study revealed the dearth of the species in Kole wetlands manifested by a sole sighting of *D. melanostictus*, that too along the road side. This observation indicates the low degree of preference of *D. melanostictus* towards wetlands (Plate 1).

5.2.3 Family Ranidae

5.2.3.1 Golden Frog (*Hylarana aurantiaca*)

The golden frog is known from southern India and Sri Lanka. In South India, it is largely confined to the Western Ghats extending from the southern tip to the south of Maharashtra. It is a small to medium sized streamside species with enlarged discs on fingers and toes. It can be identified by its bronzy gold orange colouration of the back and the distinctly large eardrum. The back may be finely dotted with black or brown. The lower rim of eye is crimson red. The sides are darker and the underside is white. The tips of fingers are black. The golden frog is more of a land frog although it does not stay far from the water. It adopts an upright stance at rest and can be seen resting on the rocks in hill streams and sometimes on small bushes (Daniels, 2005).

In the present study, they were seen very common in the wet season and the number was seen declining in the dry season. Some road kills of the species were recorded. This species is endemic to Western Ghats and Sri Lanka and a vulnerable species as per IUCN. (Plate 1).

5.2.3.2 Fungoid Frog (*Hylarana malabarica*)

The fungoid frog is restricted in range to peninsular India and is known from Orissa, Madhya Pradesh and Maharashtra and throughout the Western Ghats. It is a medium sized land frog that may be identified by its bright orange-red back and the contrasting black and white sides and under parts. The limbs and sides are spotted and streaked with black and white. The back may have a few black spots as well. The young have a grey or yellowish colour on their back. The tips of fingers and toes are enlarged into small discs and the toes are fully webbed. The vocal sacs are external and feebly visible when the males call. The adults produce a musty odour when frightened, hence the English common name (Daniels, 2005).

During the present study, many individuals were sighted mainly in the wet season. The ones seen in dry season were all young ones. This is an interesting record that this species is usually seen in forests and moist homesteads, but it is reported from three locations in the present study and this is one of the endemic species to Western Ghats which was reported in the present study (Plate 1).

5.2.4 Family Rhacophoridae

5.2.4.1 Kani Bush Frog (*Pseudophilautus kani*)

It is one of the most common species in South Kerala and Mundanthurai (Tamil Nadu). It has been located and /or collected from Bonakkad, Chathankod, Kiriparai, Neyar, Palode, Ponmudi, and the foothills of Agasthyamala. The type series was collected from about 0.5-m high in the vegetation of secondary forest patches near the Kani tribal settlement at Chathankod. The species is named after the Kani tribe of Chathankod of Kerala who live where the type series was collected. Earlier the species was under the genus *Philautus*, now it has been changed to *Psedophilautus*. *Psedophilautus kani* can be distinguished from known congeners by the following combination of characters: (1) small adult size; (2) body slender; (3) snout pointed; (4) upper two-thirds of tympanum dark black; (5) dorsum with spinular projections. *Pseudophilautus kani* is similar to *P. amboli*, but it differs from *P. kani* by the relatively larger snout–vent length and rather robust body and throat lemon yellowish with black spots of the adult male (Biju and Bossuyt, 2009).

In the present study, *P. kani* were recorded only from Enamavu and Thommana. In the wet season, all of them were adults, but in the dry season, most of them were young ones (Plate 1).

Euphlyctis cyanophlyctis

Fejervarya sp.

Hoplobatrachus tigerinus

Duttaphrynus melanostictus

Hylarana aurantiaca

Hylarana malabarica

Pseudophilautus kani

Plate 1. Amphibians recorded from Kole Wetlands

5.3 Reptiles of Kole Wetlands

The reptiles of Kole wetlands are represented in the families such as Agamidae with two species, Colubridae with two species and Gekkonidae with a single species. The various species of these families which were recorded from the wetland and their descriptions are given below.

