CHAPTER I
INTRODUCTION

1.1 Background

Nepal, with area 147,181 km^2, occupies the central part of Himalaya that stands between the Palaeartic (Holartic) and Plaeotropical (Indo-Malayan) regions. The country is located between latitudes 26^{o}22' and 30^{o}27' N and longitudes 80^{o}40' and 88^{o}12' E. The country is partitioned lengthwise into Palearctic and Oriental sets of floral and faunal provinces (Smith, 1989). Nepal comprises only 0.09% of land area on a global scale, but it possesses a disproportionately rich diversity of flora and fauna at genetic, species and ecosystem levels. Nepal has a relatively high number of fauna species invertebrates and vertebrates both.

Higher fauna groups have been relatively well studied, however the taxonomy and distribution of the lower fauna groups, except for the butterflies and to some extent the spiders, have yet to be studied. An inventory made by Thapa (1997) covers approximately 5,052 species of insects recorded from Nepal, 1,131 species (over 22 percent) have been first discovered and described from Nepalese specimen. The entomological inventory recorded 789 species of moths and 656 species of butterflies (Thapa, 1998). Among Nepal’s insect fauna, many taxonomists have worked on butterflies of Nepal and a fair amount of taxonomic studies and identification guides are available for the group (Smith 1989, 1990). 640 species of butterflies have been recorded, distributed in different ecological zones. Smith's book is the first to cover this extremely interesting fauna in a comprehensive format. He has given the complete species and subspecies name, author, date of publication, common name if available, range of wingspan, comments on distribution (usually to district within Nepal), seasonality, elevational range, distribution outside Nepal, and the species' relative abundance. The presence and identity of moths has been subject of less attention and relatively little studied. Many moths are still to be discovered and described. When more studies are conducted we expect the number of moth species count could increase. So, much taxonomic work remains to be done in case of moths, particularly in Nepal, where we may expect to discover numerous endemic species of moths.

The historical expeditions carried in mid and late 19th century added and identified many new taxa and this work indicates that Nepal is a promising area for further moth biodiversity and taxonomic research. According to published resources, *Apela* was the first moth reported from Nepal by Walker in the years 1855, 1857 (Thapa, 1998).

Numerous foreign entomologists have added to the taxonomic knowledge of moths of Nepal. The Moths of Nepal project, founded by T. Haruta (1992) has summarized much of the available knowledge about elements of the Nepalese moth fauna and yielded many new taxa. Five volumes of The *Moths of Nepal* series (edited by T. Haruta) were published between 1992-98 is the only books on the nocturnal moths found in Nepal very useful and series aims to cover much of the Nepalese macro moth fauna. Progress so far includes the publication of the families Saturniidae and Sphingidae in *Marvellous moths of Nepal* authored by M .Allen in 1993. However, there are few noteworthy local taxonomists who have contributed to increase the knowledge of moths of Nepal. Khanal (1983, 1985) has contributed to describing new species from Nepal and compiling the taxonomic knowledge of moths of Nepal.

The most taxonomist and entomologists are interested in taxonomy of a particular group or family. Among them Daniel (1966, 1972), Dierl (1970), Haruta (1992), and Allen (1993) have made noticeable contribution on taxonomy of the family Sphingidae. Surprisingly, it was found that Nepal has a great diversity of hawkmoths. Allen (1993) described 119 species of hawkmoth under 49 genera from Nepal. He stated that the hawkmoth fauna of Nepal represent over tenth of hawkmoths of world. In the study of Indian sphingids by Bell & Scott (1937) described that the sphingofauna of Nepal is particularly unknown and they assumed that sphingids to the west of Nepal belongs to the West Himalayan type and sphingids to the east of Nepal belongs to the East Himalayan type. According to Dierl (1970), for the sphingid moth fauna Nepal forming a transition between the wet East Himalaya and the dry West Himalaya. Here the study of both coincides. Dierl (1970) shows that Sphingidae distribution and ecology of Nepal show four types of species: Tropical, Himalayan, West Himalayan and Palaearctic species. The newer additions of the sphingid moth species to Sphingofauna to Nepal and their ecology in later years are not updated. So, the taxonomy of hawkmoth is not well known.

Pittaway & Kitching (2000-2007) in the Sphingidae of the Eastern Palaearctic (including Siberia, the Russian Far East, Mongolia, China, Taiwan, the Korean Peninsula and Japan) described 306 species and sub-species of sphingid moths under 69 genus. Among them 102 species and sub-species under 47 genera shows distribution to Nepal. Beck & Kitching (2004) in the Sphingidae of Southeast Asia (including New Guinea, Bismarck, Solomon Islands) described 389 species of sphingid moths under 68 genus. The distribution and range map for the species shows that 112 species of sphingid moths belonging to 45 genera has distribution to Nepal. In these studies many species of sphingid moths are reported in Nepal which is not noted in the previous literatures and papers. So this study has surely enriched the sphingid moth fauna of Nepal. In Nepal, there is no authentic database of how many genera and species of sphingid moths are present. Besides this, for the known sphingid moth species the authentic classification is also lacking.

When one contemplates the present status of moths' taxonomy in Nepal one can identify four major impediments. First and foremost among the impediments is the lack of passionate amateur entomologists. The second impediment is the lack of well curated moths' collection in the country. The national insect collection is not housed adequately nor well curated. The status of a few existing smaller collections is the same. In addition, these collections are virtually inaccessible even to local researchers as they are simply kept locked up. The third impediment is the lack of well organized education in systematic entomology. There is no satisfactory training in modern systematic biology available even at University level. Lacks of comprehensive literatures are the fourth impediment. The sporadic reports on the moths from Nepal are scattered in articles and journals throughout the world and in published in foreign languages and not readily accessible to researchers**;** they have yet to be included in Nepal's moth biodiversity databases. Not any database exists for Lepidoptera of the Nepal until now.

Major moth specimens that house Nepalese specimens are found in the NHM, Swoyambhu, Kathmandu and NHM, London, and mostly in foreign countries. Additionally, few specimens are housed in different institutions of Tribhuvan University. The primary institution for maintaining records of voucher specimens, the NHM, Swoyambhu, Kathmandu, has few collections of Nepalese moths. One auspicious development is the deposition of some authentically identified species of moths from Nepal at Nepal Agricultural Research Council.

1.2 Order: Lepidoptera

Lepidoptera are the second-most diverse order of insects after Coleoptera (beetles). The numerical strength of species in the order Lepidoptera comprises more than 100000 species (Richards & Davies, 1977). Moths along with the butterflies are both members of the order Lepidoptera.

From Linnaeus until the present century, the criteria on which entomologists based the systematic division of order Lepidoptera were numerous. Classification systems differed one from another and are difficult to compare with those in use today as they were based mainly on superficial characters, such as wing pattern and shape. As his criteria, Linnaeus used wing positions of adults at rest. Latreille based his classification on the times of adult activity (i.e. Nocturni, Diurni) whereas Boisduval used antennal shape; the Rhopalocera (butterflies) having 'clubbed horns' (i.e. clubbed antennae); the Heterocera (moths) having antennae without clubs. None of these distinctions is valid, for even though Boisduval's Rhopalocera do form a monophyletic group, his Heterocera do not. Another loose form of classification still in use today; Microlepidoptera and Macrolepidoptera, is based on adult size, although some 'Micros' have wingspans up to 200mm (Pittaway, 1997-2006).

Lepidoptera classification has changed considerably over the years. It is unfortunate that no uniform system of classification has yet been universally adapted for the order Lepidoptera. The families consisting in the order Lepidoptera is varied in text books and literatures. Hence, the recent literatures show the order Lepidoptera is divided into 128 families.

1.2.1 Family: Sphingidae

The position of the Sphingidae with in Lepidoptera is well reviewed by Scoble in 1991 in his valuable summary of the classification of the Lepidoptera at higher taxonomic level. Earlier the family Sphingidae is treated as separate superfamily Sphingoidea is now generally considered to be members of the Bombycoidea. Holloway (1987) kept the Sphingidae with in the Bombycoidea rather than treating them as separate superfamily Sphingoidea. The hawkmoths were first formally classified by Carl von Linne (Linnaeus) in 1758 under the name *Sphinx* Pittaway (1997-2006).

In monumental work, Rothschild and Jordan (1903) had recognized 772 species of hawkmoths. They were first to adopt natural, phylogenetic classification, using characters such as structure of antenna, palpi, pilfer, and feet, spination of legs, abdomen and dry genetalia preparation of large number of species. The family was split into two divisions (Asemanophorae and Semanophorae), five subfamilies and seven tribes. Hampson (1892) recorded 121 species of hawkmoths from India and Ceylon and are classified them into six subfamilies. Bell & Scott (1937) recorded 183 species of sphingid moths from Indian sub region and classified them into five subfamilies and six tribes. Holloway (1987) reported 94 species of Sphingidae from Borneo and classified them into two subfamilies and four tribes. In the last decades much taxonomic information has been generated for the enormous number of sphingid species, genera and subgenera. Systematics and nomenclature have undergone many changes.

According to Richard & Davies (1977) there are 1000 species existing throughout the world. The world's Sphingidae are catalogued and illustrated in colour by D'Abrera in "Sphingidae Mundi", he recognized approximately 1050 species, and illustrated more than 1000 (D'Abrera, 1986). The checklist of sphingids of the world includes 1288 species in 202 genera recognized by Kitching and Cadiou (2000). The known species are placed in three subfamilies and seven tribes. The subfamily Macroglossinae is the most diverse with 733 species in 86 genera. The subfamily Smerinthinae includes 328 species belonging to 77 genera, while the subfamily Sphinginae is represented by 214 species in 39 genera.

The moths belonging to family Sphingidae are commonly called the hawkmoth. These are among the most familiar and best known of Lepidoptera. This charismatic moth family is found worldwide, but is most diverse in tropics. The number of species and genera diminishes with increasing latitude and none is resident in the Arctic and Antarctic regions. With the exception of these regions, the family is found throughout the world, even on small oceanic islands (Pittaway, 1997-2006). The sphingid moth all poses very characteristics appearance which renders them distinct from all other moths. Moths of family Sphingidae can be distinguished from other lepidopterous insects by their general appearance. The adult hawkmoths are stout, long, and cigar shaped. The wings span ranging from 35-150 mm. The head is large with large compound eyes. The antennae are thickened towards or beyond the middle and pointed at apices which are nearly always hooked; in the male the antennae are pronounced fasciculate setae on ventral surface but in female these setae are simple. The proboscis is tightly curled up in and stiffly extended to its full length when the moth hovers over flower. The proboscis in many species is very long, sometimes as long as body or longer and in some species the proboscis is atrophied.

The thorax is large and densely covered with scales. It is composed of three more or less fused segments, each bearing a pair of legs. The forewing are elongate, narrow apically and acute in many groups of genera; the subcostals are very close to the costa, vein 1 forked at the base. The hind wings are much shorter than the forewing and indeed shorter than the abdomen. The forewings have either 11 to 12 veins whereas the hind wings have only 8 veins. All Sphingidae have the following unique combination of features. The subcosta and radius in the hind wings are connected by cross vein (R1), and about opposite the middle of the discal cell (Borror & Delong, 1971). At both family and generic level the wing venation has common features. The frenulum and retinaculum are usually present to join the forewings and hind wings but reduction or atrophied in some genera of the sphingids. The wings are holding over the body like the tent while the moth is in rest. The sphingid moths have ability of flying fast, and also hovering in flight so the term hawkmoth is given as synonym to the family Sphingidae.

The legs in the sphingid moths are strong, with well developed spurs and tarsi. A noticeable morphological feature of most adult sphingidae is presence of the double pair of elongate spurs on the tibia of the hind legs (Rothshild & Jordan, 1903). There is usually proximal and terminal pair of spurs and they are conspicuously long and rigid in some sphingid taxa. The functional role of this structure is unknown. The tarsi are usually five-segmented with a pre-tarsus or terminal segment, of paired apical claws. In most species, a pad-like pulvillus is present between the claws which are richly endowed with chemo-receptors.

The abdomen is robust and narrows posteriorly. These characters are constant throughout the family although in some species of genus *Macroglossum* Scopoli, the abdomen is broad instead of pointed due to presence of an expansible tuft or tuft of long hair scales on the tip of the abdomen. *Macrglossum* species are generally called hummingbird hawk moth due their habits of collecting food from flowers in the manner so like that of real hummingbirds.

The caterpillars of hawkmoths are easily distinguishable and consisting horn on the dorsal surface of the eighth segment. Due to this character the larvae are called the hornworm. The caterpillars of many species are brightly coloured, with diagonal stripes and having eye spots. The larvae feed on plants ranging from small herbs to large tress and vegetables and ornamental plants. Most larvae are the external feeders. When the larvae are disturbed, they commonly rear up with their anterior segment arched and their head facing disturbance. The scientific name ‘Sphinx’ of the family is derived from the sphinx like posture.

The larvae of the most species pupate in the ground. The pupae are usually short, cigar shaped, rounded in front and pointed behind. The adults of most species are active by night or crepuscular period but few species are also diurnal. The night flying species are mostly attracted to light of powerful mercury vapours and UV sources. The day flying species are not readily taken to light source. The few diurnal species are *Macroglossum*, *Hemaris*, *Cephonodes*, *Sataspes.* Among the tropical species many are migrating (Dierl, 1970). A number of species are known to migratory and particularly in genera *Agrius, Cephonodes, Macroglossum, Hippotion, Theretra*. Their streamlined body and aerodynamic structure give them the ability to make sustained flights over vast distances.

