DST No. SR/SO/AS-50/2002

Ecological Study of Tiger Beetles (Cicindelidae) as Indicator for Biodiversity Monitoring in Shivalik Landscape

DST-SERC Funded Research Project

Project Completion Report

Principal Investigator
Dr. V.P. Uniyal

Co-Investigator
Dr. K. Sivakumar

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

October 2007

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Ecological Study of Tiger Beetles (Cicindelidae) as Indicator for Biodiversity Monitoring in the Shivalik Landscape

Principal Investigator

Dr. V.P.UNIYAL
Scientist "D"
Deptt. of Landscape Level Planning
and Management

Co-Investigator

Dr. K.SIVAKUMAR
Scientist "C"
Deptt. of Endangered
Species Management

Researcher (s)

Ms. R.Padmawathe	(24 Dec 04 – 17 Jun 05)
Ms. Swati Kittur	(17 Nov 04 – 16 Nov 06)
Mr. Vinay Bhargav	(13 Oct 05 – 01 Apr 07)
Mr. Manish Bhardwaj	(15 Feb 07 – 31 Aug 07)
Ms. Rashmi Dobhal	(01 May 07 –31 Aug 07)

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PROJECT COMPLETION REPORT

1. Project Title: Ecological study of Tiger beetles (Cicindelidae) as indicator for Biodiversity Monitoring in Shivalik Landscape
(DST No: SR/SO/AS-50/2002)

2. Project Investigators
Principal Investigator
Dr. V.P. Uniyal — Date of Birth: 30th Dec. 1962
Wildlife Institute of India
Post Box # 18, Chandrabani
Dehradun – 248 001.

Co-Investigator
Dr. K. Sivakumar — Date of Birth: 05th Jan.1972
Wildlife Institute of India
Post Box # 18, Chandrabani
Dehradun – 248 001.

3. Implementing Institution: Wildlife Institute of India, Chandrabani, P O. Box # 18, Dehradun-248001

4. Date of Commencement: Sept. 2004

5. Planned Date of Completion: 31st Aug. 2007

6. Actual Date of Completion: 31st Aug. 2007

7. Approved Objectives of the Proposal:

1. **To assess species richness, distribution and abundance of tiger beetles, birds and butterflies in different vegetation types.**

2. **To establish correlation of tiger beetles with the diversity of birds and butterflies along the altitudinal gradient.**

8. Deviation made from original objectives if any, while implementing the project reasons thereof: **-None-**

9 Details of Experimental Work

9.1 Introduction

The sheer degree of diversity around us is very evident. Scientists speculate that we have on the globe an estimated 13.5 million extant species approximately with only 1.75 million of these currently described (Gaston and Spicer, 2004). More than half of these species are said to be restricted to the tropics. The tropics also include mainly developing countries where natural ecosystems are in serious risk from growing populations and rapid 'development'. This has led to destruction and fragmentation of natural habitats.

In a densely populated country like India the maintenance of biological diversity and its conservation in existing habitats is one of most pressing tasks that we face today. Identifying and setting aside areas of high conservation interest can require a lot of time and money (Soule, 1985). Detailed inventories of taxa that are found in our country before they go extinct are near impossible owing to the fast rate of deforestation and degradation. As a result of this, biologists are interested in selecting an efficient, limited set of biological indicators for measuring and monitoring biological diversity (Kremen, 1992; Pearson and Cassola; 1992; Faith and Walker, 1996 and Pearson and Vogler, 2001). Now, how does one identify an indicator taxon that indicates habitat quality in landscape level? Indicator species should occur in a broad range of habitat type, highly sensitive to changes in the environment, conspicuous in field and with clear taxonomic classification. Two invertebrate taxa *viz.*, butterflies tiger beetles and one vertebrate taxon, birds are used worldwide as bioindicators apart from plants.

Pearson and Cassola (1992) conducted a world wide study on species richness pattern of tiger beetles and suggested its use as an indicator taxon for the planning of biodiversity and conservation studies. The other taxa, birds and butterflies, also fit into criteria of good indicators of habitat quality (Noss, 1990) and determining which taxa is a better indicator is a major outcome of this project. Butterflies indicate change in environmental variation and also are affected by plant diversity since they are directly dependent on them (Elrich et. al. 1972). Some studies say that butterflies are affected by precipitation and other bioclimatic variables and they do not indicate minor changes in habitat quality (Hamer et. al. 2003). Birds too serve as indicators of environmental change especially in the landscape level such as habitat fragmentation (Wilcove, 1985). For the sustained conservation of biodiversity, now restricted to these degraded and patchy habitats it has become mandatory to protect and conserve these areas. But unfortunately, not all can be conserved and it is important to survey potential areas for conservation and prioritise them based on various criteria like the biodiversity (floral and faunal species), presence of rare or threatened species etc. Enumeration of biodiversity can be a daunting task due to the inherent variability and complexity of natural systems. Most enumeration efforts often need detailed field surveys requiring manpower, time and funds, which can both be limiting factors (Soule, 1985).

9.2 What is an indicator species?

After a much careful study, ecologists have determined that the presence, condition, and numbers of the types of fish, algae, insects, and plants can provide accurate information about the health of a specific ecosystem like river, estuary, lake, wetland, stream, or a forest. These types of plants or animals are called the biological indicators (McCarty and Munkittrick, 1996). An indicator is numerical value derived from actual measurements, has known statistical properties, and conveys useful information for environment decision making.

An ecological indicator is a measure, an index of measures, or a model that characterises an ecosystem or one of its critical components. Use of taxonomic groups has two aspects. On one hand, a certain insect taxon may be used to identify the state or change in a landscape. It also detects how certain insect taxa are affected by a possible or an inevitable modification to the landscape. An indicator may reflect a change in biological, chemical, or ecological condition. The primary uses of an indicator are to characterise status and to track or predict significant change. With a foundation of diagnostic research, an ecological indicator may be also used to identify major ecological stress like habitat degradation, habitat loss, or habitat fragmentation.

The class Insecta also has members, even within one order (e.g., Coleoptera) that operate at different trophic levels, therefore providing varied, sensitive indication of changes. While long term monitoring gives variability (Samways, 1990 and Wolda, 1992) since there is as such no ‘normal year’ for insect abundance. A short time study provides a fairly a true picture without having resort to long-term sampling (Owen and Owen, 1990). This excludes the species that occasionally outbreak to enormous population levels, or show major range changes.

The objective choice of insect indicator groups depends on various factors. For e.g., butterflies have been targeted for temperate regions as well as for the tropics (Gilbert, 1980; Brown, 1982; Pollard, 1982; Murphy and Wilcox, 1986 and Erhardt and Thomas, 1991), because they are generally readily identifiable, there is a relatively good taxonomic knowledge of the group and they are sensitive to environmental changes in microsite and biotope characteristics. They are often highly plant specific for their growth development (Ehrlich and Raven, 1964) and sometimes have close plant-pollinator relationships.

Pearson and Cassola (1992) have proposed the use of tiger beetles (Cicindelidae) as a good indicator group for identifying area for biodiversity conservation. Tiger beetles are well known, their biology is well understood, they occur over a broad range of biotope types and geographical areas and they also exist in remnant patches of appropriate biotopes. On a much small geographical scale, cicindelids are particularly useful as ‘fast indicators’ of biotope quality relative to disturbance (Clark and Samways, 1992). Pearson and Cassola (1992) have shown that at a site in Peru it took only 50 hrs of observation to find 93% of the tiger beetle fauna, while to find out 90% of the butterflies species required nearly 1000 hrs of fieldwork.

Wood and Samways (1991) found butterflies (Papilionoidea) to be good indicators of biotope type and landscape pattern at a mesoscale (e.g., 50 m X 50 m), but cicindelids were much more sensitive indicators at a microscale level (e.g., 1m X 1m) (Clark and Samways, 1992). Different developmental stages give different indications, often the larva being more sensitive at the smaller scale because of its relative immobility compared with the adult. Orthoptera can also be excellent bioindicators, as they can be recognised in the canopy at night without having resort to any trapping or landscape disturbance (Samways, 1989). Biological indicators (Spellerberg, 2005) can range from single organisms to biological communities. They are organisms whose condition, behaviour or very existence is an indication of the condition of the environment around it. Biological communities may change in composition and abundance in response to physical disturbance or changes in the environment. These indicators, although must be treated with caution because of the inherent variability in populations.

9.3 Tiger Beetles

Tiger beetles (family Cicindelidae) are members of the suborder Adephaga within the order Coleoptera. Species numbers of tiger beetles are relatively well known for 129 countries. Eight countries alone account for more than half the world total of 2600 known species. India has about 220 species, with 114 endemic species. Twenty five species were recorded from protected areas of Shivalik Landscape of two Indian states *viz.* Himachal Pradesh and Uttarakhand (Uniyal and Bhargav, 2007). Most adult tiger beetles are characterized by large, prominent compound eyes and eleven-segmented, filiform antennae. Tiger beetles so named because not only they are predatory insects that feed on small insects and other arthropods, but their colouration patterns merges with the background for a perfect camouflage. The adults are active, mobile predators that search and hunt for prey (Fig.1). The larvae, however, are peculiar among beetles and, unlike the adults, are waiting (ambush) predators. Tiger beetles exhibit two different general life cycles. There are spring/fall species and summer species. Depending on the species, the spring/fall life cycle generally takes 2 to 4 years to complete while the summer life cycle generally takes 1 or 2 years to complete (Pearson and Vogler, 2001).