5.3.1 Family Agamidae

5.3.1.1 Common Green Forest Lizard (*Calotes calotes*)

The Common Green Forest Lizard (*Calotes calotes*) is an agamid lizard found widely in the southern peninsula (Kerala, Tamil Nadu and Karnataka) and in Sri Lanka. The lizard has a bright green dorsal coloration, usually with 5 or 6 white, cream or dark green transverse stripes, however these are changeable. Often the stripes continue on to the tail. The head is yellowish- or brownish-green whereas the male develops a bright red head and throat in the breeding season. The underside is a pale green, the tail is light brown. A row of eight or nine compressed spines, divided into two groups, is above the tympanum, the diameter of these is less than half that of the orbit (Daniel, 2002).

The body is compressed, the dorsal scales are large and usually feebly keeled, but sometimes smooth. These scales point backwards and upwards. The gular pouch is not developed, the gular scales are feebly keeled. A short oblique fold is in front of the shoulder and is covered with small granular scales. In adult males the height of the crest on the neck equals or exceeds the diameter of the orbit, on the back it gradually diminishes in size. The Limbs are moderate, the third and fourth fingers are nearly equal, however the fourth toe is distinctly longer than third toe. The hind-limb reaches to the front of the eye or further. *C. calotes* has a very long and slender tail (Daniel, 2002). In the present study, they were only reported from Enamavu (Plate 2).

5.3.1.2 Indian Garden Lizard (*Calotes versicolor*)

The Oriental Garden Lizard, Indian Garden Lizard or Changeable Lizard (*Calotes versicolor*) is an agamid lizard found widely distributed in Asia in almost all habitats from dry deserts to thick forests. It has also been introduced in many other parts of the world. The ground-colour is generally a light brownish olive, but the lizard can change it to bright red, to black, and to a mixture of both. This change is sometimes confined to the head, at other times diffused over the whole body and tail. During the breeding season, the male's head and shoulders turns bright orange to crimson and his throat black. Males also turn red-headed after a successful battle with rivals. Thus their other gruesome name of "Bloodsucker Lizard" (Daniel, 2002).

Dorsal crest moderately elevated on the neck and anterior part of the trunk, extending on to the root of the tail in large individuals, and gradually disappearing on the middle of the trunk in younger ones. No fold is seen in front of the shoulder, but the scales behind the lower jaw are much smaller than the others and the gular sac is not developed. In the present study, they were recorded from Adat, Maranchery and Thommana; all were recorded in the wet season (Plate 2).

5.3.2 Family Colubridae

5.3.2.1 Indian Rat Snake (*Ptyas mucosa*)

Ptyas mucosa is a common species of colubrid snake found in parts of South and Southeast Asia. It is essentially a snake of the plains, but has been recorded up to 1800m. Growing to nearly two metres, they are large snakes and their colour varies from pale browns in dry regions to nearly black in moist forest areas. They are frequently found in urban areas where rodents thrive. They are diurnal, takes readily to water and swims vigorously with the head above the water (Daniel, 2002).

Their snout is obtuse, slightly projecting; eye large; rostral a little broader than deep, visible from above; suture between the inter-nasals shorter than that between the prefrontals; frontal as long as its distance from the end of the snout, as long as the parietals or slightly shorter; usually three loreals; lower labials in contact with the anterior chin-shields, which are shorter than the posterior; the latter in contact anteriorly. Scales more or less strongly keeled on the posterior part of the back, in 17 rows. Brown above, frequently with more or less distinct black cross-bands on the posterior part of the body and on the tail; young usually with light cross-bands on the front half of the body. Lower surface yellowish; the posterior ventral and the caudal shields may be edged with black (Daniel, 2002). In the present study, it was recorded only from Enamavu in the dry season. None of them were seen in other four locations in both wet and dry seasons (Plate 2).

5.3.2.2 Checkered Keelback (*Xenochrophis piscator*)

The Checkered Keelback or Asiatic Water Snake (*Xenochrophis piscator*) is a common species of non-venomous snake found in Asia. It is the commonest freshwater snake. It is found in India, Nepal, Bhutan, Bangladesh, Pakistan and Sri Lanka. Frequents water, it is seen in tanks, paddy fields, pools and rivers. In swampy areas, it is seen away from water. It strikes rapidly and with great determination, holding on tenaciously, it is an extremely active snake. In arid regions, it aestivates in summer (Daniel, 2002).