1.2.2 Importance of family Sphingidae

The family Sphingidae consist the large bodied moths also called as Hawkmoth. It has been the primary interest for the most of the Lepidopterists' from earlier centuries. hawkmoth fauna of many countries has been documented and illustrated and the annotated checklists of hawkmoths are also available. As a consequence, hawkmoth taxonomy is well developed. The importance of the hawkmoths can be described as follows.

a) Pollinators

The hawkmoths are of particular interest because of notable function as pollinators (Kitching & Cadiou, 2000). The long tongues of hawkmoths that have evolved parallel with long, tubular corollas or nectarines on flowers they pollinate. Some species hover in front of flowers to insert their long tongues into it. Orchids with very long corolla tubes and other flowers with deep calyxes have specific relation with hawkmoths since no other insects can reach the deep base of the blossom. Numerous species of flowering plants are described as Sphingophilous i.e. loving hawkmoths. These Sphingophilous flowers are largely unused by other classes of pollinators. The hawkmoths are the frequent visitors of flowers and play important role in pollination so thousands of plant species depend on these moths for successful seed production. Many research papers have been published on the relation of hawkmoths and the plants that they pollinate.

b) Pest of plants

The larvae of hawkmoths feed on many kinds of plants. The names of some sphingid moths are derived from the host plants that the larvae feed on such as *Agrius convolvuli*

(Convolvulus hawkmoth), *Hyles euphorbiae* , *Hippotion Celerio* (Vine hawkmoth) etc. Many of the larvae are important as pest and feed on many different crops. Neupane (2002) described few hawkmoth species larvae as pest of food crops as brinjal, arhar. The larvae of some species feed on large number of plants of different families, others confine themselves to single family or whole genera choose their food plants from a single family (Bell & Scott, 1937). In some species the larvae become so abundant in some location in certain seasons as to cause serious damage to the vegetation on which they feed. The knowledge of the plants that the larvae feed on is necessary and useful for breeding hawkmoths in the laboratory conditions. Bell & Scott (1937) give the list of the 135 species and subspecies of hawkmoths of which food plants are known, together with the names of these plants. Many studies are carried throughout the world on the hawkmoth species as potential pest of economic valuable plants.

c) Potential agent for biological control

The larvae of hawkmoths feed on many species of plants ranging from small herbs, shrubs to big trees. The larvae of some species are host specific and the larvae of such hawkmoth species that feeding on weeds can be used as a potential agent for the biological control for eradication of unwanted plants. Huwer & McFadyen (1999) studied the biology and host range of the Sphingid Moth *Nephele densoi*, a potential agent for the biological control of Rubbervine *Cryptostegia grandiflora* (Asclepiadaceae) in Madagascar.

d) Pest of insects and animals

Most adults feed on nectar; some species of the hawkmoths are regarded as pest of insects and animals. Adult death's head hawkmoth (*Acherontia* species) have a unique feeding biology as cleptoparasites of honeybees, stealing honey from the combs, rather than imbibing nectar from flowers. The moths have a range of features, both morphological and behavioral, that enable them to successfully enter, feed and escape from the colonies. These adaptations may vary among the three *Acherontia* species and allow them each to target different species of honeybee (Kitching, 2003). The Death's head hawkmoth (*Acherontia*) has short but massive proboscis with this it pierce the combs and imbibe honey from bee hive. A few tropical hawkmoth species feed on eye secretions.

e) Aesthetic value

Members of the family Sphingidae definitely rank as charismatic megafauna. The colour of the moths is usually sober and cryptic, resembling the bark of trees and other natural objects, but some species are brightly coloured and most have pleasing tones and markings (Bell & Scott, 1937). The Sphingidae family contains some of the largest and most spectacular moths. The images of hawkmoths are used in postal stamps in many countries. The postal stamp in Fiji features some of visually exciting hawkmoths.

f) Research

The Sphingidae have played significant role in variety of research programs such as pollination biology, biogeography, conservation biology, research in odor reorganization and moth assemblage. The Sphingidae of Asia is very well known Lepidoptera and by this reason this family can be useful for zoogeographical and ecological studies (Dierl, 1970). Hawes (2005) sampled hawkmoths and saturniid moths for the study of impacts of landscape disturbance on Amazonian moth assemblages. Mackey (1977) studied the biogeographic relationships of the New Guinea Sphingidae.

1.3 Objectives

Considering that the hawkmoths of Dakshinkali forest are poorly known the purpose of the work is to document the composition, dominant genus, dominant species, species richness and relative abundance. The study was carried for the study of the hawkmoths attracted to light in the Dakshinkali forest area. How many species of hawkmoths can be determined? How diverse are hawkmoths in the Dakshinkali forest? Most hawkmoth species are attracted to artificial light sources, which are an efficient method of assessing biodiversity, relative abundance, and faunal inventories of nocturnal Lepidoptera.

The objectives of the study are as follows:

1) To assess the hawkmoth species attracted to light and their presence in Dakshinkali forest area.
2) To find the species richness and relative abundance, seasonal abundance of hawkmoths.
3) To show the temporal and seasonal variation and environmental factors affecting on hawkmoths in Dakshinkali forest area.

CHAPTER II
REVIEW OF LITERATURE

2.1 History and Status of Moths of Nepal

Early recording of moths in Nepal is poorly documented. It is likely that, according to published resources, Thapa (1998) recited that, *Apela* was the first moth reported from Nepal by Walker in the years 1855, 1857. Material collected from Nepal in the mid 19th Century still exists in the NHM, London and NHM, Swayambhu, Kathmandu, and in many foreign countries.

The moth fauna of Nepal is relatively diverse and have received much attention from Heterocists' since the mid 19th century. The data from historical expeditions reveals that the attempts to systematically collect and comprehensively study of moths of Nepal was initiated from and by mostly foreign entomologists. So, the information regarding moths of Nepal is widely scattered in vast taxonomic literatures going back to the mid 19th century. In recent years, there has been steady progress in the documentation of the Nepalese moth fauna. The discovery and description of new species continues to this day.

Here the literatures on the moths of Nepal are provided partially as availability and literatures regarding Sphingidae are focused where presented.

Hampson (1892-1896) in his series of the fauna of British India has mentioned some Indian species having their distribution extending to Nepal. He mentioned few species of moths from different families occurring in Nepal such as Saturniidae (1sp.), Brahmaeidae (1 sp.), Eupterotidae (1sp.), Pyralidae (12 spp.), Sphingidae (2 spp.), Notodontidae (1 sp.), Syntomidea (3 spp.), Zygaenidae (5 spp.), Hepialidae (1 sp.), Drepanulidae (1 sp.), Limacodidae (2 spp.), Lasiocampidae (4 spp.), Lymanteriidae (3spp.), Arctiidae (8 spp.), Agaristidae (3 spp.), Geometridae (12 spp.) and few species belonging to the Family Zygaenidae. He described few new species of moths from Nepal.

He recorded 121 species of sphingid moths under 27 genera in family Sphingidae from India in the fauna of British India (Moths I) and the two species of the sphingid moths reported from Nepal are *Leucophlebia lineate* (Westwood, 1848) and *Sataspes infernalis* (Westwood, 1848).

Bell & Scott (1937) in their work on the Indian Sphingidae have listed 183 species and subspecies under 60 genera from India. The study shows that India is divided into three areas; the West Himalayas, the East Himalayas, and South India. The West Himalayas includes the whole Himalayan and connected ranges west of Nepal, and the Siwalik Mountains. The East Himalayas, including the whole Himalayan range east of Nepal up to the frontier of Burma, the Khasi and Jaintia Hills, the Naga Hills and adjoining areas and hills in Assam. South India, including the rest of Peninsular India. The dividing line between the West and East Himalayan sphingid fauna has been assumed to be Nepal. As although the sphingofauna of this area is particularly unknown they assumed that to the west of Nepal belongs to the West Himalayan type and to the east of Nepal to the East Himalayan type. Thus, according to this it can be assumed that the Nepalese sphingid moths are more similarly to the Indian species. Unfortunately, they have recorded only three of the Indian sphingid species as having their distribution in Nepal probably from the records made by Butler and Walker.

Kernbach (1966) described 1 species of sphingid moth species named *Acosmeryx montivaga* which is holotype to Nepal.

Daniel (1966) recorded 34 species of sphingid moths in course of Zoological collection of the Bavarian State from extensive original harvest out of Nepal.

Dierl (1966) reported 4 species of moths belonging to family Eupterotidae, and he is the only one to work on this group of moths. The further study and inventory of moths of this family is not done after him.

Povolny (1968) described three new species of Gelechid moths (Lepidoptera: Gelechidae) belonging to the tribe *Gnorimoschemini* amongst the collection of

Microlepidoptera from Nepal made by Dr. W. Driel in 1964. These new species are the first of this tribe known from Nepal.

Boursin (1968) recorded 9 species of the genus *Hermonassa* Walker belonging to family Noctuidae from various localities of Nepal.

Viette (1968) has worked on the family Hepialidae and recorded a new genus *Thitarodes* and three other new species.

Dierl (1970) recorded 58 species of Sphingid moths out of 74 expected species initially. His collection includes specimens mainly from Eastern and Central Nepal, most from Kathmandu and adjoining districts. The major part of the Himalayan species is living in forest. He shows that the Sphingidae distribution and ecology show four types of species: Tropical, Himalayan, West Himalayan and Palaearctic species. The distribution of all Sphingid moths in the Himalaya confirms that the designation of the East Himalayan sub-region is correct. The center of this sub-region is the Assam Himalaya. East-Nepal is a part of the Sikkim-Himalaya. West-Nepal a part of the Galhwal Himalaya, Nepal forming a transition between the wet East Himalaya and the dry West Himalaya. In all areas of the Himalayan tropical species are equally represented in large numbers. Palaearctic species can be found in larger numbers only in the westernmost and easternmost parts.

Inoue (1970) had contributed on the study of the moths belonging to the family Geometridae. He has described 9 species of *Abraxas* Leach and 2 species of *Arichanna* Moore. In the same year he worked on the moth family Limacodidae and described 17 species under 12 genera of it.

Werny (1970) has contributed on the study of the moths belonging to the family Thyatiridae. He is the first one to study on this family and describes 1 new genus, 4 new species and 9 new subspecies.

Dierl (1972) recorded 26 species of moths belonging to the family Drepanidae.

Wilkinson (1972) on his paper “The Drepanidae of Nepal (Lepidoptera)” shows the presence of 43 species of moths belonging to the family Drepanidae consisting 3 new species described from Nepal. In his paper these specimens are fully described and the account provides a complete record of Nepal Drepanidae known to that date.

Daniel (1972) recorded and presented systematic list of 77 species of moths belonging to the family Notodontidae from the expedition “Research Scheme Nepal Himalaya”. The knowledge of the distribution of moths of this family is distinctly increased by this record.

Dufay (1973) recorded 21 species moths belonging to the family Noctuidae.

Gozmany (1973) recorded and identified 3 Symmocid species (Fam. Symmocidae) and 34 Lecithocerid species (Lepidoptera: Lecithoceridae) from the moths collection (38 symmocid and 172 Lecithocerid specimens) made by Zoological Collection of Bavarian State, Munich in two expedition to Nepal in 1964 and 1967. Among this, 24 species of Lecithocerid moths proved to be new to science, i.e. the holotypes recorded from Nepal.

Khanal (1983) described 37 species of day flying moths belonging to 6 families. His collection is the sum of specimens collected from various places of Nepal and in different time of the years.

Khanal (1985) has collected moths from Pipar which is located on North-East corner of Pokhara. He has given a preliminary list of moths of Pipar which included 6 spp. (Fam. Arctiidae), 3 spp. (Fam. Noctuidae), 3 spp. (Geometridae), 4 spp. (Zygaenidae), 1 sp. (Fam. Drepanulidae), 7 spp. (Fam. Lymantridae), and 2 spp. (Fam. Syntomidae). The sphingid and saturniid moths were not seen during his collecting period (May, 1981) as stated by him.

Haruta (1992-1998) in five volumes of The *Moths of Nepal* series (edited by T. Haruta) were published between 1992-98 is the only books on the nocturnal moths found in Nepal has been very useful and series aims to cover much of the Nepalese macro moth fauna and has summarized much of the available knowledge about elements of the Nepalese moth fauna and yielded many new taxa. He described more than 80 species of moths in family Sphingidae collected from different parts of Nepal mainly from Godavari, Central and Western Nepal. He collected the moths from so extensively that he presumed that not so many additional species will be found hereafter in Godavari. (Moths of Nepal part-1: 63 hawk moth species) (Moths of Nepal part-2: 9 hawk moth species), (Moths of Nepal part-5: 38 hawk moth species)

Allen (1993) described 119 species of sphingid moths under 49 genera. His collections included specimens mostly from Eastern, Central and Western region of Nepal. He stated that the Hawk moth fauna of Nepal represent over tenth of Hawkmoths of world. He was also the pioneer recorder for the moths belonging to the family Saturniidae and Brahmaeidae. He recorded 22 species belonging to family Saturniidae and 2 species belonging to family Brahmaeidae.

Thapa (1998) has compiled data from historical expeditions and inventory study carried by foreign and local taxonomists. He reported all together 789 species of moths of different families in Nepal. Among them, the moths belonging to the family Sphingidae included 126 species of under 50 genera. He mentioned the distribution, flight periods, status and areas from where the specimens were collected for most species with in Nepal.

Smith (2002) has prepared "The Provisionary List of Lepidopterous Insects From Nepal" which shows that many old records for moths of Nepal were merely give data as Nepaul for Nepal. His work is most recent and updated work on the Lepidopterous insects shows the total taxa of 816 moths listed in 33genera, 726 species and 57 subspecies. He traces the vast bibliography, almost complete list of moths of Nepal with authentical author and year, type locality, references, moths sub-species described from Nepal and with list of authors describing new species and subspecies of Lepidoptera from Nepal. He had listed 1 subspecies of sphingid moth from Nepal i.e. *Hyles galli nepalensis* Daniel, 1861. His contribution on butterflies of Nepal is most noticeable.

Buchsbaum (2003) has given the overview of investigation on Drepanidae fauna of the Himalayan region and has provided the first checklist of 80 species of this family. The checklist shows that 51 species of Drepanidae alone from Nepal which is the highest among the other Himalayan region like Tibet, Sikkim, and Bhutan. This is the most updated and latest study carried on the status of moths of family Drepanidae.

Buchsbaum (2003) has compiled the checklist of 33 species of subfamily Agristinae (Lepidoptera: Noctuidae) for the Himalayan regions. Two new species are included and described. However, 21 species are alone present in Nepal having the highest records.

Beck & Kitching (2004) in the Sphingidae of Southeast Asia (including New Guinea, Bismarck, Solomon Islands) described 389 species of sphingid moths under 68 genus. The distribution and range map for the species shows that 112 species of sphingid moths belonging to 45 genera has distribution to Nepal. In this study many species of sphingid moths are reported in Nepal which is not noted in the previous literatures and papers. So this study has surely enriched the sphingofauna of Nepal.

Pittaway & Kitching (2000-2007) in the Sphingidae of the Eastern Palaearctic (including Siberia, the Russian Far East, Mongolia, China, Taiwan, the Korean Peninsula and Japan) described 306 species and sub-species of sphingid moths under 69 genus. Among them 102 species and sub-species under 47 genera shows distribution to Nepal.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Research Site

The survey of hawkmoths was conducted at Dakshinkali forest area (35^{o}40' North latitude and 85^{o}16' East longitude). This area is named after the Hindu mighty goddess "Dakshinkali Mai". The forest area occupies an area of 6 sq. km (56 hectares). This area is supported, administrated and conserved by "Dakshinkali Area Development Project". As a conservation effort this project was created with in Dakshinkali forest area in 1988 (2045 B.S) by His Majesty Government of Nepal.

Dakhsinkali, one of Nepal's most popular Hindu shrines lies in a lovely valley below Pharping and situated in southeast corner 18 km. far from Kathmandu proper. This area is popular holy spot, tourists attraction and also for picnic purpose. The Dakshinkali area is bounded by several small villages to the southeast by Yutiki village, to the south by Chhaimale-Thasigau, to the west by Phulchokigau, to the east by Gopaleshwor and to the north by Pharping village (as seen in topographic map, Fig. 2). The east west length of the area is little bit longer than the north south axis. Two small rivulets named Uddarbati khola and Chandrabatti khola flowing west to the east drain area. In dry season these rivulets are almost dry and are seasonal rain fed. These two rivulets meet to junction where the Dakshinkali temple is situated and form single rivulet afterwards called Dakshinkali khola and later mingles in Bagmati River at Katuwaldaha. The topographical feature of Daksinkali forest area is very similar with other part of the Mahabharat range. The altitude ranges from 1425m to 1600m from the sea level. The highest point called Mata temple ridge runs from north to south has the altitude 1465m.