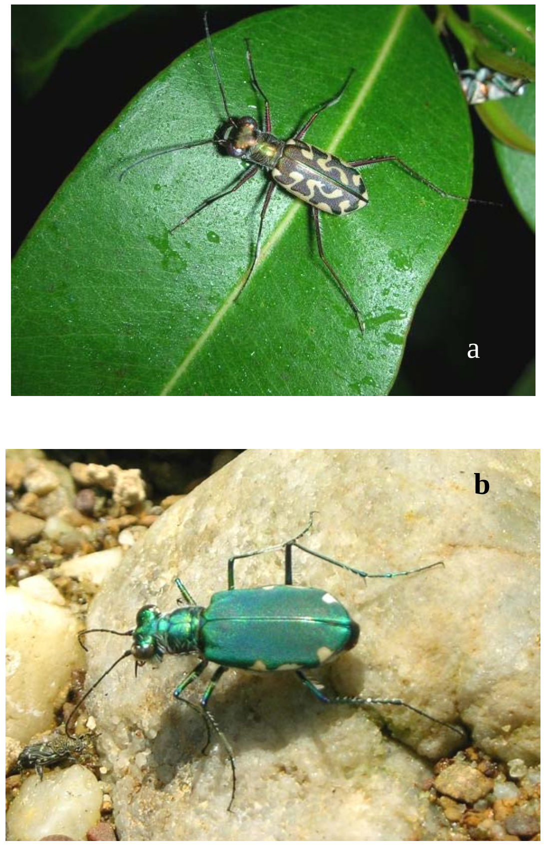


Fig. 1 Adult Tiger Beetles a. *Calomera plumigera* b. *Calomera chloris*

Tiger beetle species differ greatly in habitat preference. Some prefer soils with high clay content while others prefer sandy soils (Fig. 2a and b). Some like moist environments while others like it dry, found along roads and open paths in moist deciduous woodlands where sunlight can penetrate. Temperature is very important to tiger beetles; they are most active (unlike Carabids) on warm, sunny days. Adults prefer to run, doing so in short zig-zag bursts. They usually fly only when disturbed by a larger animal or other moving object. To become airborne the beetle squats, leaps into the air, and then begins to fly. Most species fly in a relatively low (1 to 3 feet), level, straight path and land 5 to 20 feet away from the source of the disturbance.

The adults of several species have been noted to produce defensive odors. These odors are produced by the anal, or pygidial gland. Adult tiger beetles also exude an unpleasantly scented, brownish fluid from the hypopharynx when captured. The function of this fluid is probably to predigest the prey when feeding. Predators like a dragonfly (*Aeschna interrupta*), some species of robber flies (Diptera: Asilidae), species of amphibians and reptiles also feed on tiger beetles. Few species of tiger beetles are attracted to lights to feed on other insects attracted to the lights. Within a given area of macro habitat many species of tiger beetles often coexist. However they are spared from direct competition in two ways. First, many of them actually occupy different microhabitats (e.g., soils with different moisture levels, textures, salinity, and vegetation/plant cover). Secondly, many species are separated seasonally; that is the various beetle species have different times of emergence and peak populations.

Fig. 2 a. Riverine Habitat of Tiger Beetles **b. Mating Tiger Beetles**

The techniques for collecting adult tiger beetles vary by genus. Some are diurnal, while a few others are primarily nocturnal. The best time for collection is on warm (greater then 30ºC), sunny days. The preferred habitats are variable and include riverine sandy areas, riverside forests, paths and trails, roadsides and agricultural fields.

9.4 Review of literature

9.4.1 Indicator studies

The Indian subcontinent has one of the most diverse tiger beetles fauna of the world. Pajni (1973) and Pajni et. al. (1984) studied the Cicindelid fauna of Punjab state. Pearson and Ghorpade (1987 and 1989) studied the tiger beetles of Siliguri-Darjeeling area and geographical distribution and ecological history of tiger beetles of the Indian subcontinent. Singh (1991) studied some Cicindelidae fauna of India with reference to external genitalia. While Uniyal and Mathur (2000) studied the altitudinal distribution of tiger beetles in the Great Himalayan National Park conservation area of western Himalaya, India. Sinu et. al. (2006) studied the feeding fauna and foraging habits of tiger beetles found in agro-ecosystems in western Ghats of India. The potential use of indicator species for conservation research can be divided in two basic categories (Kremen et. al. 1993 and Pearson, 1994). Firstly, monitoring studies, so as to evaluate changes in habitats or ecosystems over time, such as successional stage or habitat degradation. Therefore, the choice of an indicator will be served best by a taxon that is sensitive to environmental change. Secondly, inventory studies, so as to record distribution patterns of taxa or ecological units over geographical space, often with the purpose of identifying the areas for establishing nature reserves. The choice of indicators thus favours taxa whose distribution or abundance correlate, for example, with areas of high endemism or high species diversity (Erwin, 1991). However, the vast majority of studies that rely on bioindicators have used taxa with little or no initial assessment of their adequacy as indicators. Many of these studies have focused on taxa that either are of high public concern (such as endangered species) or have been coincidentally the object of previous studies to use as indicators (Shivashankar et. al. 1994).

Indicator or flag species are associated with a particular plantscape, biotope, or landscape, depending on the scale of measurement. However, a single species, which is highly sensitive to environmental perturbations, may simply disappear not because of a disturbance, but because of an intrinsic feature of population dynamics. Indicator species need not always be amongst the rarest of species. Abundant species have value that they can be easily located. However, abundant species can also be generally more eurytopic than the rarer species, because stenotopic species are bound to be rare as their particular habitat is automatically defined. The highest level of endemism tends to occur in the most severe landscapes, which are predictably unfavourable (Greenslade, 1983). Endemism is lowest in temporary and disturbed biotopes such as agricultural land, and the fauna shows high population variability and high dispersal ability. Diversity will be greatest in relatively stable, favourable biotopes.

Thus, for the determination of impact at a single localised site, a stenotopic, endemic species (even just one of its life stages) may be appropriate. Nevertheless, for a large-scale survey, an abundant but biotope restricted species may be the best tool. The characteristics which will be monitored will include life history style, local or widespread abundance and distribution, availability and seasonality, sensitivity to disturbance for a complete biogeographical perspective. Noss (1990) suggests various indicators for monitoring compositional, structural and functional biodiversity at regional landscape, community-ecosystem, population-species and genetic scales. He also recommends steps for implementing a biodiversity monitoring project. Pearson (1994) suggested seven criteria that ideal indicator taxa should fulfill. The taxa should have an economic potential, occur over broad geographic range, its response patterns should be reflected in other taxa, its biology and natural history should be well known, should be easily observed and manipulated, well known and stable taxonomically and should have a specialised habitat requirement. These criteria would apply in different orders of importance for monitoring and inventories. Based on these criteria Rodriguez et. al. (1998) identified tiger Beetles as adequate indicators of habitat quality.

Weaver (1995) studied leaf litter invertebrates in forest stands located in south Missouri to investigate the influence of sample size and scale on indicator taxa. Eight arthropod taxa were considered at three scales. The study showed that scale of observation could affect relative richness and correlation data. Landres et. al. (1988) suggested making the use of vertebrate indicators more rigorous and put forth recommendations for the same. He concluded that the use of indicators to predict the habitat suitability of other species may be inappropriate without confirmatory research. He evaluated criteria such as sensitivity, size, population turnover, species turnover, area requirement, residency status etc. which are generally used to select indicator taxa. Richness-based indicators derived from small fixed-count sub samples may substantially underestimate true biological impairment during bio assessment (Cao and Hawkins, 2005). Simila et. al. (2006), support the view that different indicators should be used for different forest types and taxonomic groups. And these indicators should facilitate relatively rapid methods to assess biodiversity patterns at the forest stand level.

The importance of indicator species or surrogates and recommendations for using them effectively were discussed by Favreau et. al. (2006). While Kremen et. al. (1992) discusses the role that terrestrial arthropods can play in conservation inventory and monitoring programmes. Kati et. al. (2004) discusses and compares five different scenarios to conserve biodiversity of a single target group and overall biodiversity of the area. Selection of complimentary areas in a network was found to be most effective in conserving biodiversity of both the selected taxonomic group as well as the area. Spellerbreg (2005) mentions that species with a high specificity and high fidelity are considered to have high indicator value for example occurrence of stinging nettles (*Urtica dioca*), which is an indication of possible high levels of nitrogen in soil and appearance of rosebay willow herb (*Chamaenerion angustifolium*), which indicates that soil may have been disturbed.