This snake's eye is rather small, and shorter than its distance from the nostril in the adult. Its rostral scale is visible from above. The internasal scales are much narrowed anteriorly and sub triangular, with the anterior angle truncated and as long as the prefrontal scales. The frontal scale is longer than its distance from the end of the snout, and as long as the parietals or a little shorter. This snake is found in or near fresh water lakes or rivers. It feeds mainly on small fish and water frogs (Daniel, 2002). In the present study, this is the most commonly seen reptile in the Kole Wetlands. It was sighted very common in Adat, where they were seen in the small canals in the paddy fields (Plate 2).

5.3.3 Family Gekkonidae

5.3.3.1 Brook's Gecko (*Hemidactylus brookii*)

Brook's gecko is widely distributed in Asia and Africa and has been introduced elsewhere in the tropics of the world. The colour is brown or varying shades of grey with brown spots and whitish below. They live on a variety of habitats, on trees, rocks, under stones and on buildings. Scales of the throat are granular. Body covered with small granules, intermixed with large keeled trihedral tubercles, arranged in 16-20 longitudinal series, the keels of the outer ones indistinct; the diameter of the largest tubercles on the flanks exceeds the diameter of the ear-opening. Ventral scales larger than those on the throat, cycloid, imbricate (Daniel, 2002).

Male is with 7-20 femoral pores on each side. Tail is depressed, annulate, with rows of 8 or 6 spine-like tubercles, below with a series of transversely dilated plates. Limbs granular, the upper part of the hind limb with large keeled tubercles; digits free, dilated, the free distal joint long, 3-6 lamellae under the inner, 6-8 under the median toes. Yellowish-brown above with irregular dark spots and one or two dark lines on the side of the head, passing through the eye; lips with dark bars are present (Daniel, 2002). In the present study, it was only recorded from Thommana in wet season and not seen from the other three locations in wet and dry locations (Plate 2).

Calotes calotes

Calotes versicolor

Ptyas mucosa

Xenochrophis piscator

Hemidactylus brookii

Plate 2. Reptiles recorded from Kole Wetlands

5.4 Diversity and Relative Abundance of Herpetofauna in Kole Wetlands

The present study revealed the presence of seven species of amphibians and five species of reptiles from the Kole Wetlands. With the earlier reported and observed species, the total number of amphibians in Kole Wetlands becomes eight and total number of reptiles in Kole Wetlands becomes 17. The seven species of amphibians include Common Indian Toad (*Duttaphrynus melanostictus*), Skittering Frog (*Euphlyctis cyanophlyctis*), Cricket Frog (*Fejervarya sp.*), Indian Bull Frog (*Hoplobatrachus tigerinus*), Golden Frog (*Hylarana aurantiaca*), Fungoid Frog (*Hylarana malabarica*) and Kani Bush Frog (*Pseudophilautus kani*) and Paddy Field Frog (*Fejervarya limnocharis)* which was earlier reported from the wetlands. They are represented in the families such as Dicroglossidae with three members, Ranidae with two members and Bufonidae and Rhacophoridae with one member each.

The reptiles include Common Green Forest Lizard (*Calotes calotes*), Indian Garden Lizard (*Calotes versicolor*), Brook's gecko (*Hemidactylus brookii*), Common rat snake (*Ptyas mucosus*) and Checkered keelback (*Xenochrophis piscator*). They are represented by the families Agamidae with two members, Colubridae with two members and Gekkonidae with a single member. The other species observed earlier from the Kole lands are Common Keeled Skink (*Eutropis carinata*), Indian Rock Python (*Python molurus*), Indian Cobra (*Naja naja*), Russels Viper (*Daboia russelii*), Green Vine Snake (*Ahaetulla nasuta*), Common Bronzeback Snake (*Dendrelaphis tristis*), Common Wolf Snake (*Lycodon aulicus*), Common Sand Boa (*Gongylophis conicus*), Indian Flapshell turtle (*Lissemys punctate*), Indian black turtle (*Melanochelys trijuga*), Asian giant softshell turtle (*Pelochelys cantorii*) and Common Indian Monitor (*Varanus bengalensis*) represented in the families Scincidae, Pythonidae, Elapidae, Viperidae, Colubridae, Colubridae, Boidae, Trionychidae, Bataguridae and Varanidae.