The climate of the Dakshinkali forest is similar to that of Kathmandu valley. The area has mild climate neither very cold nor very hot. The climatological data of the Dakshinkali area is not available. However, the closest climatological records for the Dakshinkali forest are from Khokana which is 6 km east from the study area. These records include 5 years of average data indicating an average maximum and minimum temperature are 28.34 ^{o}C and 1.7 ^{o}C respectively (Table 1). The highest temperature occurs in June and

August and the lowest temperatures in December and January. The summer (June-August) is warm and rainy and the winter (December-February) is moderately cool.

An average annual rainfall is nearly 1422 mm. The highest rainfall occurs in July and November has the minimum rainfall (Fig.1). In the study area more than 70% of the total rainfall is occurred in the monsoon period from early June to last September. Post-monsoon, starting from September to November there is a gradual decrease in temperature and rainfall. Few rainfalls occur during winter from January to February. Snow is uncommon in this area.

Table 1: Mean Monthly Climatic Factors (2001-2005)

Months	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Average Rainfall (mm)	36.56	32.68	45.08	76.28	140.02	177.34	406.82	290.2	164.24	44.66	2.94	5.36
Average max. Temp.	17.52	20.16	23.84	26.72	27.74	28.34	27.82	28.2	27.54	25.9	22.64	19.04
Average min. Temp.	1.7	3.44	6.94	10.28	14.5	18.7	20.2	19.94	18.04	12.08	6.12	1.78

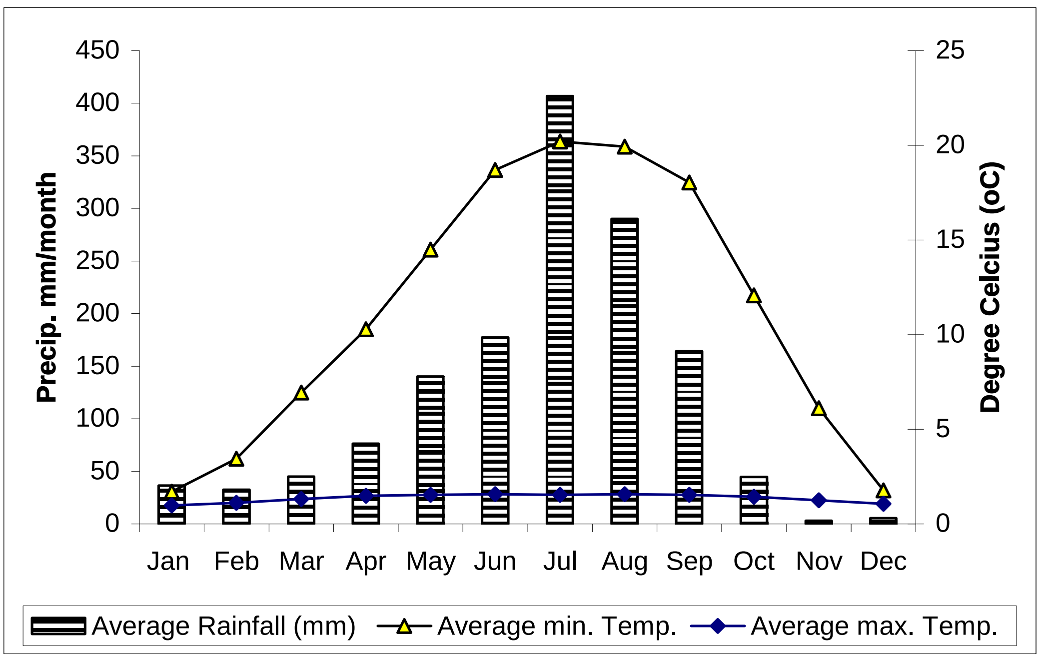


Figure 1: Five year (2001-2005) mean monthly climatological factors (minimum temperature, maximum temperature and rainfall) at "Khokana" climatological station.

The vegetation of Dakshinkali forest was exploited before 1988. After the establishment of "Dakshinkali Area Development Project" in 1988 the vegetation of this area has been flourished then the forest was made axe restricted zone. The vegetation is similar to the flora of Kathmandu Valley. The physical characteristics and vegetation of the site have been described (Shrestha, 2000). Briefly, the study area is composed of the floral vegetation of 201 spp. belonging to 167 genera and 80 families. The forest has a diversity of flora ranging from the trees to ground layer shrubs and herbs.

The area is covered by subtropical forest characterized by different types of particular forests and Shrestha (2000) categorized four types of forests on the basis of dominance of tree species as follows.

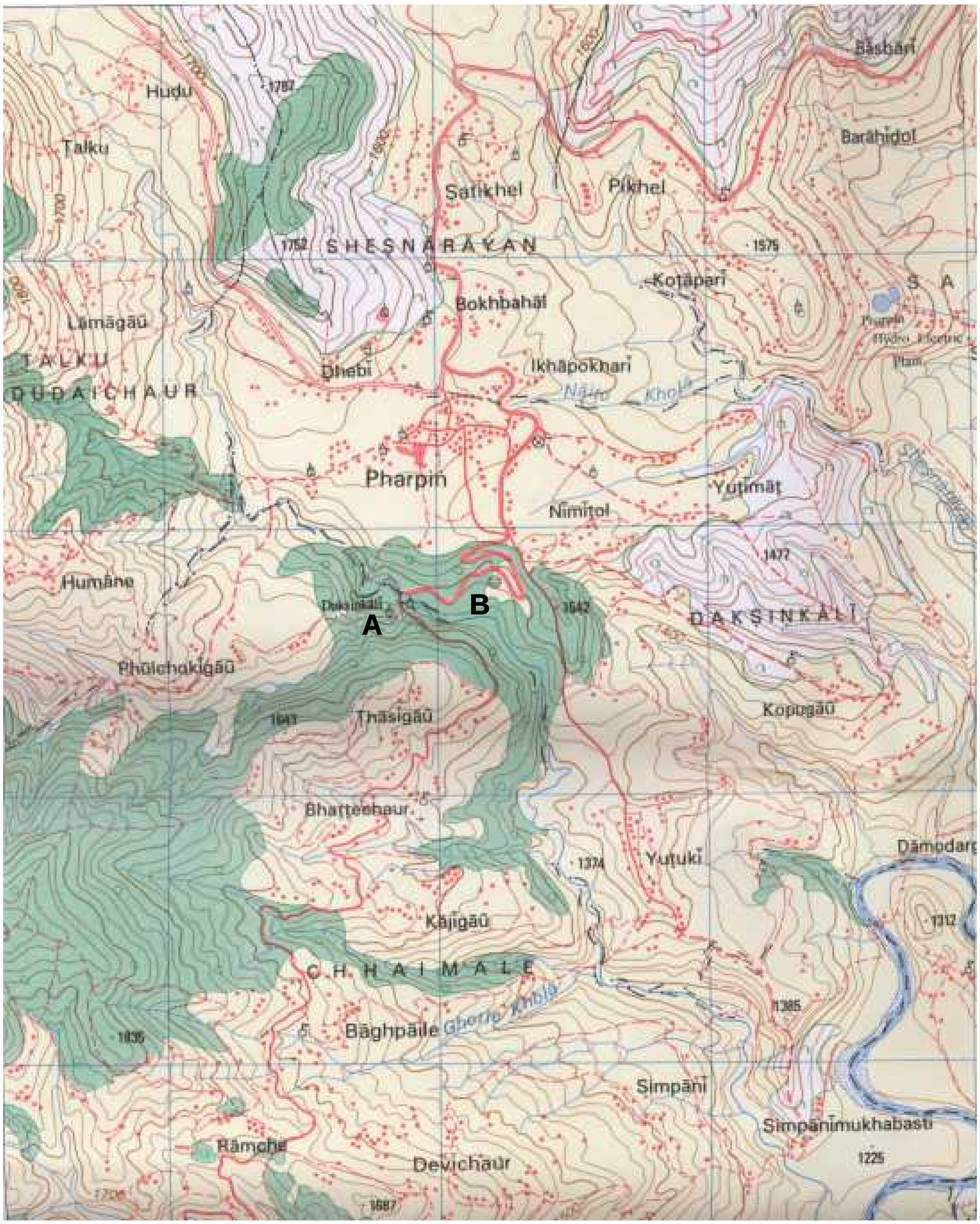
a) Sub-tropical evergreen forest
b) *Alnus* forest
c) *Schima-castonopsis* forest
d) *Pinus roxburghii* forest

The forest encompasses about 56 hectares. The land use in the Dakshinkali forest area consist 2 parking lot, 27 picnic sheds, blacked pitched road, grounds and man made terrenes. The army camp is situated on the top of the hill in northern face called Pauchadada (hill top). Large proportions have been severely disturbed by human activities. The elevation near the Daksinkali khola is occupied by retailers.

The two sites were selected with in the forest area where the mercury vapour was operated during the study period. The selected sites were open areas with in the forest. During the site selection, it was taken in consideration the places where electricity as well as accommodation was available during the collecting night.

3.2 Description of Sites

The two study sites were with in Dakshinkali forest area (Fig. 2). The first site (A) is situated at the highest point of the forest called Mata temple at the altitude of 1465m (Plate 1). It is a small platform where the temple of the Mata Dakshinkali is located atop and opens area surrounded by mostly pine forest and having the wide range of view towards the north. The second site (B) is situated at the main bus depot at the altitude of 1415m it is also the open area surrounded by forest (Plate 2). The forest type is mixed type with *Alnus* forest and sub-tropical evergreen forest.



Site A: Mata Temple, 1465m

Site B: Bus Depot, 1415 m

Figure 2: Topographic Map Showing Study Sites

3.3 Study duration & Collection Time

The collection of moths in Dakshinkali forest area was carried out from May 2006 to October 2006. The mercury vapour lamp was operated for total 24 nights of collecting during the study period. In each months total 4 nights collecting were done, 2/2 in each sites resulting 12 nights collecting per site. The two sites, locality name, altitude, and date of collection for the respective sites were given in Table 2.

The lamp was lighted up from 8 pm to 11 pm in night.

Table 2: List of sample sites, locality, altitude, and date of collections. Date of collection day, month (May-v, June-vi, July-vii, August-viii, September- ix, and October-x), year (2006).

Site	Locality	Altitude (m)	Date of Collection
Site A	Mata temple	1465 m	1. v. 2006; 15. v. 2006; 5. vi. 2006; 19. vi. 2006; 3. vii. 2006; 17. vii. 2006; 7. viii. 2006; 21. viii. 2006; 4. ix. 2006; 18. ix. 2006; 2. x. 2006; 16. x. 2006;
Site B	Bus depot	1415 m	8. v. 2006; 22. v. 2006; 12. vi. 2006; 26. vi. 2006; 10. vii. 2006;24. vii. 2006; 14. viii. 2006; 28. viii. 2006; 11. ix. 2006; 25. ix. 2006; 9. x. 2006; 21. x. 2006;

3.4 Collection of Specimens

The adults of hawkmoths were collected on nightly basis by operating 125 watt mercury vapour light. The light was suspended in front of white cotton sheet affixed. Moths visiting the luminated lamp were numerous, the selective collection of hawkmoths were done while the light was operated. The specimen which rested on the white sheet was subsequently scooped up with a killing bottle and quickly closing the lid. Numerous killing bottles were used for collecting the specimens. The killing bottles were prepared from wide mouth bottles and cotton wool placed in bottom and charged with ethyl acetate. A thick cardboard was kept above cotton wool so to reduce scales catches on cotton fibers. This method has the advantages like capture only the selected species of interest and the delicate specimens are not damaged.

3.5 Preparation of Specimens (Curating and Setting of Specimens)

Curating and setting is the essential step before proceeding the identification. As the moths were collected in late night it was quite impossible to set the specimens properly in the field. So the collected specimens were pinned through the thorax and stored in entomological boxes in the field and collecting site and date of collection was labeled in the boxes.

As the moths were left in entomological boxes the moths became dry, brittle and prone to breakage of antennae, wings, and legs. Before setting the dry specimens it was relaxed. For the relaxing the moth specimens, two methods were used. The first method included relaxing by keeping specimens in desiccators containing soaked sand. The second method included relaxing the specimens by injecting with hot water in the thoracic region from upper and lower sides. The initial process of relaxing was slow and the specimens were needed to keep in dissectors for a whole day. And the second method was quick and the specimens became pliable soon.

All collected specimens were spread to facilitate identification. The relaxed specimens were set in wing spreading blocks. During the setting of the wings the edge of the fore wings was at 90 degree angle to the body and the front edge of the hind wings was under the fore wings so that the tip of hind wings was under the fore wings and the tip of hind wings creating a small notch with the outer edge of the fore wings. The position of the antennae and the abdomen was also set. The specimens were kept in the spreading blocks for few days for complete setting.

3.6 Identification and Classification of Specimens

The collected hawkmoths were identified by using different sources. Hampson (1892), Bell & Scott (1937), Allen (1993), and Haruta (1992, 1993, 1994, 1995) were main literature sources for identifying the collection. The keys and characters of hawk species were noticed and the morphological characters like colour patterns on head, thorax, abdomen, wings, the antennal structures, and wing venation were observed and studied by using binocular microscope. The specimens were identified up to species level and some were identified up to genus level on the availability of the literatures. The study of genital structures was not done, and sexes were not distinguished.

The specimens were reconfirmed by comparing with already authentically identified reference specimens maintained in NHM, Swoyambhu, Kathmandu, and NARC Khumaltar, Lalitpur.

Besides, the internet sources were also used. The collected hawkmoths were classified to the subfamilies, tribes and nomenclature are followed as used by Kitching & Cadiou (2000), and Pittaway & Kitching (2000-2007) and have been adopted here.

3.7 Storage and Preservation

The identified specimens were kept in entomological boxes with glass top drawers. The necessary data available for the specimens as location, date of collection, altitude, collector name, and scientific name were tagged. The common name for the few specimens were tagged where available and known. Naphthalene balls were placed in the corners of the entomological boxes.

3.8 Photographing

The photographs include the featured photos of the collection area, different types of forests of the study area, the materials used, and of the collected specimens. The photographs of the mounted specimens were taken to show the upper sides with wings folded and spread.

3.9 Data Collection & Generation

The number of moths including species and individuals collected per catch, its date and the month in which they were caught were recorded. For showing the relation of collected hawkmoths with environmental factors like temperature and rainfall meteorological data were collected. As there is no meteorological station in the study area, the meteorological data regarding Temperature, Relative Humidity, and Rainfall of the nearest station Khokana which is situated in six kilometers east from the study area. The required meteorological data of Kokhana were obtained the Department of Hydrology and Meteorology, Minister of Science and Technology, Nepal Government, Babarmahal, Kathmandu.

3.10 Data Analysis

For each identified species, months of capture were recorded. The total number of species documented for each month (from May to October) was tallied and used to generate histogram illustrating temporal distribution.

Species diversity of hawkmoths of Dakshinklai forest was calculated. For this purpose the data about hawkmoths which was collected during the survey was listed and constructed in terms of species richness, species dominance and individual number (*N*). Species diversity refers to the frequency and variety of species within a geographical area. There are different ways to describe species diversity. One often used to measure species diversity is species richness, which gives the total number of species within a particular sample area or geographical area.