The presence or absence of an indicator alone does not reflect environment conditions. The species should be tested under different spatial and temporal conditions. Dufrene and Legendre (1997) developed a method to quantify the value of a biological indicator, this they named as the ‘Indicator Value’. Amongst some studies (Botes et. al. 2006) around the world, in India, Shahabuddin and Kumar (2006) have used indicator values to evaluate the response of bird communities to disturbance in Sariska Tiger Reserve. Carlisle et. al. (2005) created Indicator values using transformed weighed averages for each stress gradient of urbanization in New England and Alabama to demonstrate the application of these Indicator values to detect alterations in benthic macro invertebrate assemblages along gradients. The use of higher-level taxa (such as genera or families) which might be more easily surveyed, may still act as reliable surrogates for patterns of species richness (Balmford et. al. 1996; Gaston and Williams 1993 and Williams and Gaston, 1994)

9.4.2 Indicators of environmental variables

Many taxonomic groups have been used as indicators of the type of the environment or the habitat in studies carried out in the past. Terrestrial habitats were classified on the basis of bird communities (Bevanger, 1977), soil animals (Mountford, 1962) and carabidae beetle composition (Refseth, 1980) while, Savage (1982) used water boatmen (Corixidae) to classify water bodies. Butterflies indicate change in environmental variation and also are affected by plant diversity since they are directly dependent on them (Elrich et. al. 1972). Some studies say that butterflies are affected by precipitation and other bioclimatic variables and they do not indicate minor changes in habitat quality (Hamer et. al. 2003). Birds too serve as indicators of environmental change especially in the landscape level such as habitat fragmentation (Wilcove, 1985).

Blair (1999) assessed the biodiversity of butterflies and birds along an urbanization gradient and found that the two taxa displayed similar patterns across the gradient i.e. the diversity peaked at intermediate levels of urbanization and at spatial scales of 1 to 10 km one taxa could be used to infer the response of the other in assessing biodiversity. In another study in the Chiapas, Mexico, fruit feeding butterflies were found to be very sensitive to intensification in management of shade canopy in coffee plantations and could be used to monitor ecological changes (Mas and Dietsch, 2003). Many other studies have studied the use of butterflies as indicators (Ockinger et. al. 2005; Nelson, 2006 and Maes, 2005).

However, Kremen (1992), found that although butterflies were good indicators of heterogeneity due to topographic or moisture gradient they were limited indicators of heterogeneity due to anthropogenic disturbance and poor indicators of plant diversity. Bird species richness could indicate forest maturity and productivity as indicated by Braithewaite et.al. (1989) where a positive association between the number of bird species was found with tree basal area, including dead trees, and foliar magnesium in *Eucalyptus* forests in south - eastern New South Wales, Australia.

Tognelli (2005) compared IUCN listed, geographically rare, flagship and large mammalian species as four indicators using complementarity analysis and found that the geographically rare species preformed better. Other taxa like ants (Andersen, 1997), ground beetles (Pearce and Venier, 2006; Luff, 1996 and Rainio and Niemela, 2003), dung beetles (Davis et. al. 2001), orthopteran assemblages (Baldi and Kisbenedek, 1997), are proposed as good indicators.

9.4.3 Indicators of other taxonomic groups

Butterfly groups have extensively been studied as indicators of other taxa or whole butterfly richness. Beccaloni and Gaston (1995) used sub-family Ithomiinae (Lepidoptera: Nymphalidae) species richness to predict over all species richness of butterflies using a mean proportion of Ithomiinae as 4.6 % of the overall species richness of butterflies. Similar studies in India by Singh and Pandey (2004) have found that subfamily Papilionidae formed 7% of the total butterfly species richness in the Indian subcontinent and could be used effectively to estimate butterfly species richness at both local and regional scales. Kremen (1994) found the sub genus *Henotesia* (Satyrinae) proved to be good target taxa at delineating a variety of environmental gradients at both local and landscape scales.

Kerr et. al. (2000) found that butterflies and skippers could be used to predict species richness of Hymenoptera in their study site in the highly fragmented oak savannas of southern Ontario. In bird studies on the similar lines Mikusinski et. al. (1999) used woodpecker species richness as an indicator of the total species richness using the Polish Ornithological atlas data.

Tognelli et. al. (2005) used congruence among different target groups to identify priority areas for marine biodiversity. To test the response of different groups to human impacts Schulze et. al. (2004) characterised habitats on a gradient of modifications by humans based on the inventories of trees, under storey plants, birds, butterflies, and dung beetles. They found that richness amongst most of the groups was highly correlated in addition to a general decrease within the gradient. Vanclay (2004) suggested birds, butterflies and termites as potential indicators that can be used alone or in combination as their species richness correlated significantly with total faunal richness in the Mbalmayo forest reserve in Cameroon. Oertli et. al. (2005) did not find significant correlations between diversity of bees, grasshoppers and aculeate wasps in a mosaic landscape in the Swiss Alps. Butterflies, although phylogenetically related to moths are unlikely to be indicators of moth diversity as suggested by Ricketts et. al. (2002).

Bilton et. al. (2006) studied the performance of Macro-invertebrate taxa as surrogates for the rapid assessment of pond biodiversity. Species richness of four dominant groups (Chironomidae, Coleoptera, Gastropoda and Trichoptera) was studied in 46 ponds in two regions in U.K. All the taxonomic groups were related in a similar manner to measured environmental parameters, suggesting that limited additional ecological information is gained by including a wider range of pond taxa in rapid site assessment. They further suggest that coleoptera have a number of advantages as a surrogate taxon, being diverse, easily sampled, readily identified, taxonomically stable, ecologically well understood and occurring across a wide spectrum of pond types.

Pearson and Cassola (1992) studied the distribution patterns of tiger beetles, butterflies and birds using girded squares across North America, the Indian subcontinent and Australia. They suggest that tiger beetles are suitable indicators for planning of biodiversity and conservation studies as they correlate significantly with butterflies as well as birds and take comparatively very little time to be sampled. Tiger beetle richness was found to correlate with butterfly and bird species richness better than precipitation data (Pearson and Carroll, 1998). A statistically significant relationship was also found in the richness of tiger beetles and butterflies in North America (Carrol and Pearson, 1998).

9.5 Justification of study

Tiger beetles (Cicindelidae) of order coleoptera are considered as good indicators of habitat quality. This is especially important for monitoring and rapid assessment of biodiversity for identification of areas for protection and biodiversity conservation. Tiger beetles are well studied and their biological and ecological aspects are well known. They occur over a broad range of biotope types and geographical areas. This study attempts to document patterns in diversity and distribution of tiger beetles in different habitat types in the Shivalik landscape. Other taxa, for example, birds and butterflies are also monitored as part of the study, to investigate patterns of congruence in diversity (richness) of the three groups in different habitats across the Shivalik landscape. The present study not only aims to explore the relationship between species richness of tiger beetles with birds and butterflies in the Shivalik landscape but also tries to monitor biodiversity at multiple levels of organization at multiple scales.

9.6 Hypothesis

Tiger beetles' diversity is a good biodiversity indicator if its species richness correlates with the species richness of other unrelated groups like butterflies and birds.

9.7 Objectives

To satisfy the above hypothesis the following objectives were put forth

1. To assess species richness, distribution and abundance of tiger beetles, birds and butterflies in different vegetation types.