There were no previous studies done exclusively for herpetofauna in Kole Wetlands. In the present study, data were recorded for two separate seasons viz. dry and wet, and from the observations, it can be clearly noted that the diversity was more in the wet season, especially for the amphibians possibly because of the breeding season. The maximum number of species was recorded from Enamavu and Thommana in wet season and from Thommana and Adat in dry season. The species number was low in Maranchery in both seasons, may be because, the area was totally covered by water and the paddy fields were seen less.

The most frequently seen species of amphibians in wet and dry seasons were *Hoplobatrachus tigerinus, Euphlyctis cyanophlyctis, Fejervarya sp, Hyalarana malabarica* and *Hylarana aurantiaca.* In dry seasons, most of them were juveniles. *Hyalarana malabarica is* endemic to Western Ghats and *Hylarana aurantiaca* is endemic to Sri Lanka and Western Ghats. Both were commonly seen common in the wetland in the wet season. *Duttaphrynus melanostictus* was the least seen species in the Kole wetlands. Only one individual was reported, that too along the roadside. This may be because of the low preference of *Duttaphrynus melanostictus* to wetlands.

5.5 Conservation Status of Herpetofauna in Kole Wetlands

Out of the seven species of amphibians recorded from the Kole wetlands, according to IUCN, *Hylarana aurantiaca,* which is endemic to Sri Lanka and Western Ghats, is a vulnerable species and its population is decreasing. It is listed as Vulnerable because its extent of occurrence is less than 20,000 km^2, its distribution is severely fragmented, and there is continuing decline in the extent and quality of its forest habitat in the Western Ghats of India and southwestern Sri Lanka. There is continuing loss of the habitat of this species largely caused by the conversion of land for agricultural use (including the drainage of wetlands) and the development of mining. Agrochemical pollution is also a threat. (Biju et al., 2004). *Duttaphrynus melanostictus, Euphlyctis cyanophlyctis* and *Hoplobatrachus*

tigerinus are all least concern species. *Hylarana malabarica* although endemic to Western Ghats is a least concern species with a stable population as per IUCN.

5.6 Mortality and Conservation Threats of Herpetofauna in Kole Wetlands

5.6.1 Road Kill

The amphibians were susceptible to mortality at Kole wetlands than reptiles. The primary cause of mortality was road kills. The amphibians that cross from one field to the other over the crisscrossing mud roads in the Kole wetlands were seen over run by the vehicles. *Hoplobatrachus tigerinus, Hylarana malabarica, Hylarana aurantiaca and Fejervarya sp.* were seen mostly killed by road kills. Among them, *Hoplobatrachus tigerinus* was the most susceptible species to road kill which accounted for 68%. This may be due to the larger size of the frog and its slow movement. In future, the roads should not be made through the wetlands.

5.6.2 Habitat Destruction

Reclamation of wetlands and change in the landuse pattern are the most serious problems being faced by the Kole Wetlands (Nameer, 2010). The wetlands are being converted to other landuse patterns including cash crops and/or to brick kilns and this could affect the herpetofaunal population adversely. The conversion of the wetlands to other landuse patterns should be prohibited.

5.6.3 Poaching

Poaching is another major threat mainly for the amphibians. Although banned, the frogs are still being caught in large numbers from the Kole Wetlands. On several occasions, it was found that sack full of frogs were being collected and taken away from the Kole wetlands. Monitoring should be done to check the poaching in these wetlands.

Summary

SUMMARY

Amphibians and reptiles together known as herpetofauna though very fascinating and enormously diverse are one of the least studied groups among the vertebrates in India. With a high level of endemism for herpetofauna in India and in Western Ghats, very little is known about their distribution and ecology. Amphibians are popularly known as environmental barometers as they indicate the state of environmental health and both amphibians and reptiles have a very crucial role in the functioning of ecosystem.