Species dominance refers to the most abundant species. The comment on the relative abundance of various species based on collection from Daksinkali forest was done. The abundance categories were established using the criteria of Robinowitz et. al. (1986) and based on the number of the specimens of each species collected. It has nominated three abundance levels. These categories were “Rare” (1 to 2 specimens); “Common” (3 to 19 specimens); and “Abundant” (20 to 50 specimens).

Indices that take into account both richness and the proportional abundances of species, such as those of Shannon and Simpson, are therefore useful in diversity studies are also calculated. The different diversity indices Shannon Diversity Index, Simpson’s Index, Berger-Parker Dominance index, Similarity measures (Jaccard measure) were calculated for sites A and B for comparison. The Berger-Parker Dominance index expresses the proportional importance of the most abundant species (the dominant species) and was considered as one of the most satisfactory diversity measures. The calculation regarding the different diversity indices was facilitated by the software Biodiversity Data Analysis Package (Bio~DAP Ecological diversity and its measurement, scientific authority: Douglas Clay, Park Ecologist, Resource Conservation Fundy National Park, Alma and New Brunswick, Canada).

Faunal similarity (FS) was calculated by the following equation. FS= C/(A+B)+C where ‘A’ is the number of species recorded from site A; ‘B’ is the number of species recorded from site B; and ‘C’ is the number of species shared by sites A and B. The result given by this is equal to the Jaccard measure for similarity measure and it is related to qualitative data. Complimentarity (D) dissimilarity, which is defined as inverse of faunal similarity, was derived by using the following equation: D= 1-FS, where FS is equal to Faunal Similarity.

The graphical representation of the number of the species collected each month to the average monthly rainfall and temperatures (minimum and maximum) was shown. Unfortunately, due to the fewer samples collected and short study period there was no statistical analysis of the result to determine the effects of the climatological factors (Relative Humidity% and Temperature) on moth catches was done. However, the Correlation coefficient (Pearson r) between number of species collected in each months and the average monthly Rainfall was calculated.

CHAPTER IV

RESULTS

4.1 Description of the Hawkmoth Species Collected

Altogether, during the whole study period, a total of 117 specimens of hawkmoths were collected representing 22 species within 15 genera and these species were classified into 6 tribes within three subfamilies (Table 3). The number of moths collected and the month in which they were caught were also shown in each case. The details of the collected species are given below.

Family: Sphingidae Latreille, 1802

The collected hawkmoths were classified to the subfamilies, tribes and nomenclature are followed as used by Kitching & Cadiou (2000), Pittaway & Kitching (2000-2007), Beck & Kitching (2004).

The classification of collected hawkmoths into subfamily, tribes, genera and species is given in Appendix 1.

1) Subfamily Smerinthinae Grote & Robinson, 1865

Beck & Kitching (2004) has enlisted 32 species under 18 genera in this subfamily showing the distribution towards Nepal.

A) Tribe Smerinthini Grote & Robinson, 1865

1) Genus *Marumba* Moore, (1882)

Allen (1993) described 6 species of this genus.

I) *Marumba cristata* (Butler, 1875) (Plate 8a & 8b)

Triptogon cristata Butler,1875; *Proc. zool. Soc. Lond.*, 1875, p.253.

Marumba cristata Rothschild & Jordan, 1903, p. 272.

Wingspan: 100--124mm.

Date of collection and total number of specimens: 5 vi 2006 (2), 15 vi 2006 (2), 26 vi 2006 (1), 21 viii 2006 (2),

Total specimen: 7

Location: site A and B

II) *Marumba dyras* (Walker, 1865) (Plate 9)

Smerinthus dyras Walker, 1856; List Specimens lepid. Insects Colln. Br. Mus.,8:250.

Marumba dyras Rothschild & Jordan, 1907: p. 274.

Triptogon javanica Butler; 1875, Proc. zool. Soc. Lond., 1875: 254.

Wingspan: 90--125mm

Date of collection and total number of specimens in parentheses: 7 viii 2006 (1), 11 ix 2006 (1)

Total specimen: 2

Location: site A and B

III) *Marumba gaschkewitschii* (Bremer & Grey, 1853) (Plate 10)

Smerinthus gaschkewitschii Bremer & Grey, 1853, *in* Motschulsky (ed.), *Etudes ent.* 1: 62.

Wingspan: 85-105mm

Date of collection and total number of specimens: 19 vi 2006 (1)

Total specimen: 1

Location: site A

2) Genus *Polyptychus* Hübner, (1819)

Allen (1993) described 2 species of this genus.

I) *Polyptychus sp.* (Plate 11)

Wingspan: 100-120mm

Date of collection and total number of specimens : 25 ix 2006 (1)

Total specimen: 1

Location: site B

B) Tribe Sphingulini Rothschild & Jordan, 1903

3) Genus *Dolbina* Staudinger, 1877

Allen (1993) described 1 species of this genus.

I) *Dolbina inexacta* (Walker, 1856) (Plate 12a & 12b)

Macrosila inexacta Walker, 1856, *List Specimens lepid. Insects Colln Br. Mus.* 8: 208

Dolbina inexacta, Rothschild & Jordan, 1903, p.160

Wingspan: 55--86mm

Date of collection and total number of specimens: 12 vi 2006 (5), 17 vii 2006 (5), 21 viii 2006 (4), 11 ix 2006 (3), 18 ix 2006 (2), 25 ix 2006 (4), 2 x 2006 (2), 9 x 2006 (1)

Total specimen: 26

Location: site A and B

C) Tribe Ambulycini Butler, 1876

4) Genus *Ambulyx* Westwood, 1847

Allen (1993) described 7 species of this genus.

I) *Ambulyx ochracea* Butler,1885 (Plate 13a & 13b)

Ambulyx ochracea Butler, 1885; *Cistula Ent.,* 3: 113

Wingspan: 90-115mm

Date of collection and total number of specimens: 15 v 2006 (1), 5 vi 2006 (2), 24 vi 2006 (3), 7 viii 2006 (4)

Total specimen: 10

Location: site A and B

II) *Ambulyx maculifera* (Walker, 1866) (Plate 14)

Oxyambulyx maculifera Rothschild & Jordan, 1903, p. 197

Ambulyx substrigilis Hampson, 1892, p. 77

Wingspan: 95-115mm

Date of collection and total number of specimens: 10 vii 2006 (3)

Total specimen: 3

Location: site B

III) *Ambulyx sericeipennis* (Butler, 1875) (Plate 15)

Ambulyx sericeipennis Butler, 1875, *Proc. zool. Soc. London* 1875: 252

Oxyambulyx amaculata Meng, 1989; *Entomotaxonomia* 11: 4

Wingspan: 100--124mm

Date of collection and total number of specimens: 1 v 2006 (2), 21 viii 2006 (2)

Total specimen: 4

Location: site A

IV) *Ambulyx substrigilis* (Westwood, 1847) (Plate 16)

Sphinx (Ambulyx) substrigilis Westwood, 1848, *Cab. Orient. Ent.*, p. 61.

Oxyambulyx substrigilis Westwood; Rothschild & Jordan, 1903: 201.

Oxyambulyx brooksi Clark, 1923, Proc. *New Engl. Zool. Club*, 8: 52.

Wingspan: 96--120mm

Date of collection and total number of specimens: 17 vii 2006 (3)

Total specimen: 3

Location: site A

5) Genus *Amplypterus* Hübner, (1819)

Allen (1993) described 2 species of this genus.

I) *Amplypterus panopus* (Cramer, 1779) (Plate 17)

Sphinx panopus Cramer, 1779, *Uitlandsche Kapellen.*, 3: p. 50.

Compsogene panopus Cramer, 1779, Rothschild & Jordan, 1903, p.189.

Wingspan: 130--168mm

Date of collection and total number of specimens: 14 vii 2006 (1)

Total specimen: 1

Location: site B

2) Subfamily: Sphinginae Latreille, (1802)

This is the smallest subfamily of the family Sphingidae. Beck & Kitching (2004) has enlisted 9 species under 5 genera in this subfamily showing the distribution towards Nepal. Allen (1993) has reported 8 species for this subfamily.

A) Tribe: Sphingini Latreille, (1802)

6) Genus *Meganoton* Boisduval, (1875)

Allen (1993) described 2 species of this genus. Beck & Kitching (2004) in the study of Sphingidae of Southeast Asia, the distribution and range map for the species shows that 3 species of sphingid moths under this genus has distribution to Nepal.

I) *Meganoton analis* (R. Felder, 1874) (Plate 18)

Sphinx analis Felder, 1874, *Reise Ost. Fregatte Novara, Lep.(Zool.)* 2(Abt.2): 78
Meganoton analis Felder; Rothschild & Jordan, 1903, p.37.

Wingspan: 120-140mm

Date of collection and total number of specimens: 22 v 2006 (2), 19 vi 2006 (1), 11 ix 2006 (3)

Total specimen: 6

Location: site A and B

7) Genus *Psilogramma* Rothschild & Jordan, 1903

Allen (1993) & Beck & Kitching (2004) described 2 species of this genus in Nepal.

I) *Psilogramma menephron* (Cramer, 1780) (Plate 19a & 19b)

Sphinx menephron Cramer, 1780, *Uitlandsche Kapellen*. 3: p.164.
Psilogramma menephron Rothschild & Jordan, 1903, p. 42.

Wingspan: 110-140mm

Date of collection and total number of specimens: 15 v 2006 (2), 7 viii 2006 (3), 18 ix 2006 (3)

Total specimen: 8

Location: site A

B) Tribe: Acherontiini Boisduval, (1875)

8) Genus *Acherontia* Laspeyres, 1809

Allen (1993) & Beck & Kitching (2004) described 2 species of this genus in Nepal.

I) *Acherontia lachesis* (Fabricius, 1798) (Plate 20a & 20b)

Sphinx lachesis Fabricius, 1798, *Ent. Syst Suppl.*: 434

Acherontia lachesis Fabricius; Rothschild & Jordan, 1903, p.17

Common name: Death's head hawk moth

Wingspan: 100--132mm.

Date of collection and total number of specimens: 8 v 2006 (1), 15 v 2006 (1), 7 viii 2006 (1)

Total specimen: 3

Location: site A and B

9) Genus *Agrius* Hübner, (1819)

Only single species of this genus is found in Nepal.

I) *Agrius convolvuli* (Linnaeus, 1758) (Plate 21a & 21b)

Sphinx convolvuli Linnaeus, 1758, *Syst. Nat.* edn. 10: 490.

Herse convolvuli Linnaeus, Rothschild & Jordan, 1903, p.11.

Common name: Convolvulus hawk moth, Sweet potato hornworm

Wingspan: 80--120mm

Date of collection and total number of specimens: 1 v 2006 (1), 8 v 2006 (2), 19 vi 2006 (1), 21viii 2006 (1), 25 ix 2006 (2), 23 x 2006 (1)

Total specimen: 8

Location: site A and B

3) Subfamily: Macroglossinae Harris, 1839

This is the largest subfamily of the family Sphingidae. Beck & Kitching (2004) has enlisted 71 species under 22 genera in this subfamily showing the distribution towards Nepal.

Beck & Kitching (2004) has divided this subfamily into three tribus, Pittaway & Kitching (2000-2007) has divided into two tribes.

A) Tribe: Macroglossini Harris, 1839

10) Genus *Cechenena* Rothschild & Jordan, 1903

Allen (1993) described 6 species of this genus.

I) *Cechenena lineosa* (Walker, 1856) (Plate 22)

Chaerocampa lineosa Walker, 1856, *List Specimens lepid. Insects Colln Br. Mus.* 8: 144

Cechenena lineosa; Rothschild & Jordan, 1903, 803

Wingspan: 74--120mm.

Date of collection and total number of specimens: 1 v 2006 (2), 15 v 2006 (2), 5 vi 2006 (3)

Total specimen: 7

Location: site A

II) *Cechenena minor* (Butler, 1875) (Plate 23)

Chaerocampa minor Butler, 1875, *Proc. zool. Soc. Lond.* 1875: 249.

Wingspan: 90--98mm.

Date of collection and total number of specimens: 15 v 2006 (2), 5 vi 2006 (2)

Total specimen: 4

Location: site A

III) *Cechenena scotti* (Rothschild, 1920) (Plate 24)

Cechenena scotti Rothschild, 1920, Ann. Mag. Nat. Hist. (9) 5: 481

Wingspan:

Date of collection and total number of specimens: 12 vi 2006 (1), 14 viii 2006 (1)

Total specimen: 2

Location: site B

11) Genus *Daphnis* Hübner, (1819)

Allen (1993) described 2 species of this genus. Beck & Kitching (2004) in the study of Sphingidae of Southeast Asia, the distribution and range map for the species shows that 2 species of sphingid moths under this genus has distribution to Nepal.

I) *Daphnis hypothous* (Cramer, 1780) (Plate 25)

Sphinx hypothous Cramer, 1780, *Uitlandsche Kapellen*, 3: 165. *Deilephila hypothous*; Rothschild & Jordan, 1903: 509.

Wingspan: 86-120mm.

Date of collection and total number of specimens: 12 vi 2006 (1), 28 viii 2006 (1)

Total specimen: 2

Location: site B

12) Genus *Hippotion* (Hübner, 1819)

Allen (1993) described 4 species of this genus. Beck & Kitching (2004) in the study of Sphingidae of Southeast Asia, the distribution and range map for the species shows that 5 species of sphingid moths under this genus has distribution to Nepal.

I) *Hippotion celerio* (Linnaeus, 1758) (Plate 26a & 26b)

Sphinx celerio Linnaeus, 1758, *Syst. Nat.* (Edn. 10) 1: 491.

Hippotion celerio Rothschild & Jordan, 1903, 751

Common name: Silver–striped Hawk moth, Grape Vine Hawk moth

Wingspan: 60--80mm

Date of collection and total number of specimens: 7 viii 2006 (3), 18 ix 2006 (3), 2 x 2006 (2), 23 x 2006 (2)

Total specimen: 10

Location: site A and B

13) Genus *Pergesa* Walker, 1856

Only single species of this genus is reported in Nepal.

I) *Pergesa acteus* (Cramer, 1779) (Plate 27a & 27b)

Sphinx acteus Cramer, 1779, *Uitlandsche Kapellen* 3: 93

Rhyncholaba acteus ; Rothschild & Jordan, 1903, 789

Wingspan: 64--80mm.

Date of collection and total number of specimens: 28 viii 2006 (1)

Total specimen: 1

Location: site B

14) Genus *Rhagastis* Rothschild & Jordan, 1903

Allen (1993) described 7 species of this genus.

I) *Rhagastis confusa* (Rothschild & Jordan, 1903) (Plate 28)

Rhagastis confusa Rothschild & Jordan, 1903, *Novit. zool.* 9 (suppl.): 793 (key), 79

Wingspan: 84--90mm.

Date of collection and total number of specimens: 22 v 2006 (1), 26 vi 2006 (1), 14 viii 2006 (2)

Total specimen: 4

Location: site B

15) Genus *Theretra* (Hübner, 1819)

Allen (1993) described 11 species of this genus.

I) *Theretra clotho* (Drury, 1773) (Plate 29)

Sphinx clotho Drury, 1773, *Illust. nat. Hist. exot. Insects* 2: index [91].