2. To establish correlation of tiger beetles with the diversity of birds and butterflies along the altitudinal gradient.

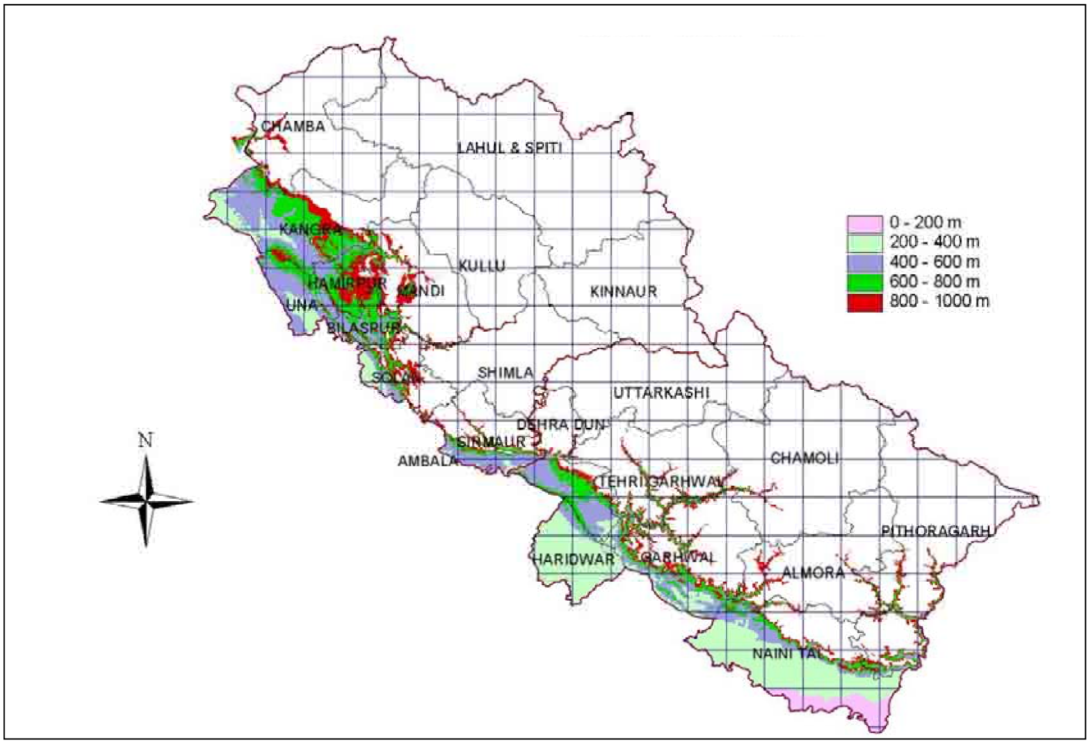
9.8 Study Area

9.8.1 The Shivalik Landscape

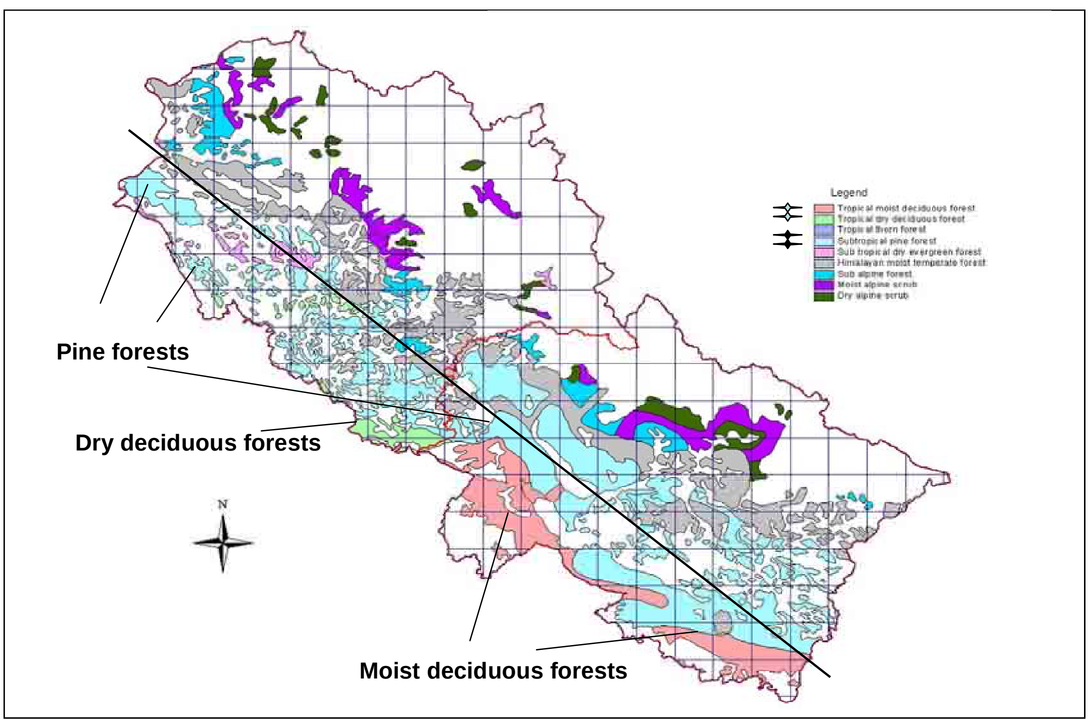
These low mountains were formed by a deposition of detritus and sediment as a skirt at the southern base of the rising Himalayas. These sediments were themselves up thrust in the last major folding event as the Indian plate pushed and ground against the Eurasian continent. This narrow strip is 2,000 kilometers long and forms a continuous chain known as the Shivalik landscape. Structurally, its sediments reflect the history of the up thrust of the emergent Himalayas, and numerous mammalian fossil finds testify to the young age of the Himalayas. The Shivalik is also known as the lower or sub-Himalayas, as it forms the southernmost belt of the Himalayan range. It is also the lowest and narrowest range in the entire Himalayan system, with an average elevation of only 900 - 1200 m above msl and in places, a width of only 16 km. It rises steeply from the great northern plains of India and Pakistan and runs parallel to the main ranges of the Himalayas.

In the states of Himachal Pradesh, Punjab and Haryana, the Shivalik covers over 20,000 sq. km area, and it is separated from the main Himalayas by high mountains and deep valleys. The study was conducted in the Shivalik landscape (29°57’ to 31°20’N and 77°35’ to 79°20’ E), which is also called the sub-Himalaya, and is aligned more or less parallel to Himalayas. The study area includes the Shivaliks of Himachal Pradesh and Uttarakhand (Fig. 3). The climate of the study area is tropical and subtropical in nature (Plate 1). There seems to be a precipitation gradient from the western to eastern regions, the east being the wettest, and this cause the change in vegetation types (Plate 1). The vegetation of Shivaliks has been characterized by sal, mixed deciduous

Digital Elevation Model of the Shivaliks of Himachal Pradesh and Uttarakhand



Forest types in Himachal Pradesh and Uttarakhand



- Plate 1 -

forests, grassy slopes, riverine khair sissoo (*Acacia catechu*, *Dalbergia sissoo*), degraded scrub, pine forests, and subtropical dry evergreen forests. The areas include protected and non-protected forests.

9.8.2 Protected Areas in the Shivaliks of Himachal Pradesh

Extensive field surveys in the Shivalik areas of Himachal Pradesh were carried out in the Pong Dam Wetland Sanctuary and adjoining forests (PWLS), Naina Devi Wildlife Sanctuary (NWLS) and surrounding forests, Nahan Reserve Forest (NRF), Renuka Wetland Wildlife Sanctuary (RWLS) and Simbalbara Wildlife Sanctuary (SWLS).

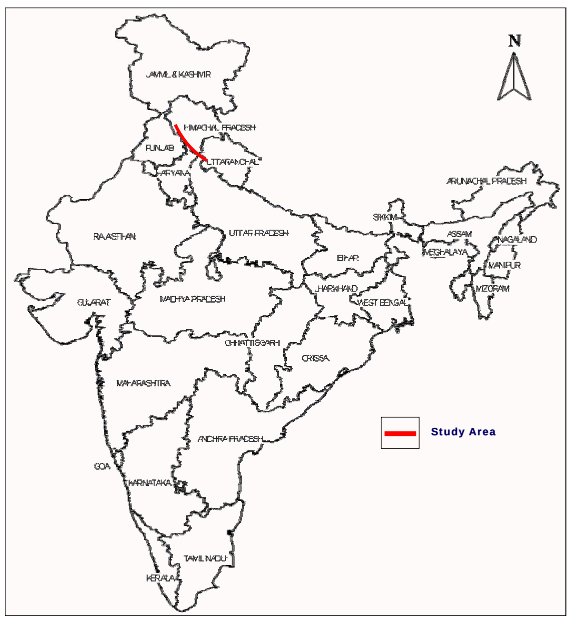


Fig. 3 Study Area along altitudinal gradient of Shivaliks of Himachal Pradesh and Uttarakhand

I. Pong Dam Wetland Sanctuary (PWLS)

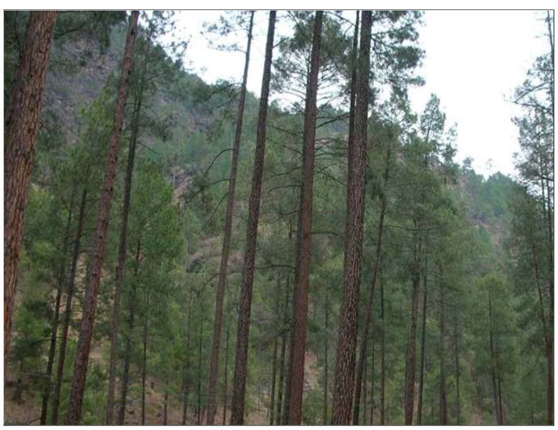
This sanctuary (31^{o} 50' 32^{o} 07'N, 75^{o} 58'-76^{o} 25'E) lies in the Kangra District, Himachal Pradesh, on the border with Punjab State. Covering an area of 307 sq. km it encompasses a lake created by damming the Beas River in 1976 (Plate 2). The Beas Bhakra Management Board controls the reservoir and the state forest department the catchment areas. Local people have rights to fish in the lake. Lying between the outer Shivaliks and Dhauladhar, Pong Dam is the largest standing water body in Himachal Pradesh and covers about 7,000ha at its maximum extent. It includes one permanent island (Ranser) and several others that are periodically connected to the shore (Gaston, 1985, 1986 and Scott, 1989). Five perennial streams flow south-west into the reservoir, namely Bul Khad, Dehr Khad, Dehri Khad, Gaj Khad and Baner Khad. Climate is monsoonal, with hot humid summers and cool, dry winters. Mean annual rainfall is 1780mm. Temperatures range from 5.6^0C to 44.3^0C.

There is a little submerged aquatic vegetation, but the shoreline does not support much emergent vegetation due to the pronounced seasonal changes in water level. There is an extensive swamp with river beds and grasslands in the seepage area below the dam (Gaston, 1985, 1986). The surrounding hillsides still support some mixed deciduous and chir pine forest. Some of the dominant trees are chir pine, (*Pinus roxburghii), khair (Acacia catechu), Mallotus* sp. *Cassia fistula, Bombax ceiba* and *Ehretia laevis.* The undergrowth mostly consisting of *Murraya* sp., *Adathoda* sp. and *Lantana camara*. The lake is an important wintering ground for waterfowls. Some 10,000 ducks were recorded in December 1985, with mallard (*Anas platyrhynchos)* predominant and smaller numbers of northern pintail (*Anas acuta)*, common teal (*Anas crecca),* Bar headed geese *(Anser indicus)* and common pochard (*Aythya ferina)* (Gaston, 1985; Gaston and Pandey, 1987). Waders, such as greenshank (*Tringa nebularia)*, green sandpiper (*T. ochropus)*, common sandpiper (*T. hypoleucos)* and Temmink's stint (*Calidris temminkii)* occur in considerable numbers. A wide variety of raptors was also recorded including osprey (*Pandion haliaetus)*, Pallas' sea eagle (*Haliaetus leucoryphus)*, marsh harrier (*Circus aeruginosus)* and tawny eagle (*Aquila rapax)*. Gaston (1985) observed a total of 103 species in the area, but more than 220 species have been recorded (Pandey, 1989). Other bird species include white-rumped vulture, Himalayan Long-billed vulture, Eurasian griffon, yellow-wattled lapwing, white-tailed stonechat, rufous-tailed shrike and Indian peafowl etc.