The present study was conducted to understand the distribution and abundance of herpetofauna in the Kole Wetlands, which is first of its kind in the Kole region. The method for the study was visual encounter survey which is the direct method by which the herpetofauna is noted. The amphibians were identified from calls also. The study period was divided into two seasons viz. wet and dry and observations were taken in these two seasons. The study was conducted from July 2011 to June 2012. The salient findings are summarised below.

- A total of 12 species of herpetofauna (seven species of amphibians and five species of reptiles) were reported in the Kole Wetlands in the study period.

- Among the amphibians, *Hoplobatrachus tigerinus* was the most abundant and frequently seen species in the Kole Wetlands. It was followed by *Euphlyctis cyanophlyctis* and *Fejervarya sp. Duttaphrynus melanostictus* was the least found species.

- Among the reptiles, *Xenochrophis piscator* was the most abundant in the Kole Wetlands. *Calotes calotes* was the least found reptile species in the wetlands.

- Two endemic species of amphibians were sighted from the Kole wetlands. *Hylarana malabarica* is endemic to Western Ghats and *Hylarana aurantiaca* is endemic to Sri Lanka and Western Ghats. *Hylarana aurantiaca* is a Vulnerable species reported from the wetlands as per the IUCN redlist.

- The maximum species diversity was recorded from Enamavu and Thommana.

- Bray-Curtis cluster analysis of similarity of herpetofauna showed that there is a greater degree of similarity between the herpetofauna of Thommana and Enamavu in the wet season and a greater degree of similarity between the herpetofauna of Thommana and Maranchery in the dry season.

- The diversity t test for two seasons revealed that there is a significant difference of the species with respect to the season in the various study locations within the Kole wetlands.

- The mortality observations showed that road kills were quite frequent at Kole wetlands. Most of the road kills happened during the rainy season. Road kill incidence was more at Adat and Thommana regions. *Hoplobatrachus tigerinus* was the most killed species.

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DIVERSITY AND ABUNDANCE OF HERPETOFAUNA IN KOLE WETLANDS, THRISSUR

By

SREEHARI, V.S

(2009-17-109)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Forestry

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF WILDLIFE SCIENCES
COLLEGE OF FORESTRY
VELLANIKKARA, THRISSUR – 680 656
KERALA, INDIA

2011

ABSTRACT

Kole wetland is an internationally important Ramsar site, an Important Bird Area and a High Value Biodiversity Area. The wetland diversity is not fully assessed in our country. Herpetofauna including the amphibians and reptiles are one of the least studied groups of animals in India as well as in Kerala. In this study, an attempt was made to understand the diversity and abundance of herpetofauna in the Kole Wetlands, which is the first ever study on the herpetofauna of the Kole wetlands. The study was mainly concentrated in four locations of Kole Wetlands viz. Adat, Enamavu, Thommana and Maranchery. The study period was divided into two seasons as wet season (June to October) and dry season (November to May) in 2011 and the difference in the population was compared. Visual encounter survey was the method to study the hepetofauna. A total of 12 species of herpetofauna was recorded in the study period which includes seven species of amphibians and five species of reptiles. Among the amphibians, *Hoplobatrachus tigerinus* was the most abundant and frequently seen species in the Kole Wetlands and among the reptiles, *Xenochrophis piscator* was the most abundant in the Kole Wetlands. Two endemic species of amphibians *Hylarana malabarica* which is endemic to Western Ghats and *Hylarana aurantiaca* which is endemic to Sri Lanka and Western Ghats was reported in the study. The maximum number of species was recorded from Enamavu and Thommana. The mortality observations showed that road kill is a serious problem for the amphibians at Kole wetlands and habitat destruction as well as poaching is also negatively affecting the populations of herpetofauna at Kole wetlands. Strict conservation measures including the non-construction of any more new roads at Kole wetlands, checking the land use or habitat conversion and strict enforcement of law against poaching could only save the herpetofauna of this internationally important wetland habitat- the Kole wetlands.