Wingspan:

Date of collection and total number of specimens: 21 viii 2006 (2), 23 x 2006 (2)

Total specimen: 4

Location: site A and B

* Number given in parentheses- Number of individuals of given species

4.2 Monthly Distribution of Hawkmoths

Temporal variation occurs in insect communities with regard to the number of species and specimens. The number of moths collected and the month in which they were caught are shown (Table 4). The potential number of species captured per month ranged from a high 15 in August to a low of 4 in July and October (Fig.3). The biggest collection was made in August with 29 individuals were captured, belonging to 15 species. The lowest record was in October with 10 individuals belonging to 4 species. On the whole 22 species were recorded during the study period (Table 6). Although the majority of the species exhibited in distinct months only, few species were captured almost round the study duration; *Ambulyx ochracea*, *Dolbina inexacta*, and *Agrius convolvuli*. The temporal distribution showing the presence and absence of the hawkmoth species in the months from May to October is given in Appendix 2.

The number of individuals per species and summation of species and specimens for each month from May to October is given in Appendix 3.

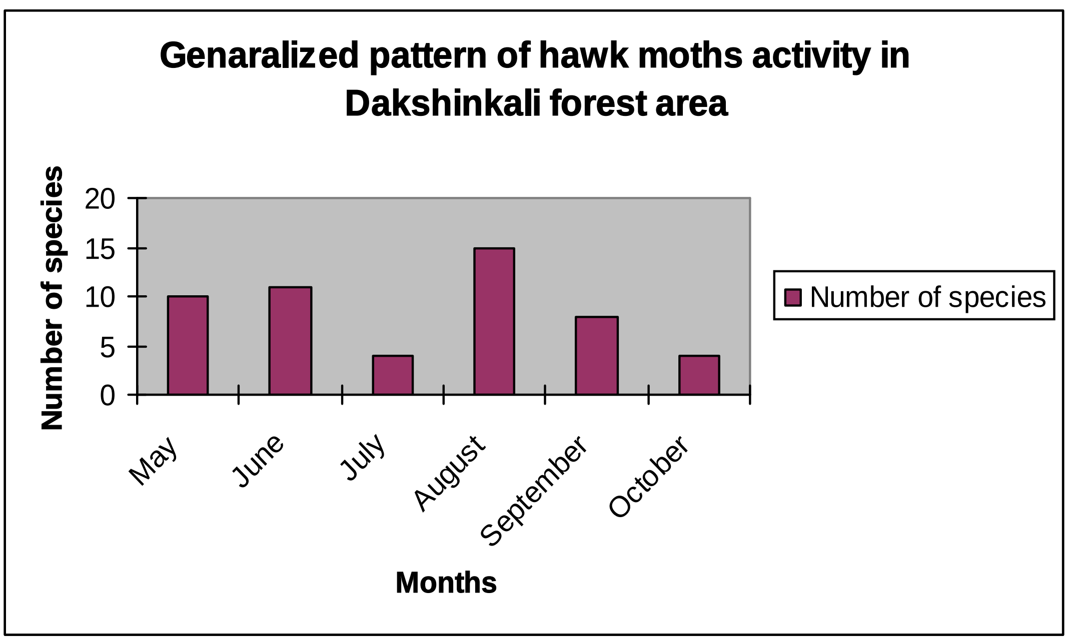


Figure 3: Generalized pattern of hawk moth activity in Dakshinkali forest area; X-axis= Months (May to October), Y-axis=number of species collected.

4.3 Species richness

One often used to measure species diversity is species richness, which gives the total number of species within a particular sample area or study area. *Ambulyx* was the most species rich hawk moth genus with 4 species (17%) followed by *Cechenena* and *Marumba* with 3 species (13%). These three genera represented 30% of the species collected in Daksinkali forest area. Other remaining genuses are represented by single species only (Table 3).

Smerinthinae was the most abundant and richest subfamily in study area, being followed by Macroglossinae, and Sphinginae. Hence, Smerinthinae contained 10 species (46%), Macroglossinae contained 8 species (36%) and Sphinginae contained only 4 species (18%) (Fig.3a)

Macroglossini (Macroglossinae) was the richest tribe with 8 species (36%), Ambulycini (Smerinthinae), and Smerinthini (Smerinthinae) with 5 species (23%), and 4 species (18%) respectively. Sphingini (Sphinginae) and Acherontiini (Sphinginae) with 2 species (9%) each one and Sphingulini (Smerinthinae) with only one species (5%) (Fig. 3b).

The species diversity was determined in terms of Shannon Diversity (H`) and its value was 2.73. Species dominance refers to the most abundant species. *Dolbina inexacta* was the most collected hawk moth species with highest number of specimens and the value of Berger-Parker Index is 0.222.

Table 3: Number of species and individuals per each hawkmoth genus (Lepidoptera: Sphinigdae) collected at Dakshinkali forest from May 2006 to October 2006.

Subfamilies	Tribes	Genera	No. of species	No. of total individuals
Smerinthinae	Smerinthini	*Marumba*	3	10

		Polyptychus	1	1
	Sphingulini	*Dolbina*	1	26
	Ambulycini	*Ambulyx*	4	20
		Amplypterus	1	1
Sphinginae	Sphingini	*Meganoton*	1	6
		Psilogramma	1	8
	Acherontiini	*Acherontia*	1	3
		Agrius	1	8
Macroglossinae	Macroglossini	*Cechenena*	3	13
		Hippotion	1	10
		Daphnis	1	2
		Pergesa	1	1
		Rhagastis	1	4
		Theretra	1	4
Total	**6**	**15**	**22**	**117**

Figure 4: Relative proportions in the number of hawk moth species collected per subfamilies and tribes at Dakshinkali forest from May 2006 to October 2006.

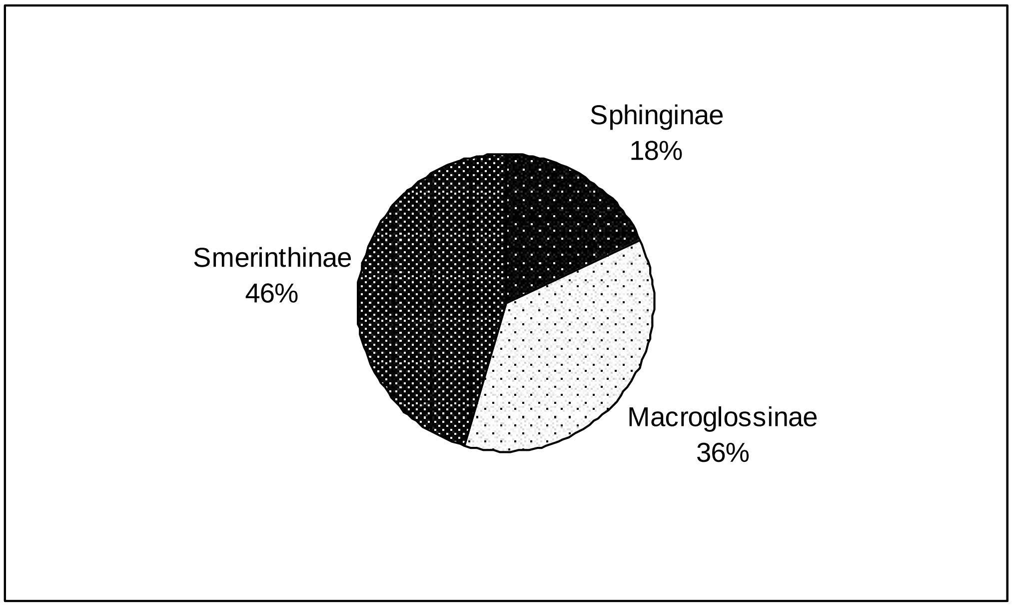


Figure 4a: Species richness of hawk moth with in three subfamilies

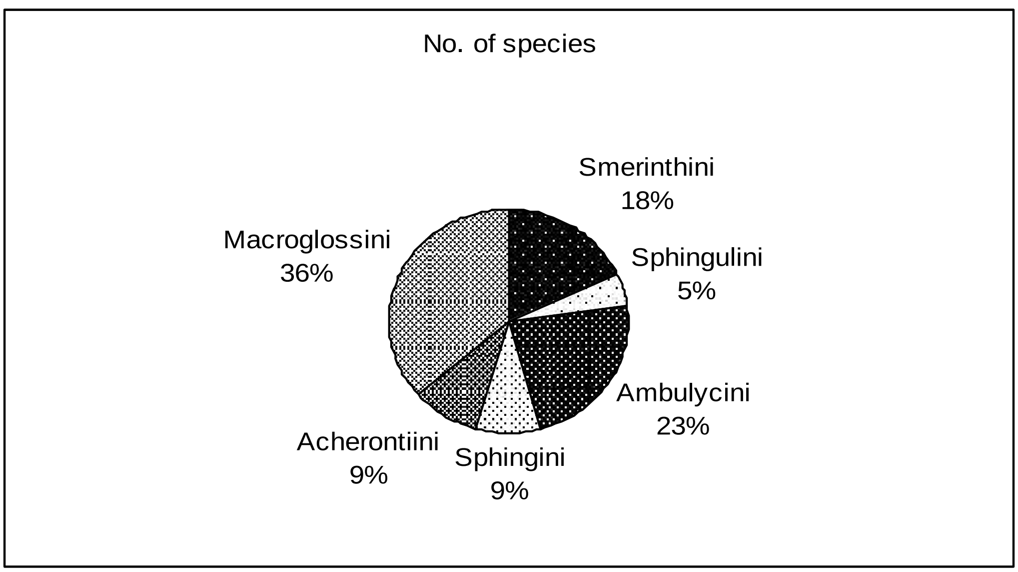


Figure 4b: Species richness of hawk moth with in six tribes.

4.4 Relative Abundance and its Categories

Smerinthinae was the most abundant subfamily with 50% of collected individuals, being followed by Macroglossinae (29%) and Sphingidae (21%) (Fig. 4a).

Among the tribes, Macoglossini had the highest percentage of individuals with 30% and Smerinthini and Acherontini had the lowest with only 9% (Fig. 4b).

Like any other biological species some species are rare while others are common and abundant. A comparison of relative abundance of the different species, based solely upon the total number of individuals per species caught during the study time. The number of specimens of each species is given to illustrate a rough idea of their abundance during the period. The abundance categories are differentiated into three types, they are; Rare (1 to 2 individuals), Common (3 to 19 individuals), and Abundant (20 to 50 individuals). Among 22 species collected, 7 species were ranked as "Rare", 14 species were "Common" and Only 1 species is "Abundant" (Table 4). This results that the hawkmoths in Dakshinkali forest are mostly common. The number of specimens to the number of species for the rare species was 10:7 and for the common species was 81:14.

Four species were represented by only one individuals in collection: Smerinthinae: *Marumba gaschkewitschii*, *Polyptychus sp.*, *Amplypterus panopus*; Macroglossinae: *Pergesa acteus*. The most common hawk moth species were *Agrius convolvuli*, *Hippotion celerio*, *Ambulyx ochracea*, *Psilogramma menepheron*, *Marumba cristata*, *Meganoton analis* and *Cechenena lineosa.* The average number of specimens captured for the common species was 5.78 (nearly 6) from the ratio 81:14 stated above. *Dolbina inexacta* was the most collected hawk moth and only abundant species as indicated by total catch of 26 individuals i.e 22.22% of whole specimens. The total number of individuals for each species in descending pattern after *Dolbina inexacta* were *Hippotion celerio*, *Ambulyx ochracea*, *Psilogramma menephron*, *Agrius convolvuli* and others (Fig. 6). The biggest collection was made in the months August and September.

Figure 5: Relative proportions in the number of hawk moth individuals collected per subfamilies and tribes at Dakshinkali forest from May 2006 to October 2006.

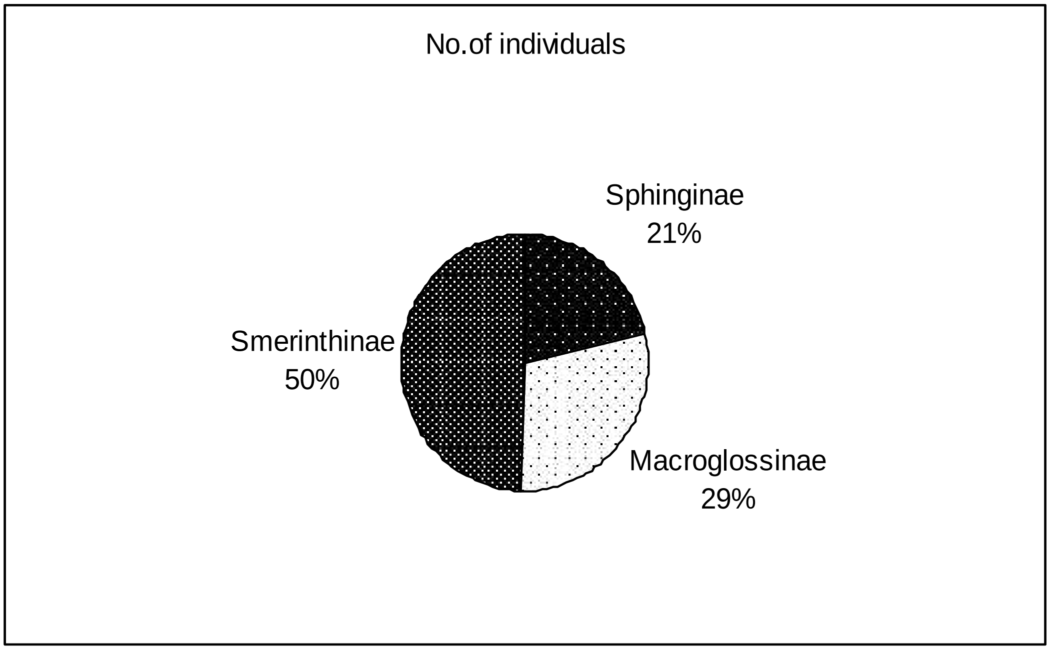


Figure 5a: Relative abundance of number of hawk moth individuals with in three subfamilies