Study area along altitudinal gradient of the Shivaliks of North Western India

1. Pong Dam Wetland Sanctuary

2. Naina Devi Wildlife Sanctuary



3. Nahan Reserve Forest

- Plate 2 -

Mammals like wild boar, barking deer and nilgai are also sighted. Reptiles include common cobra (*Naja naja)*, python (*Python molurus)* and common monitor lizard (*Varanus bengalensis)*. Fishes are mahseer (*Tor pitutora)*, mallip (*Wallago attu)* and soal (*Ophiocaphalus marulius)*. The sanctuary is uninhabited, but there are 128 villages in the intensively cultivated buffer zone, with a total population of 50,000 people. Here, residents enjoy rights to cultivate, collect fallen wood and fodder, and graze livestock.

II. Naina Devi Wildlife Sanctuary (NWLS)

The sanctuary (31^{o} 16’ – 31^{o} 24’ N – 76^{o} 25’ – 76^{o} 35’ E), lies in Bilaspur district, covers an area of 123 sq km. and was established in the year 1974. It is under severe anthropogenic pressure from a large number of devotees to the Naina Devi shrine, after which the sanctuary has been named. Altitude within the sanctuary varies from 500 to 1,000 m, with a rainfall of about 1150 mm and temperatures from -1 to 44^{o}C. The vegetation is mostly mixed deciduous forests with *Mallotus* sp., *Ehretia* sp., Jamun, and some *Ficus* sp. (Plate 2). The forests have an abundant population of jungle fowl besides other birds like the blue throated fly catcher, grey hornbill, blue throated barbet, speckled piculet, black partridge etc. Mammals include common langur, rhesus macaque, leopard, jungle cat, barking deer, wild boar and sambar etc.

III. Nahan Reserve Forest (NRF)

These reserve forests (30^{o} 37’ 43” N 77^{o} 17’ 10”) consist of pine (*Pinus roxburghii)* forests interspersed with *Pyrus* sp. at an altitude between 1200 to 1400 m. The undergrowth mainly has shrubs such as *Murraya koenigii*, *Carissa carandus*, *Lantana camara*, *Rubus* sp., *Berberis* sp., and seedlings of *Mallotus philipennsis* and pine (Plate 2).

IV. Renuka Wetland Wildlife Sanctuary (RWLS)

It is a small sanctuary (30°35'58"-30°37'08"N to 77°26'34"-78°28'21"E) occupying an area of 4 sq. km. in Sirmaur district with a mean altitude of 220 m to 880 m above msl (Plate 3). The vegetation is mainly dry mixed deciduous forest and submerged aquatic vegetation.

The wild fauna includes leopard, Himalayan black bear, jungle cat, goral and Himalayan palm civet. The sanctuary has about 48 species of butterflies.

V. Simbalbara Wildlife Sanctuary (SWLS)

Simbalbara wildlife sanctuary (30° 24' 21"N & 77° 27' 18" E) lies at the border of Himachal Pradesh with adjoining Darpur reserved forests of Haryana. This area is a representative of the lower Shivalik region and lies in the confluence of the peninsular plains and the main Shivalik system (Fig. 4). The flora, fauna and physical features show affinities to western Himalaya, Punjab plains and upper Gangetic plains (Biogeography zones 2B, 4A and 7A respectively, Rodgers and Panwar, 1988), though it is present in the biogeographic province 4A.

The altitudinal range is about 350 m to 700 m above msl. The hills are composed of unconsolidated sandstone and conglomerate that are extremely prone to erosion. The soil is extremely porous and thereby highly drained. But in many low lying areas springs emerge and create microhabitat for tiger beetles and butterflies. The area receives a mean annual rainfall of about 1260mm. The relative humidity varies from 100% during monsoon to 26% in summer. This sanctuary is characterized by moist sal- bearing forests and Northern dry mixed deciduous forests, according to Champion and Seth (1968). Apart from these two major types, there are *Eucalyptus* mixed woodlands and riverine forests.

4. Renuka Wetland Sanctuary

5. Simbalbara Wildlife Sanctuary

6. Chilla Wildlife Sanctuary

- Plate 3 -

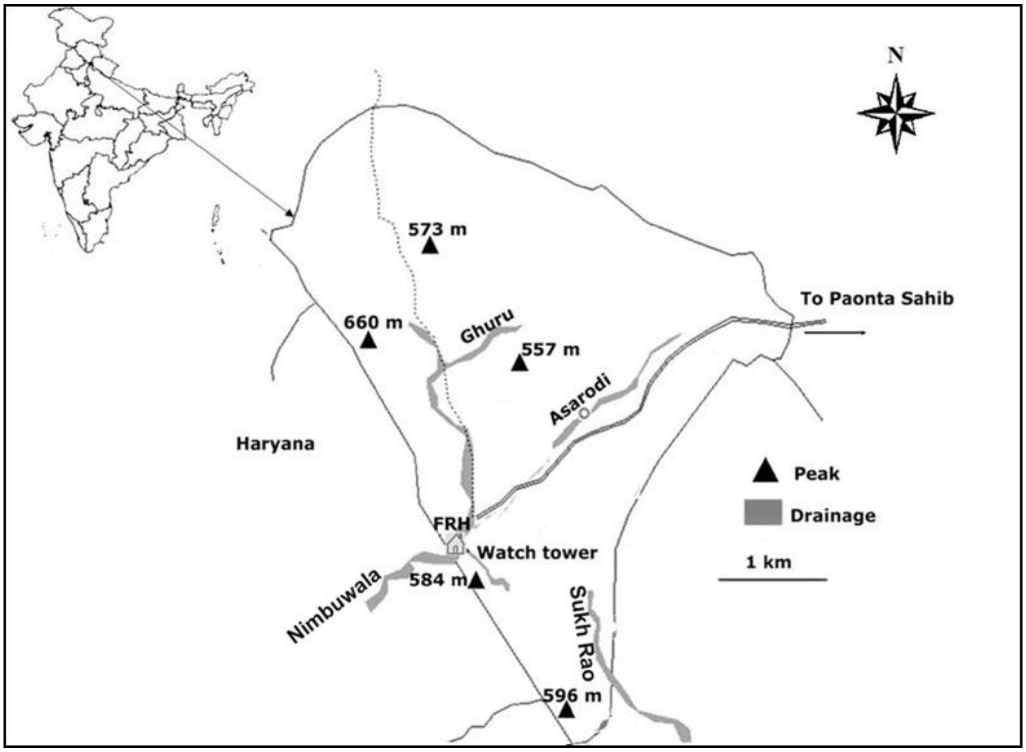


Fig. 4 Map of Simbalbara Wildlife Sanctuary, Himachal Pradesh

The study area is a home for many species of mammals, birds, amphibians, and reptiles. Most of the mammals present have a wide geographical distribution and are not unique to the study area. A few representatives are goral, sambar, barking deer, wild pig, Hanuman langur, rhesus macaque, jackal, and porcupine. Chital are known to migrate in the summer months between the plains of Darpur and Kalesar sanctuary, Haryana and to the water holes in Simbalbara. Tiger, leopard, jungle cat, leopard cat, and pangolin are the rare inhabitants. The occurrence of all these mammals and birds such as Kaleej pheasant, red-billed blue magpie in the study area is indicative of the Himalayan influence on fauna of Simbalbara. Similarly, presence of grey partridge, saker falcon, and imperial eagle is indicative of influence of peninsular India's plains of Darpur region. The sanctuary is subjected to grazing and other interference like lopping, grass cutting and fire. Sampling for birds, butterflies and beetles were conducted on three habitat types in this area *viz*, sal forests, *Eucalyptus* plantations and *Eucalyptus* mixed sal woodlands. Previously research work on habitat use and activity pattern of goral was undertaken by Pendharkar (1993). Recently through this project first information on birds and butterflies (Kittur et. al. 2006) has been recorded.

9.8.3 Protected Areas of the Shivaliks of Uttarakhand

Extensive field studies in the Shivalik areas of Uttarakhand were carried out in the Chilla Wildlife Sanctuary of Rajaji National Park.

I. Chilla Wildlife Sanctuary (CWLS)

Chilla WLS (148 km^2) is a part of Rajaji National Park (820 km^2). It is situated at the Shivalik foothills falling in Haridwar, Pauri-Garhwal district of Uttarakhand (Fig. 5). The area is hilly which is bisected by monsoon sandy river beds (raus). Except monsoon the raus are dry. CWLS is thickly foliated predominantly by the sal (*Shorea robusta*) mixed forest and a number of other forest types which includes the western Gangetic moist and northern dry deciduous and khair-sissoo forests (Plate 3). Major tree species are *Shorea robusta, Mallotus philipennsis, Ehretia laevis, Tectona grandis* and *Haplophragma adenophyllum*.

There are three seasons in the Himalayan foothills: winter, summer and monsoon. During the winter season (November to February), days are warm (20-25^{0}C), nights are cold and humidity is low. Precipitation in December to February totals 50 to 150 mm. Temperature rises rapidly to 40-48^{0}C in the hot season (March to June) and rainfall increases with the occasional thunderstorm. Humidity is high in the rainy season (July to October), with over 750 mm of precipitation in July to August, and there is little temperature variation. Annual rainfall ranges from 1200 to 1500 mm and mean monthly temperature from 13.1^{0}C in January to 38.9^{0}C in May.

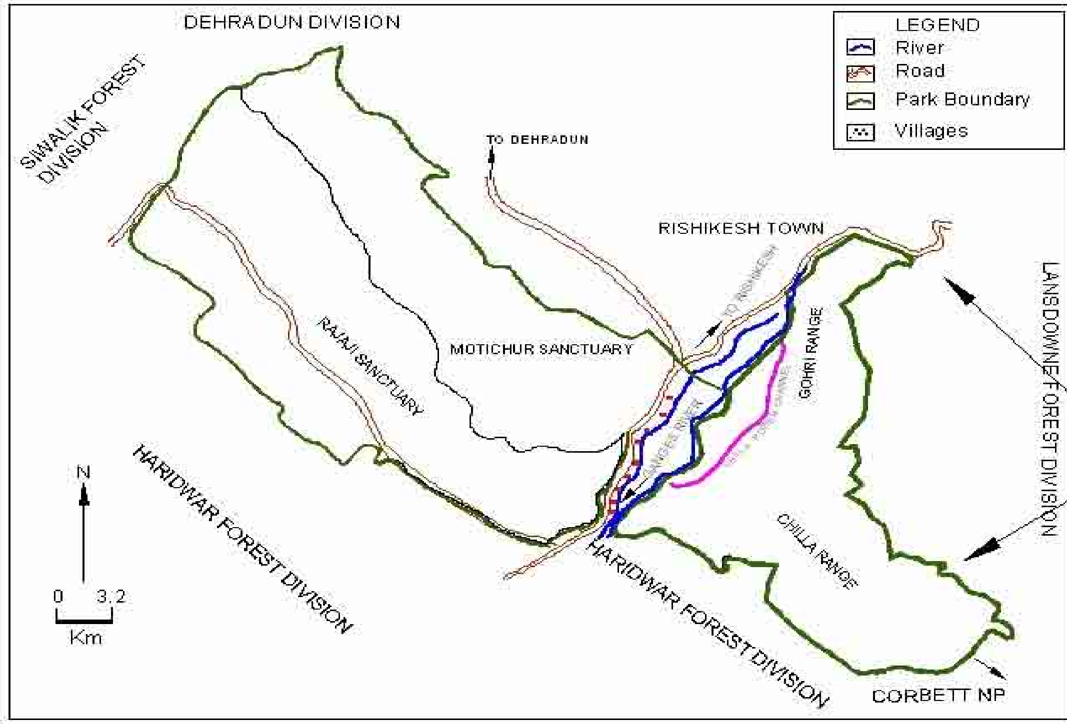


Fig. 5 Map of Chilla Wildlife Sanctuary (Rajaji National Park), Uttarakhand

Based on Landsat imagery for 1986, approximately 84% of the proposed national park is forested. Some 65% of forested land is under 20% crown cover in CWLS, whereas a similar percentage of forested land exceeds 50% crown cover in Motichur Sanctuary. Canopy cover is intermediate for forests in the sanctuary. Of the five vegetation types of the Shivaliks, distinguished by Champion and Seth (1968), four occur in the Sanctuary, namely moist Shivalik sal (*Shorea robusta*), dry Shivalik sal, northern dry mixed deciduous and khair-sissoo (*Acacia catechu*/*Dalbergia sissoo*)

The area is important as the western limit of the Asian elephant (*Elephas maximus*). Other large mammals recorded in the Sanctuary include rhesus macaque (*Macaca mulatta*), langur (*Presbytis entellus*), golden jackal (*Canis aureus*), sloth bear (*Melursus ursinus*), striped hyaena (*Hyaena hyaena*), leopard (*Panthera pardus*), tiger (*P. tigris*), wild boar (*Sus scrofa*), Indian muntjac (*Muntiacus muntjak*), spotted deer

(*Axis axis*), sambar. (*Cervus unicolor*), nilgai (*Boselaphus tragocamelus*) and goral (*Nemorrhaedus goral*).

9.9 Methods

Thirty transects were laid in different habitat types of the study area. They were monitored for birds, butterflies and tiger beetles from October 2004 to August 2007. The fauna of some of the habitats that were sampled have previously not been studied extensively. Pong Dam WLS is well known for its diversity of birds which is well documented, but no study of butterflies and beetles has been conducted. In Naina Devi WLS, Nahan RF, Renuka WLS and Simbalbara WLS no such study has been previously conducted. In Chilla WLS studies on vertebrates, especially mammals have been conducted but information about invertebrate fauna is little explored. The present findings provided baseline information on the diversity patterns and composition of species of birds, butterflies and tiger beetles for these areas. Geographic locations of all transects in the study area were recorded.

9.9.1 Vegetation and disturbance sampling

All habitat parameters were quantified using stratified random sampling. Square plots 10x10 m were laid on either sides of transects at 100 m interval. In each plot 2 plots of 1x1 m were laid for estimating herb abundance and grass cover including the grass height. The following variables were measured in each vegetation plot *viz*. abundance of trees, shrubs, herbs, grass cover, snag, termite mound, tree height, girth class, grass height, canopy cover and disturbance.

Parameters for disturbance including cattle grazing, lopping, fuel collection, fire, NTFP collection etc. were graded from 1 to 5 (1 being very low intensity and 5 being very high intensity. For bio climate and soil temperature, humidity and soil pH were noted from each plot. Temperature and humidity were measured at the beginning of each transect for birds, butterflies and beetles.

9.9.2 Tiger Beetles

A combination of sampling techniques was used to measure species richness of beetles which are both nocturnal and diurnal. Information on *ad libitum* observations is also being documented. Sweeping were done on the pre-established line transect across homogenous habitat types, on sighting of tiger beetles. This method permitted the collection of some arboreal species

Fig. 6 (a) Light Trap Collection (b) An adult tiger beetle

that occurred in the lower canopy and ground living species, most of which are diurnal. Light trap was also used to collect nocturnal species (Fig. 6). While larvae of tiger beetles were collected directly from their subterranean habitat by manual picking (Fig. 7). A reference collection of tiger beetles is maintained (Fig. 8) and will be submitted to respective forest departments and to national reference collection at Division of Entomology, Indian Agriculture Research Institute, Pusa, New Delhi.

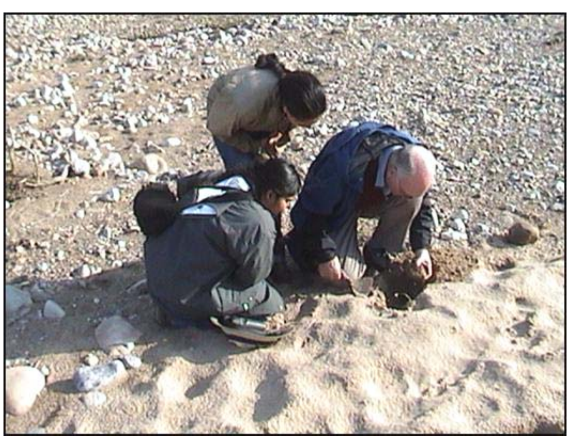


Fig. 7 Collection technique of tiger beetle larva

Fig. 8 Preservation technique of adult tiger beetles and butterflies

9.9.3 Butterflies

Pollard transects: Butterflies were sampled in each habitat type by using Pollard transects or a modification of it. Transects of 300-500 m were laid in different habitat types. The distance between two transects was maintained at least 1 km to maintain spatial independence. Butterflies flying at 5 m on either sides of transect, in front and above the head were counted between 0900h and 1130 h. All transects were walked twice. This method helped in sampling a wide range of diurnal butterflies. Nullah walks were done to find out the ratio of butterflies that are missed during sampling by transects. A reference collection is maintained (Fig. 8) and butterflies that could not be identified were collected using nets (Fig. 9).

Fig. 9 Sweep Net Collection technique for butterflies

9.9.4 Birds

The species richness was measured by line transects in different habitat types. Pilot sampling were done in field and a transect length of 300-500 m was fixed as the optimum levels of transect length. Each transect was walked twice between 0630h and 0830h. The distance between two transects was at least 1 km. Sampling were undertaken between May and September during which all the land bird species breed in Shivaliks and extreme weather are avoided for sampling. Nocturnal birds were not be used in the analysis. *Ad libitum* observations are also documented and information on all such birds encountered is recorded.

10. Results

Sampling was carried out over three years (Plate 4). The period of sampling for butterflies and birds was pre and post monsoon and for tiger beetles was monsoon. A total of 161 birds, 116 butterflies and 25 tiger beetles' species were documented.