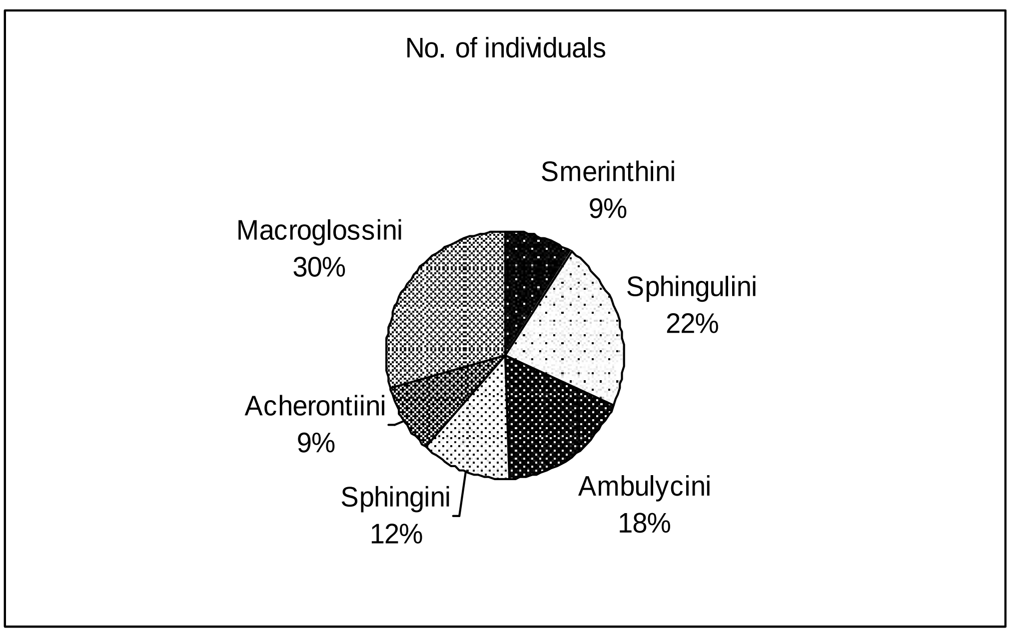
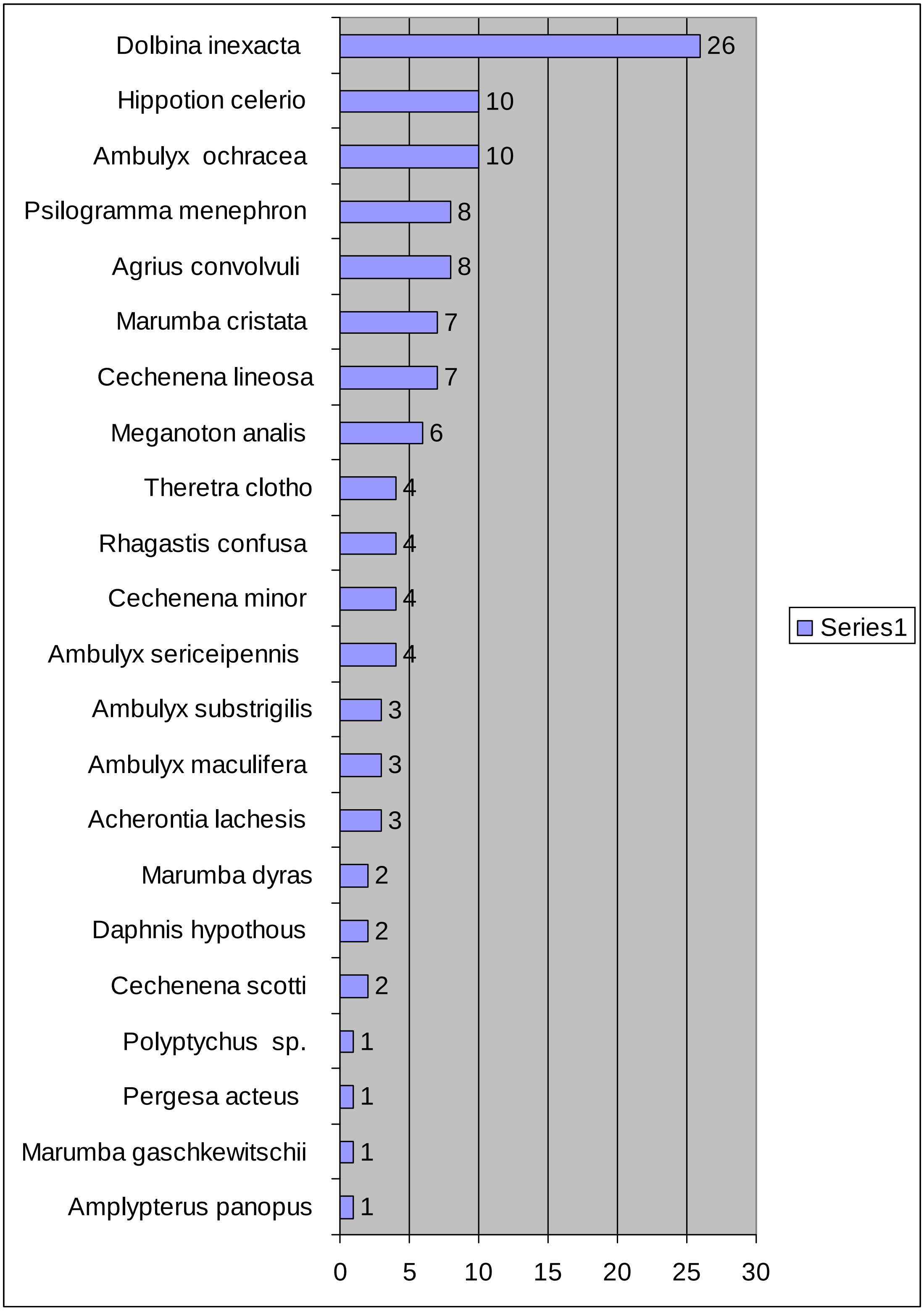


Figure 5b: Relative abundance of number of hawk moth individuals with in six tribes

Table 4: Monthly distribution of Hawkmoths (May 2006-October2006) and Abundance categories.

Moth species	Number of moths	Months	Status
Subfamily: Smerinthinae			
Tribe: Smerinthini			
Marumba cristata	7	May, June, Aug	Common
Marumba dyras	2	Aug, Sep	Rare
Marumba gaschkewitschii	1	June	Rare
Polyptychus sp.	1	Sep	Rare
Tribe: Sphingulini			
Dolbina inexacta	26	June, Jul, Aug, Sep, Oct	Abundant
Tribe: Ambulycini			
Ambulyx ochracea	10	May, June, Jul, Aug, Sep	Common
Ambulyx maculifera	3	Jul	Common
Ambulyx sericeipennis	4	May, Aug	Common
Ambulyx substrigilis	3	Jul	Common
Amplypterus panopus	1	Aug	Rare
Subfamily: Sphinginae			
Tribe: Sphingini			
Meganoton analis	6	May, June, Sep	Common
Psilogramma menephron	8	May, Aug, Sep	Common

Tribe: Acherontiini			
Acherontia lachesis	3	May, Aug	Common
Agrius convolvuli	8	May, June, Aug, Sep, Oct	Common
Subfamily: Macroglossinae			
Tribe: Macroglossini			
Cechenena lineosa	7	May, June	Common
Cechenena minor	4	May, June	Common
Cechenena scotti	2	June, Aug	Rare
Daphnis hypothous	2	June, Aug	Rare
Hippotion celerio	10	Aug, Sep, Oct	Common
Pergesa acteus	1	Aug	Rare
Rhagastis confusa	4	May, June, Aug	Common
Theretra clotho	4	Aug, Oct.	Common



Dolbina inexacta 26
Hippotion celerio 10
Ambulyx ochracea 10
Psilogramma menephron 8
Agrius convolvuli 8
Marumba cristata 7
Cechenena lineosa 7
Meganoton analis 6
Theretra clotho 4
Rhagastis confusa 4
Cechenena minor 4
Ambulyx sericeipennis 4
Ambulyx substrigilis 3
Ambulyx maculifera 3
Acherontia lachesis 3
Marumba dyras 2
Daphnis hypothous 2
Cechenena scotti 2
Polyptychus sp. 1
Pergesa acteus 1
Marumba gaschkewitschii 1
Amplypterus panopus 1
0 5 10 15 20 25 30
Series1

Figure 6: Horizontal bars showing the total number of individuals captured per species and arranged in descending order from top to bottom, sphingid moths collected in Dakshinkali forest from May 2006 to October 2006.

4.5 Effect of Environmental Factors Affecting the Monthly Catch

The environmental factors like temperature and rainfall were used to study the effect on the number of hawkmoth species captured per month. The average monthly temperature (minimum and maximum) and average rainfall of the study period (May 2006-October 2006) were given in Appendix 4.

A) Effect of temperature:

The relation between the number of hawkmoth species captured per month and the minimum and maximum temperature of respective months was shown in Fig. 6 a, and Fig. 6 b respectively. The rise in minimum temperature was seen from May to July and there was decline in the minimum temperature from July and in descending up to October. Where as the number of species increase from May to June and drastically decreased in July (4 spp.). The highest number of species recorded in August (16spp.) and number of species decrease in the consecutive months in descending order. The minimum temperature was recorded in October and so was the number of species.

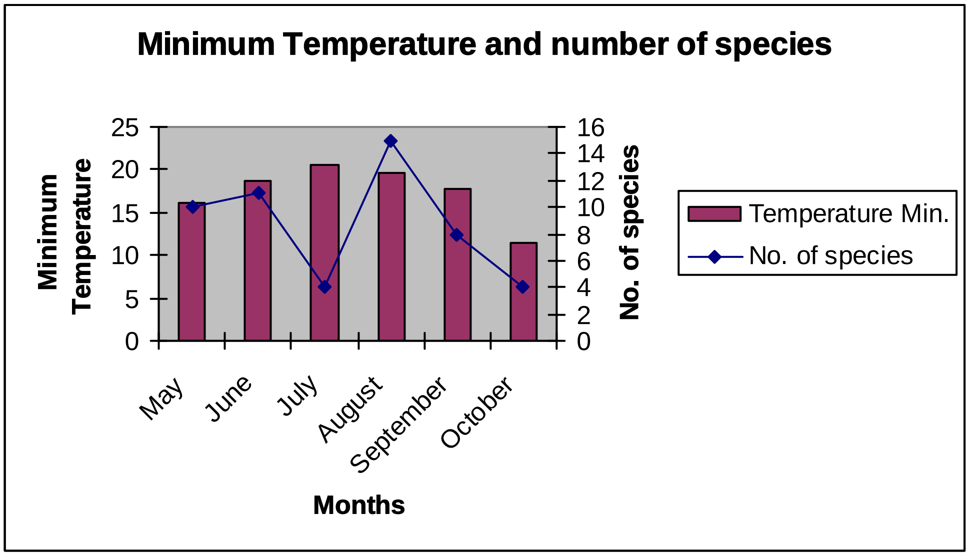


Figure 7 a: Relation of average monthly minimum temperature and monthly number of species captured (May 2006 –October 2006).

There was same trend on increase in maximum temperatures and decrease in temperatures and so was the occurrence of the hawk moth species in the respective months. The rise in maximum temperature was seen from May to July and there was decline in the temperature from July and in descending up to October. The lowest maximum temperature was recorded in October and so was the number of species. So the relation of maximum temperature with the number of species appeared and collected were same as described previous.

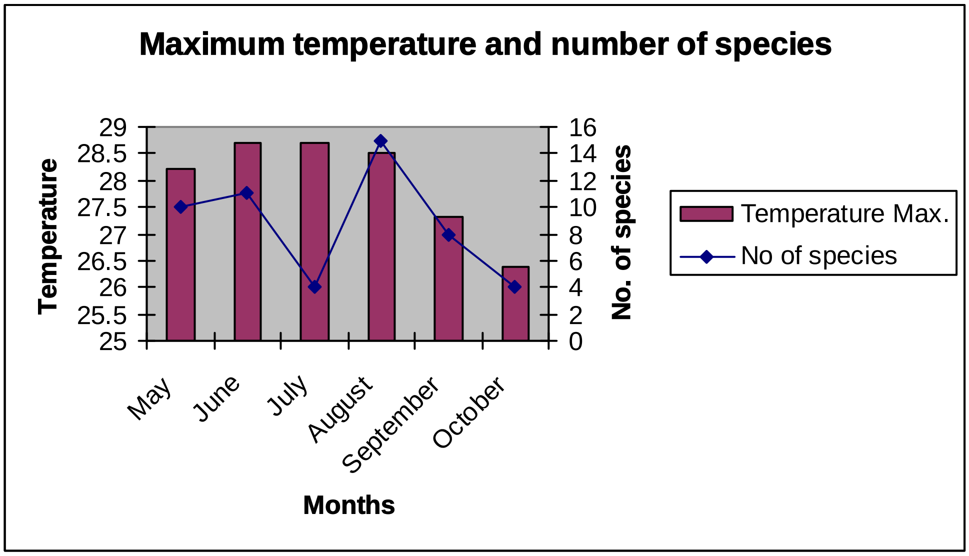


Figure 7b: Relation of average monthly maximum temperature and monthly number of species captured (May 2006 –October 2006).

The least number of hawkmoth species were captured in July in spite of higher temperatures out of 11 species captured in preceding month (June), 9 species were not captured in July and 5 species reappeared and captured in August.

While in October, the fluctuation of maximum and minimum temperature was the highest resulting in the capture of less number of species and less number of individuals.

The relation between monthly average temperature and number of species captured can not be statistically determined due two the fewer samples. But, from these data it can be generalized that there was increase in number of species captured was corresponded to the increase in temperature and vise versa. Besides, high fluctuation of temperatures was not favored resulting decrease in number of species and individuals.

B) Effect of Rainfall:

The relation between the number of hawkmoth species captured per month and the monthly rainfall was shown in Fig. 6c. The highest rainfall was recorded in September and the lowest rainfall was recorded in October.

Pre-monsoon season is March to May. Onset of rains in May resulted in emergences of few hawkmoth species. The monsoon season starting from early June ending by late September. In this season, from June to September, it has high humidity and gets heavy rain. During the whole study time, out of 22 species of hawk moth collected, most species was appeared and captured in that time. The monsoon season was the best time for collecting hawkmoths.

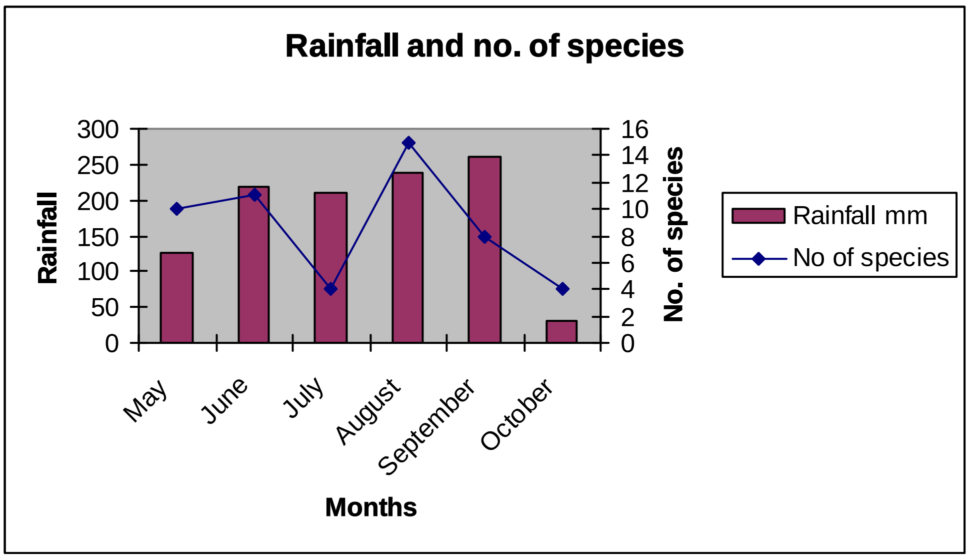


Figure 7 c: Relation of average monthly rainfall and monthly number of species captured (May 2006 –October 2006).