10.1 Species distributions

10.1.1 Tiger beetles

Simbalbara WLS was found to have the highest number of tiger beetles followed by Chilla WLS. Table 1 gives the number of species found in each area. The species of beetles and the areas in which each were found are given in Appendix I. Fig. 10 shows a comparison of the average number of tiger beetles that were calculated to be encountered per transect. Sampling for beetles could have been biased as the species present along river banks were missed during transect sampling as all transects were in forested areas. In Chilla WLS 12 species of tiger beetles were found in five different habitat types. Riverine habitat was found to be most rich and was characterized by species *viz*. *Calomera angulata*, *C. plumigera*, *Cicindela multiguttata* and *Cylindera venosa*. Fig. 11 shows a comparison of the cumulative number of species encountered along transects and the total number of species found from checklist data (compiled from opportunistic sightings) in the study site.

Table 1. Species richness of Tiger Beetles across the study area

Study sites	Tiger beetles	N	Mean	Min.	Max.
PWLS	10	14	0.2857 (± 0.61)	0	2
NWLS	6	6	0.8333 (± 0.75)	0	2
NRF	4	6	0.6667 (± 0.81)	0	2
RWLS	3	2	2	2	2
SWLS	16	48	0.9375 (± 0.93)	0	3
CWLS	12	21	0.8314 (± 0.77)	1	3
Total	**25**	**76**	**-**	**-**	**-**

N - Number of transects (including pseudo replicates)

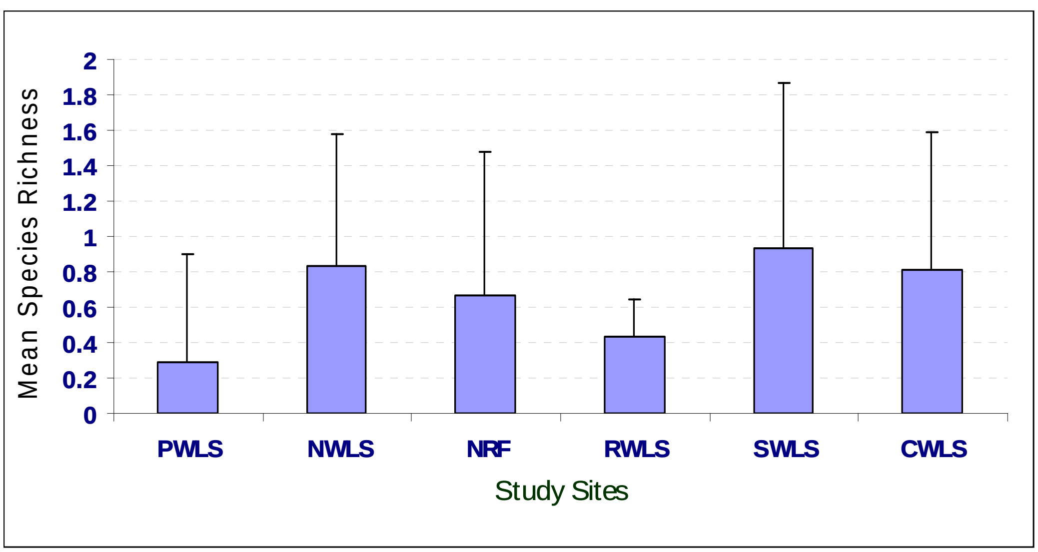
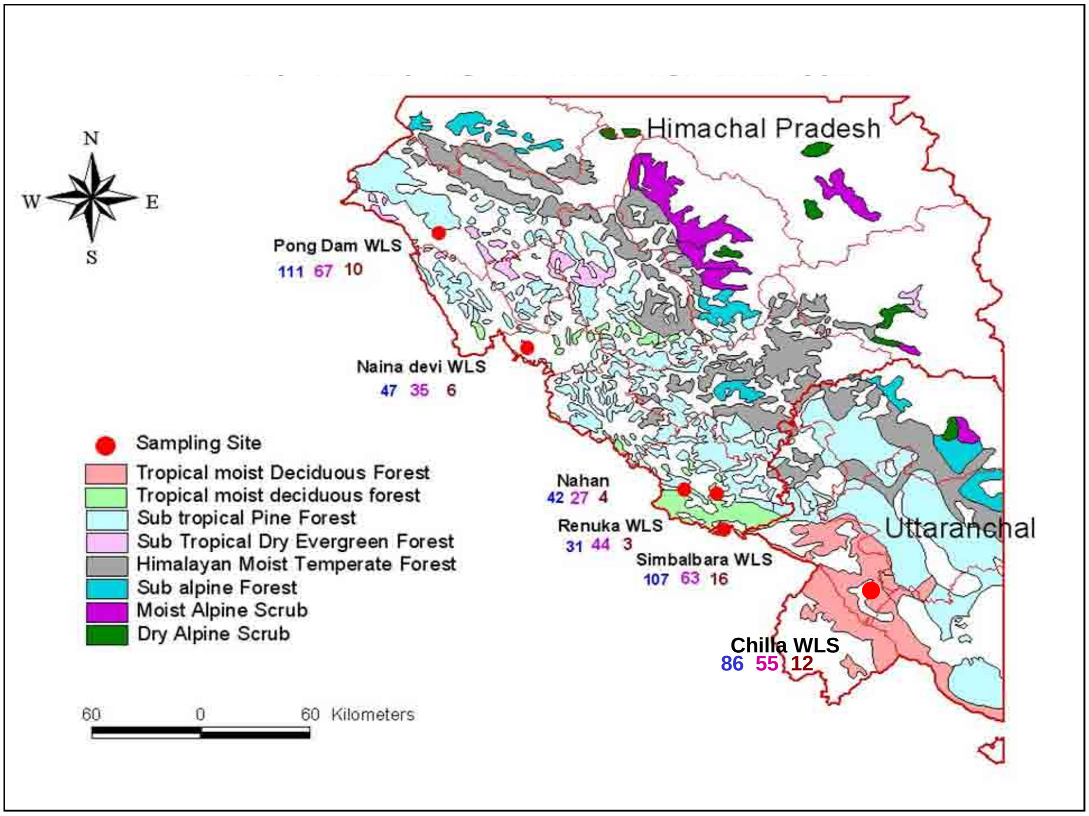


Fig. 10 Average number of Tiger beetle species encountered per transect walk

Map of study area showing sampling sites and number of species encountered at each point.



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Numbers in: **Blue – denote number of Bird species**
Pink – Butterfly species
Brown – Tiger beetle species

- Plate 4 -

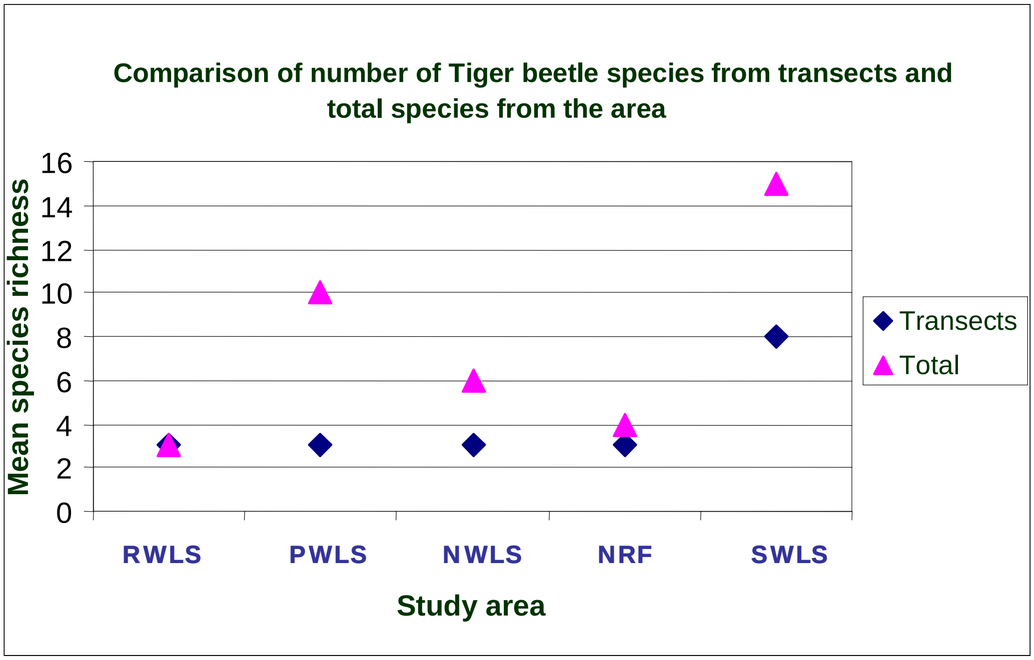


Fig. 11 Comparison of Tiger beetle species encountered from transects (cumulative) and number of species

10.1.2 Taxonomic Identification of Tiger Beetles (Plates 5 to 10)

Fowler (1912), Acciavatti and Pearson (1989) were used to make preliminary identifications of tiger beetle specimens. Their identifications were confirmed by comparing with voucher specimens available at the Dept. of Zoology, Punjab University, Chandigarh using Singh (1991) and Pajni and Bedi (1973).