The post-monsoon, starting from late September there were fewer rain as well as decrease in temperature resulting in the decrease in number of hawkmoths species and its individuals. From September onwards there was a gradual decrease in hawkmoth's activity till October. The lowest rainfall was recorded in October and so was the number of species.

The Correlation coefficient (Pearson r) between the monthly Rainfall and number of species collected in respective months was 0.4802, showing poor co-relationship.

4.6 Comparison between the Sites

The number of individuals and number of species collected in two sites were used to calculate richness and dominance. The Shannon Index (H') was used to calculate the richness and Simpson's Index was used to calculate dominance and its values of two sites were compared.

From site 'A' total 70 individuals belonging to 15 species was collected. The Shannon Index for site 'A' is 2.46. While from the site 'B' a total of 47 individuals belonging to 16 species was collected (Table 5). The Shannon Index for site 'B' is 2.42. Besides, the number of individuals in site 'A' was comparatively greater than in site B, it may be due to the increase of lumination of lights operated in site A area other than the mercury lamp. The value of Evenness for site A and site B are 0.91 and 0.87 respectively.

The value of Simpson's Index for site A and site B were 0.087 and 0.105 respectively. The higher the value of D, the lower the diversity, therefore the index is usually expressed as the reciprocal = $1/D_{s.}$ The inverse value (1 / Simpson's Index) was 11.445 and 9.482 respectively. From all above indices, it shows that site A is more diverse than site B.

The species comprising the highest number of individuals in site A and site B was *Dolbina inexacta*. It was most abundant and maximum number collected 13/13 individuals from both sites. The Berger-Parker Dominance index expresses the proportional importance of the most abundant species (the dominant species) and the value for site A is 0.186 for site B is 0.277. Hence the reciprocal values (1/berger parker index) are 5.385 and 3.615 respectively. This shows that the site A had increase in diversity and reduction in dominance of one species.

The number of species shared by site 'A' and site 'B' is 9 species. The two sites show 29% similarity in number of species. Beside this, in site A, 6 species were present that was not present in other site. While, in site B had 7 species representing unique to it. Faunal Similarity (FS) emphasizes shared presence and disregarding shared absence and is useful in many conservation contexts. This measure is equivalent to Jacard's coefficient similarity. This coefficient gives equal weight to the all species and hence tends to place too much significance on the rare species whose capture will depend heavily on chance. The value of faunal similarity for site A and site B is 0.409.

The Complimentarity is a relative indicator of Dissimilarity; its value does not precisely reflect the presence of ‘different’ species at the sites compared. The value of Dissimilarity was 0.590. The overall high Complementarity is the result of its lower species number (i.e. absence of shares species with other site) rather than its uniqueness (the presence of different species).

Table 5: Comparison between the sites in Number of individuals and Number of species of hawkmoths. (Number in parentheses is the total number of individuals for each species).

Species Names	Site A	Site B
Subfamily: Smerinthinae		
Tribe: Smerinthini		
Marumba cristata (7)	6	1
Marumba dyras (2)	1	1
Marumba gaschkewitschii (1)	1	0
Polyptychus sp. (1)	0	1
Tribe: Sphingulini		
Dolbina inexacta (26)	13	13
Tribe: Ambulycini		
Ambulyx ochracea (10)	7	3

Ambulyx maculifera (3)	0	3
Ambulyx sericeipennis (4)	4	0
Ambulyx substrigilis (3)	3	0
Amplypterus panopus (1)	0	1
Subfamily: Sphinginae		
Tribe: Sphingini		
Meganoton analis (6)	1	5
Psilogramma menephron (8)	8	0
Tribe: Acherontiini		
Acherontia lachesis (3)	2	1
Agrius convolvuli (8)	3	5
Subfamily: Macroglossinae		
Tribe: Macroglossini		
Cechenena lineosa (7)	7	0
Cechenena minor (4)	4	0
Cechenena scotti (2)	0	2
Daphnis hypothous (2)	0	2
Hippotion celerio (10)	8	2
Pergesa acteus (1)	0	1
Rhagastis confusa (4)	0	4
Theretra clotho (4)	2	2
# of Individuals (N)	70	47
# of Species (S)	15	16

Table 6: List of Hawkmoths (Lepidoptera: Sphingidae) collected at Dakshinkali forest from May 2006 to October 2006.

	Genera	species	Authorship
1.	*Acherontia*	*lachesis*	(Fabricius, 1798)
2.	*Agrius*	*convolvuli*	(Linnaeus, 1758)
3.	*Ambulyx*	*maculifera*	(Walker, 1866)
4.	*Ambulyx*	*substrigilis*	(Westwood, 1847)
5.	*Ambulyx*	*ochracea*	(Butler,1885)
6.	*Ambulyx*	*sericeipennis*	(Butler, 1875)
7.	*Amplypterus*	*panopus*	(Cramer, 1779)
8.	*Cechenena*	*scotti*	(Rothschild, 1920)
9.	*Cechenena*	*lineosa*	(Walker, 1856)
10.	*Cechenena*	*minor*	(Butler, 1875)
11.	*Daphnis*	*hypothous*	(Cramer, 1780)
12.	*Dolbina*	*inexacta*	(Walker, 1856)
13.	*Hippotion*	*celerio*	(Linnaeus, 1758)
14.	*Marumba*	*cristata*	(Butler, 1875)
15.	*Marumba*	*dyras*	(Walker, 1865)
16.	*Marumba*	*gaschkewitschii*	(Bremer & Grey, 1853)
17.	*Meganoton*	*analis*	(R. Felder, 1874)
18.	*Pergesa*	*acteus*	(Cramer, 1779)
19.	*Polyptychus*	*sp.*	
20.	*Psilogramma*	*menephron*	(Cramer, 1780)

21. Rhagastis	*confusa*	(Rothschild & Jordan, 1903)
22. Theretra	*clotho*	(Drury, 1773)

CHAPTER V
DISSCUSION & CONCLUSION

5.1 Discussion

Altogether, during the whole study period, a total of 117 specimens of hawkmoths representing 22 species within 15 genera were collected. Among 22 species collected, 7 species were ranked as “Rare”, 14 species were “Common” and Only 1 species is “Abundant”. South-wood (1978) commented on the abundances of species that no community consists of species of equal abundance. It is normally the case that the majority of species are rare while a number are moderately common with the remaining few species being very abundant. But the majority hawkmoths in Dakshinkali forest are common.

Four species were represented by only one individuals in collection: Smerinthinae: *Marumba gaschkewitschii*, *Polyptychus sp.*, *Amplypterus panopus*; Macroglossinae: *Pergesa acteus*.

Polyptychus sp. was collected in September month with only one specimen. The species identification could not be done; probably it could be *P. trilineatus* Moore, 1888. Allen (1993) reported two species of genus *Polyptychus* have been recorded from Nepal; they are *P. trilineatus* Moore, 1888 and *P. dentatus* Cramer, 1777. The former species reported as sub species *undates* by Allen and collected from the Central Hills (1500m-2500m), Arun Valley (900m) and Chitwan (300m). He was able to collect only 1/1 specimens from later two areas showing its least prevalence and coinciding the same type of prevalence in Dakshinkali forest. Allen (1993) was not able to collect *P. dentatus*. He emphasizes the presence of this species in Nepal from the record of the specimen from NHM, London. Very few individuals was caught as described by (Owen, 1969), the species in this genus are with slow flying species which fly much less than most of others.

Only one specimen of *Amplypterus panopus* is collected in August during the whole study period. Allen (1993) had only collected this species occasionally in the middle hills from 1200m to 2100m in the months from July to September. The specimen illustrated in his book (*Marvellous Moths of Nepal*) was collected in August, 1991 by Mr. Tony Harmen. He commented this beautiful and striking moth was common Thailand. Pittaway & Kitching (2000-2007) commented for this species, less specimens were collected due to its sluggish nature during the daytime and allows itself to be handled, but at night it flies strongly. It has never been seen feeding at flowers, nor does it seem to come readily to light, though Mell states that it has frequently been caught at light in Java (Bell & Scott, 1937).

Marumba dyras were collected 2 specimens. Few specimens were collected and the result concluded, *Marumba dyras* are rarely attracted by light (Bell & Scott, 1937).

Daphnis hypothous was collected in months June and August with only 2 specimens. Allen (1993) reported this species as non uncommon and moth's ranges from the middle hills up to over 4000m and flies from April to November. *Daphnis hypothous* is a very fast flyer, attracted to both sweet-smelling flowers and light, but little else is known of its behavior (Pittaway & Kitching, 2000-2007). The moths of Borneo by Holloway (1976) found that the habitat preference for the hawk moth species *Daphnis hypothous* is abundant at all altitudes, coming mostly to lights set in open situations.

The majority of hawk moth species in Dakshinkali forest were common. The most common species were *Agrius convolvuli*, *Hippotion celerio*, *Ambulyx ochracea*, *Psilogramma menepheron*, *Marumba cristata*, *Meganoton analis* and *Cechenena lineosa.*

The total of 8 specimens of *Agrius convolvuli* was collected from Dakshinkali forest and ranked as common species. *Agrius convolvuli* shows a preference for warm open areas, i.e. agricultural steppes, but can be found almost anywhere except dense forest. Outside its resident range, it is particularly attracted to cultivated fields and, in suburbs, to roadside verges, flower-beds and hedges overgrown with *Convolvulus*. This species while on the wing between dusk and midnight, neither rain nor winds seem to deter this species.

Light is also very attractive, most individuals arriving about two hours after dark. (Pittaway& Kitching, 2000-2007). They are often attracted by light, and are amongst and commonest sphingids to be caught at light (Bell & Scott, 1937).

Hippotion celerio is the second abundant hawk moth in Dakshinkali forest. Thapa (1998) commented this species is more common at Gusum Bhanjyang but less common in other places. The study carried out by Holloway (1976) in Borneo shows that habitat preference of hawk moth species *Hippotion celerio* is most frequently encountered in agricultural areas and other open habitats in the lowlands, but has also been taken up to 2600m on G. Kinabalu. In many localities in India, where it is very common and widely spread, though less so in forest areas with heavy rainfall than in open areas (Bell & Scott, 1937).

The total of 8 specimens of *Psilogramma menephron* was collected. (Allen 1993) *Psilogramma menephron* frequently comes to light, and may often be caught feeding at tubular flowers after dusk (Bell & Scott, 1937). Thapa (1998) this species is less common in Kathmandu.

Cechenena lineosa with the total of 7 specimens was collected in months May and June. Thapa (1998) this species is quite common at Godavari and less common at other places. This species is widespread and common in Central and Eastern Hills (900m-2800m) and specimens once recovered at 3800m North of Kathmandu by Allen (1993). This species is swift on the wing visits flowers after dusk, as well as being attracted by light (Bell & Scott, 1937).

Only 3 specimens of *Acherontia lachesis* was collected. Thapa (1998) categorized this species is a less common species and caught in April to September. *Acherontia lachesis* comes to light freely and common, specially in hills and forest areas (Bell & Scott, 1937).

The total of 3 specimens of *Ambulyx maculifera* was collected in month July in Dakshinkali forest. Allen (1993) reported, in Nepal, *Ambulyx maculifera* is only recorded in the Eastern Hills and Arun Valley, 900m to 1200m, where it is common in July and August.

Rhagastis confusa was captured in May, June and August with 4 specimens. Allen (1993) reported this species is not common one and in Nepal only recorded in the Central Hills around the Kathmandu Valley, 1550m to 2500m, May to September.

Theretra clotho was collected in August and October with total 4 specimens. Thapa (1998) this species is common at Godawari and Gusum Bhanjyang and uncommon at other places. According to Allen (1993) this species is widespread and common in Nepal. *Theretra clotho* are frequents open forest, forest edge, orchards, plantations, wooded scrub, suburban gardens and city parks. This species likes warm humid areas, being confined to regions with medium to heavy rainfall (Pittaway & Kitching, 2000-2007). They avidly visit flowers at and after dusk (Bell and Scott, 1937) and may sometimes be attracted to light.

Dolbina inexacta was the most collected hawk moth and ranked as abundant species as indicated by total catch of 26 individuals i.e. 22.22% of whole specimens collected. This species was collected in the highest number (13/13) from each sites. Besides, this species was most prevalent hawk moth species occurred continuous from June to October in Dakshinkali forest. Allen (1993) found this species is relatively common and widespread in Central hills and valley, including Pokhara, 900m to 2500m and on wings from May to October. In East Himalayas and South India it is confined to wooden hills and is fairly common (Bell & Scott, 1937)

The biggest collection of hawkmoths was made in August with 29 individuals were captured, belonging to15 species. The lowest record was in October with 10 individuals belonging to 4 species. Allen (1993) had collected the hawkmoths extensively in the Eastern, Central, and Western Regions of Nepal and reported the best collecting season for the hawkmoths is April to September results many hundreds of moths and other insects resting on the white sheet or fluttering around the lamp. The collection of moths by Shull & Nadkerny (1964) in Surat Dangs, Gujarat State found that the monsoon season is the best time to collect moths. Their result reveals the most hawk moth species were collected in months August and September. However, the study of seasonality and abundance of sphingids in a garden on the lower slopes of the Uluguru Mountains in

Morogoro Township in Tanzania by Kingston & Nummelin (1998) shows that the hawkmoths are most abundantly on the wing from March to June peaking in May (late rainy season).

Pre-monsoon season is March to May. Onset of rains in May resulted in emergences of few hawkmoth species. Monsoon season starting from early June and ending by late September. In this season, from June to September, it has high humidity and gets heavy rain. The monsoon season was the best time for collecting hawkmoths. The post-monsoon, starting from late September there were fewer rain as well as decrease in temperature resulting in the decrease in number of hawkmoths species and its individuals. From September onwards there was a gradual decrease in moths' activity till October. The result is similar to the study of abundance and distribution of moths of the families Saturniidae and Sphingidae in Sanjay Gandhi National Park, Mumbai by Shubhalaxmi & Chaturvedi (1999). It was observed that the moth activity was greater during the monsoon and post monsoon period, when the larval food plants were available in abundance. Moth activity begin by early monsoon season and reached a peak level in mid monsoon, slowly decreasing, by the end if the post-monsoon period. Similarly, seasonal occurrence of sphingids in tropical areas generally related directly to the rainfall (Owen, 1969).

In peak flowering period in Dakshinklali forest is in the summer season (June-August) so at that time there is more prevalence of the hawkmoths. Haber & Frankie (1989) in their study of A Tropical Hawkmoth Community: Costa Rican Dry Forest Sphingidae, found that the abundance of both hawkmoths and flowers pollinated by hawkmoth peaked in the first half of the wet season (May-July). Number of hawkmoths decreased through the dry season (December to April) with lowest number during April. Flowers mostly pollinated by hawkmoths also decreased through the dry season, but several species began flowering before the onset of the wet season and before the sudden increase in hawk moth number that followed shortly after the first rains.

Of the commonest and regularly recorded species that occur at Dakshinkali forest are *Dolbina inexacta*, *Ambulyx ochracea*, *Agrius convolvuli* which numbers increase on set of the rain. The study of species diversity in tropical Sphingidae and a systematic list of species collected in Sierra Leone by Owen (1972) showed that the most common species of Sphingidae occurred in all months of the year, but some of the most abundant species reached peak numbers with the onset of the rainy season in March to May.

The Correlation coefficient (Pearson r) between the monthly Rainfall and number of species collected in respective months was 0.4802, showing poor co-relationship. In the study of Species richness, abundance and seasonality of Sphingidae (Lepidoptera) in a fragment of Atlantic Rainforest of Pernambuco, Brazil by Júnior & Schlindwein (2005) found that the sphingofauna showed no seasonal patterns and species richness and hawkmoth abundance were not correlated with mean monthly precipitation and temperature.

The fluctuation among maximum and minimum temperature was lower for the month August resulting the biggest collection with 29 individuals belonging to15 species. For the month October the fluctuation among maximum and minimum temperature was higher resulting the lowest record with 10 individuals belonging to 4 species. The result is similar to the study of abundance and distribution of moths of the families Saturniidae and Sphingidae in Sanjay Gandhi National Park, Mumbai by Shubhalaxmi & Chaturvedi (1999) which showed that whenever fluctuation among maximum and minimum temperature was low, leads to a peak level in moth activity.

5.2 Conclusion

The Dakshinkali forest has a number of diverse hawkmoths represented. The overall richness and diversity of this area shows the total of 22 species of the hawkmoths species have been collected, and this accounts and represent for about 17% of the total Nepalese fauna of family sphingidae. Furthermore, the hawkmoths collected from Dakshinkali forest are almost identical species that from Godavari (1600m), southeast of Kathmandu.

Smerinthinae was the most abundant and rich subfamily in number of species and individuals. Of the commonest and regularly recorded species that occur at Dakshinkali forest are *Dolbina inexacta*, *Ambulyx ochracea*, *Agrius convolvuli*. Few species are rare.

Amplypterus panopus is the beautiful and striking moth collected from Dakshinkali forest.

The Shannon diversity index value is 2.73 where as the Shannon index for real communities' falls between 1.5 and 3.5, so the Dakshinkali forest is a real community.

Hawkmoth activity, presence on the basis of the collection shows that the most hawkmoths were collected in months August and September. The collection of more species of hawkmoth is favored by the different factors like rise in temperature, low fluctuation of maximum and minimum temperatures and also the flowering period of the plants.

A clear outline of hawkmoth fauna couldn't be determined due to the study and collection of hawkmoth was carried for only six months periods. No significant effort to record diurnal hawkmoth species has taken place.

CHAPTER VI
RECOMMENDATION

6.1 Conservation Implication and Recommendation

1. As a conservation effort, "Dakshinkali Area Development Project" was created with in Dakshinkali forest area in 1988 by HMG of Nepal. This project has been working for the development of the area as well as conservation and protection of the forest. But it is unaware of the all type of diversity inside the forest areas and any works regarding this has not been initiated and promoted. Shrestha (2000) has only the preliminary study of flora of this region.
2. Different levels of disturbance have different effects on hawkmoth diversity. If our goal is to preserve biodiversity in a given area, we need to be able to understand how diversity is impacted by different management strategies. Habitat fragmentation is the subdivision of larger habitat segments into smaller, scattered, unsustainable segments as a result of urban development, transportation infrastructure and other forms of land-use change. The visible examples of habitat fragmentation in the Dakshinkali forest is the constructions of infrastructures like picnic spots, roads and toilets. So, the vegetation is relatively decreasing and large proportion has been severely disturbed by human activities. So the plants being host for several moths are decreasing. Current management practices should be reduced in order to give the large number of species that utilize this habitat type.
3. However, the hawkmoths are of ecological importance in their role of pollinators for many woody plants, and the conservation of hawkmoth diversity in at Dakshinkali forest may continue to be an important objective.
4. Lack of well-curated moth collections in the country and poor accessibility to existing collection, lack of well organized training in systematic entomology and lack of comprehensive literature collection. The NHM, Swoyambhu, Kathmandu and the Universities of Nepal should undertake the proper deposition of voucher specimens of Nepalese moth fauna. Clearly, the need for a database on moth diversity within Nepal is urgent to fill this information gap.

5. Research institutions and conservation organizations should offer research opportunities for young taxonomists.
6. The collection of baseline information on hawkmoths including spatial diversity and distribution should be established as a national research priority. Much taxonomic work remains to be done, particularly in Nepal, where we may expect to discover numerous endemic species of moths in family Sphingidae and others family respectively.
7. The survey work carried out so far still covers only a limited area of the forest. This collection doesn't provide a complete representation of the diversity and flight periods of hawkmoths of Dakshinkali forests. Many other habitats remain to be recorded. Clearly, additional collecting is required before the hawk moth fauna of this area is known completely. It is anticipated that further recording will result in more species being found at Dakshinkali forest. However, it is, of course, quite possible that other species are present at different times of year may also be included in.
8. As expected, more species of hawkmoths were collected when multiple sites and multiple years were examined. Moths should be collected systematically enough over a large number of years to give results approaching completeness (Hampson, 1892).

PHOTO PLATES

Plate 1: Mata temple - site A (1465m) and surrounding vegetation

Plate 2a: Bus depot - site B (1415m)

Plate 2b: Bus depot-site B (1415m) in flowering season (June-August)

Plate 3: Operating Mercury vapour light

Plate 4: Killing bottles

Plate 5: Ethyl acetate-Killing agent

Plate 6: Wing spreading box

Plate 7: Some hawkmoths stored in Entomological box

Plate 8: *Marumba cristata*

Plate 9: *Marumba dyras*

Plate 10: *Marumba gaschkewtichhi*

Plate 11: *Polyptychus* sp.


Plate 12: *Dolbina inexacta*


Plate 13 a: *Ambulyx ochracea* (wing folded)


Plate 13 b: *Ambulyx ochracea* (wing spread)


Plate 14: *Ambulyx maculifera*


Plate 15: *Ambulyx sericeipennis*


Plate 16: *Ambulyx substrigilis*


Plate 17: *Amplypters panopus*


Plate 18: *Meganoton analis*


Plate 19 a: *Psilogramma menephron* (wing folded)

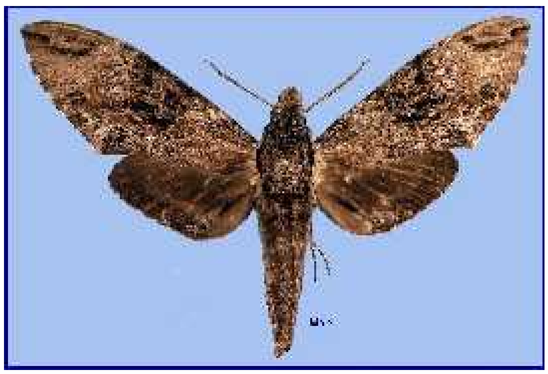


Plate 19 b: *Psilogramma menephron* (wing spread)

Plate 20 a: *Acherontia lachesis* (not well wing spread)

Plate 20 b: *Acherontia lachesis* (well wing spread)

Plate 21 a: *Agrius convolvuli* (wing folded)

Plate 21 b: *Agrius convolvuli*

Plate 22: *Cechenena lineosa*

Plate 23: *Cechenena minor*

Plate 24: *Cechenena scotti*

Plate 25: *Daphnis hypothous*

Plate 26 a: *Hippotion celerio* (wing folded)

Plate 26 b: *Hippotion celerio*

Plate 27 a: *Pergesa acteus* (wing folded)

Plate 27 b: *Pergesa acteus*

Plate 28: *Rhagastis confuse*

Plate 29: *Theretra clotho*

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APPENDIX 1

Classification of hawkmoths collected

Family: Sphingidae Latreille, 1802

1) Subfamily: Smerinthinae Grote & Robinson, 1865

A) Tribe: Smerinthini Grote & Robinson, 1865

1) Genus *Marumba* Moore, 1882

Marumba dyras (Walker, 1865)
Marumba cristata (Butler, 1875)
Marumba gaschkewitschii (Bremer & Grey, 1853)

2) Genus *Polyptychus* Hübner, 1819

Polyptychus sp.

B) Tribe: Sphingulini Rothschild & Jordan, 1903

3) Genus *Dolbina* Staudinger, 1877

Dolbina inexacta (Walker, 1856)

C) Tribe: Ambulycini Butler, 1876

4) Genus *Ambulyx* Westwood, 1847

Ambulyx sericeipennis (Butler, 1875)
Ambulyx ochracea (Butler, 1885)

Ambulyx substrigilis (Westwood, 1847)
Ambulyx maculifera (Walker, 1866)

5) Genus *Amplypterus* Hübner, 1819
Amplypterus panopus (Cramer, 1779)

2) Subfamily: Sphinginae Latreille, 1802

A) Tribe: Sphingini Latreille, [1802]

6) Genus *Meganoton* Boisduval, 1875
Meganoton analis (R. Felder, 1874)

7) Genus *Psilogramma* Rothschild & Jordan, 1903
Psilogramma menephron (Cramer, 1780)

B) Tribe: Acherontiini Boisduval, [1875]

8) Genus *Agrius* Hübner, 1819
Agrius convolvuli (Linnaeus, 1758)

9) Genus *Acherontia* Laspeyres, 1809
Acherontia lachesis (Fabricius, 1798)

3) Subfamily: Macroglossinae Harris, 1839

A) Tribe: Macroglossini Harris, 1839

10) Genus *Daphnis* Hübner, 1819
Daphnis hypothous (Cramer, 1780)

11) Genus *Hippotion* Hübner, 1819
Hippotion celerio (Linnaeus, 1758)

12) Genus *Pergesa* Walker, 1856
Pergesa acteus (Cramer, 1779)

13) Genus *Theretra* Hübner, 1819
Theretra clotho (Drury, 1773)

14) Genus *Rhagastis* Rothschild & Jordan, 1903
Rhagastis confusa (Rothschild & Jordan, 1903)

15) Genus *Cechenena* Rothschild & Jordan, 1903

Cechenena lineosa (Walker, 1856)
Cechenena minor (Butler, 1875)
Cechenena scotti (Rothschild, 1920)

APPENDIX 2

Total catches and monthly presence/absence occurrence of Hawkmoth species between May, 06 to October, 06 in Dakchhinkali forest. Roman numbers indicate months of the year and Number in parentheses is the number of individuals for each species. (+ indicates the presence and – indicates the absence of that species in that month).

Species name	**v**	**vi**	**vii**	**viiii**	**ix**	**x**
Subfamily: Smerinthinae						
Tribe: Smerinthini						
Marumba cristata (7)	+	+	-	+	-	-
Marumba dyras (2)	-	-	-	+	+	-
Marumba gaschkewitschii (1)	-	+	-	-	-	-

Polyptychus sp. (1)	-	-	-	-	+	-

Tribe: Sphingulini

Dolbina inexacta (26)	-	+	+	+	+	+

Tribe: Ambulycini

Ambulyx ochracea (10)	+	+	+	+	+	-
Ambulyx maculifera (3)	-	-	+	-	-	-
Ambulyx sericeipennis (4)	+	-	-	+	-	-
Ambulyx substrigilis (3)	-	-	+	-	-	-
Amplypterus panopus (1)	-	-	-	+	-	-

Subfamily: Sphinginae

Tribe: Sphingini

Meganoton analis (6)	+	+	-	-	+	-
Psilogramma menephron (8)	+	-	-	+	+	-

Tribe: Acherontiini

Acherontia lachesis (3)	+	-	-	+	-	-
Agrius convolvuli (8)	+	+	-	+	+	+

Subfamily: Macroglossinae

Tribe: Macroglossini

Cechenena lineosa (7)	+	+	-	-	-	-
Cechenena minor (4)	+	+	-	-	-	-
Cechenena scotti (2)	-	+	-	+	-	-
Daphnis hypothous (2)	-	+	-	+	-	-
Hippotion celerio (10)	-	-	-	+	+	+
Pergesa acteus (1)	-	-	-	+	-	-
Rhagastis confusa (4)	+	+	-	+	-	-
Theretra clotho (4)	-	-	-	+	-	+

APPENDIX 3

List of number of specimens per species and total no. of species and total no. of specimens (given in parentheses) in monthly wise from May, 06 to Oct, 06.

Month: May

1. *Acherontia lachesis* (**2**)
2. *Agrius convolvuli* (**3**)
3. *Ambulyx ochracea* (**1**)
4. *Ambulyx sericeipennis* (**2**)
5. *Cechenena lineosa* (**4**)
6. *Cechenena minor* (**2**)
7. *Marumba cristata* (**2**)
8. *Meganoton analis* (**2**)
9. *Psilogramma menephron* (**2**)
10. *Rhagastis confusa* (**1**)

Total: **10** species, **21** specimens

Month: June

1. *Agrius convolvuli* (**1**)
2. *Ambulyx ochracea* (**2**)
3. *Cechenena lineosa* (**3**)
4. *Cechenena minor* (**2**)
5. *Cechenena scotti* (**1**)
6. *Daphnis hypothous* (**1**)
7. *Dolbina inexacta* (**5**)
8. *Marumba cristata* (**3**)
9. *Marumba gaschkewitschii* (**1**)
10. *Meganoton analis* (**1**)
11. *Rhagastis confusa* (**1**)

Total: **11** species, **21** specimens

Month: July

1. *Ambulyx maculifera* (**3**)
2. *Ambulyx ochracea* (**3**)
3. *Ambulyx substrigilis* (**3**)
4. *Dolbina inexacta* (**5**)

Total: **4** species, **14** specimens

Month: August

1. *Acherontia lachesis* (**1**)
2. *Agrius convolvuli* (**1**)
3. *Ambulyx ochracea* (**4**)
4. *Ambulyx sericeipennis* (**2**)

5. *Amplypterus panopus* (**1**)
6. *Cechenena scotti* (**1**)
7. *Daphnis hypothous* (**1**)
8. *Dolbina inexacta* (**4**)
9. *Hippotion celerio* (**3**)
10. *Marumba cristata* (**2**)
11. *Marumba dyras* (**1**)
12. *Pergesa acteus* (**1**)
13. *Psilogramma menephron* (**3**)
14. *Rhagastis confusa* (**2**)
15. *Theretra clotho* (**2**)

Total: **15** species, **29** specimens

Month: September

1. *Agrius convolvuli* (**2**)
2. *Ambulyx ochracea* (**2**)
3. *Dolbina inexacta* (**9**)
4. *Hippotion celerio* (**3**)
5. *Marumba dyras* (**1**)
6. *Meganoton analis* (**3**)
7. *Polyptychus sp.* (**1**)
8. *Psilogramma menephron* (**3**)

Total: **8** species, **22** specimens

Month: October

1. *Agrius convolvuli* (**1**)
2. *Dolbina inexacta* (**3**)
3. *Hippotion celerio* (**4**)
4. *Theretra clotho* (**2**)

Total: **4** species, **10** specimens

APPENDIX 4

Average Temperature (Minimum and Maximum) and average Rainfall data year 2006 (May to October), Khokana

Month	Tem. min(^oC)	Tem. max(^oC)	Rainfall (mm)
May	16.1	28.2	126.8
Jun	18.6	28.7	217.4
Jul	20.6	28.7	211.4
Aug	19.7	28.5	238.8
Sep	17.8	27.3	259.8
Oct	11.5	26.4	29.8