1*. Calomera plumigera* (Horn)

Diagnostic characters

- Length 12.5-16 mm; Head is dark greenish and coppery, antennae black with four basal joints with purple reflection.
- Pronotum is contracted before the base with greenish central line and green punctures.
- Elytra are much broader than pronotum dark brown or olive green with elaborate or white testaceous markings. White colour extends from the shoulders to the apex, with an interruption before the apical lunate

patch; there is a transverse extension towards suture, a large inverted V- or S-shaped patch at middle extending backwards.

- Legs are greenish and coppery with reddish trochanters.

2. *Calomera angulata* (Fabricius)

Diagnostic characters

- Length 10.5-14 mm; Head dull coppery, brilliant bright and greenish, broad and flat between eyes, glabrous, very finely striated longitudinally between eyes. Pubescence coarser and thicker, hairs in front of the white labrum are also thicker, antennae black with four basal joints with blue or green reflection.
- Pronotum with colour similar to that of head, slightly rounded near apex, narrowed towards base, with impressions strongly marked, central line slightly marked. The margins of the elytra in the female are sometimes irregular and sinuate.
- Elytra with colour similar to head and pronotum, with greenish punctures and white markings, slightly widened in middle. White colour extends from the shoulders to the apex, with an interruption before the apical lunate patch; there is a transverse extension towards suture, a large inverted V- or S-shaped patch at middle extending backwards.
- Legs are greenish sometimes with coppery reflection.

3. *Cicindela multiguttata* (Dejean)

Diagnostic characters

- Length 12-14 mm; Head and pronotum brilliantly coloured with different shades of green and blue; white setae extend across the entire anterior margin and scattered over the pronotum.
- Elytra greenish black, weakly pitted, each elytron with seven variable spots.

4. *Cicindela erudita* (Wiedmann)

Diagnostic characters

- Length 8-10 mm; head and pronotum beautiful green and blue, the latter margined with short white setae.

Species account of Tiger Beetles across study area

Calomera plumigera ***Calomera angulata***

Cicindela multiguttata ***Cicindela erudita***

- Plate 5 -

- Elytra blackish green, each with humeral and apical lunules and middle band, surface not distinctly pitted. Each elytron also has, in its anterior fourth, an irregular row of five thin setae parallel to sutural margin.

5. *Cosmodela intermedia* (Chaudoir)

Diagnostic characters

- Length 14-15 mm; Head greenish, coppery in middle, with two purple blue stripes in front of eyes, slightly raised in middle between eyes, glabrous; antennae with four basal segments greenish black and deep blue.
- Pronotum reddish coppery, with margins and impressions green and blue, with sides slightly rounded, narrowed towards base, with well marked impressions. Central line is moderately marked, rugose.
- Elytra much broader than the pronotum, with the sides being slightly rounded shoulders sub-rectangular, greenish and coppery. Each elytron has a white spot at the shoulder, and four others on each elytron, three in a longitudinal row near the margin (marginal spots), and a small one (humeral spot) just behind the middle one and near the suture.
- Underside shining green and deep blue, legs blue and black and trochanters are dark brownish-grey, femora metallic, tibiae and tarsi dark; genae with few white hairs.

6. *Cicindela vigintiguttata* (Herbst)

Diagnostic characters

- 12-15 mm, Dull coloured species, with head and pronotum dark brown, setae on lateral margins of pronotum short and sparse.
- Elytra are greenish black, each elytron with ten short, dull white spots.

7. *Calomera chloris* (Hope)

Diagnostic characters

- Length 11.5-12 mm; Head is greenish with coppery and bluish reflection, broad slightly raised in middle between eyes, surface is finely striated; antennae with four basal segments green with coppery reflection, rest black.

- Pronotum green, with the sides and depressions blue or violaceous, slightly transverse.
- Elytra green to bluish green with blue punctures, much broader than pronotum, dull, granulose, at the margin about the middle there are two white spots joined by a thin line, before the apex a more or less comma-shaped spot.
- Legs metallic, underside green and violaceous, with the whole of the sides of the abdomen, the episterna and the genae thickly clothed with long white coarse pubescence.

8*. Lophyra parvimaculata* **(Fowler)**

Diagnostic characters

- Length 15-16 mm; Head is dark green with bluish coppery reflection in the middle. Pronotum is setose on lateral sides.
- Elytra are dull greenish, long and the markings on each elytron include three spots along mid-sutural line roughly in middle. Humeral lunule is pale white coloured, extends and becomes broad towards centre. Middle band is short, inclined while apical lunules are separate spots without any connections

9*. Neocollyris (Neocollyris) bonellii* **(Guérin-M)**

Diagnostic characters

- Length 8.8-13 mm; Head is blue green, bright greenish or bluish-green colour, more of less coppery, narrow slightly impressed between eyes; antennae are long and slender, very slightly thickened, with the four basal joints deep blue and eyes are only moderately prominent.
- Pronotum is bluish green, elongate, slender, much constricted before base, elongate conical, with the pronotal collum almost or quite merged into the posterior portion.
- Elytra is bluish, long, narrow, parallel-sided, with the shoulders oblique, distinctly, closely, and regularly punctured, the punctures becoming finer at the apex which is dentate and somewhat excised near the suture.
- Legs with coxae blue-green with their apices black. Femora and trochanters are brick red coloured.

Cosmodela intermedia

Cicindela vigintiguttata

Calomera chloris

Cicindela parvimaculata

- Plate 6 -

- In males, head is more ovate than in the female, the antennae longer, and the pronotum longer and more slender in front.

10*. Neocollyris (Neocollyris) saphyrina* (Chaudoir)

Diagnostic characters

- Length 13.5-17 mm; It is of the same subgenus as *N. (N.) bonellii* in overall form but differs in having five intermediate teeth of the labrum strong and blunt.
- Head is bluish, a little longer, with the sides less rounded behind the eyes.
- Pronotum is short, bluish, elongate, slender, constricted before base as in *N. (N.) bonellii*; antennae variable in colour, terminal joints indistinctly dark at the apex.
- Elytra are more elongate, with the shoulders more obsolete, and the whole upper surface more finely and closely punctured.
- Legs with coxae blue-green and their apices are black, with black trochanters and femora brick red coloured.

11*. Heptodonta pulchella* (Hope)

Diagnostic characters

- Length 15-17 mm; Head is large, brown coloured, striated between the eyes, without setae, lateral margins are metallic green and bluish; antennae are long, filiform pedicel is metallic coppery while the segments are dull brown coloured. Labrum with seven teeth in front.
- Pronotum is medium, dull red coloured, with rounded sides and without setae, margins are metallic green and bluish with some coppery tinge.
- Elytra are uniformly pitted, dull red brown coloured with mid lateral margins metallic green and bluish. It has NO markings or any spots.
- Legs are with trochanters thickly setose brown coloured while rest of the segments are also red brown to brown coloured, tarsi ending in two claws.

12. *Calochroa bicolor* (Fabricius)

Diagnostic characters

- Length 15-17 mm; Head is coppery and dark green, flat between eyes, front parts green, finely and rugosely sculptured; broad between the eyes; antennae metallic black with four basal segments greenish.
- Pronotum as long as head without the labrum with colour and sculpture similar to that of head, sides convex and narrow base.
- Elytra dark greenish, cyaneous or bluish with very fine sculpture, almost smooth and with two large yellow spots.
- Underside of the parts violaceous or partly green, abdomen dark, with the apex and the side margins reddish.
- Legs metallic, episterna of metasterna bare with a tuft of white hairs at inner posterior corner.

13. *Calochroa flavomaculata* (Hope)

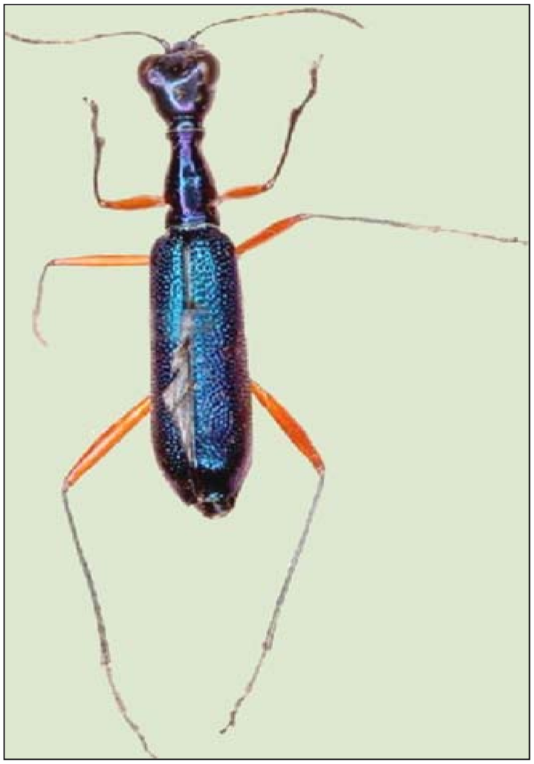
Diagnostic characters

- Length 13.5-16 mm; Moderate sized, dark velvety species, head and pronotum with very obscure metallic reflections, blue or green at the sides.
- Pronotum quadrangular, with the impressions and central line distinct, and with a bright metallic callosity at each end of the basal one.
- Elytra with the sides somewhat rounded, velvety with the sides and suture narrowly bright green or blue with three white or yellowish spots on each of about the same size, arranged in a line.
- Femora are metallic green or violet, tibiae and tarsi more or less pitchy; underside bright green or violaceous, sides of abdomen with scanty pubescence.

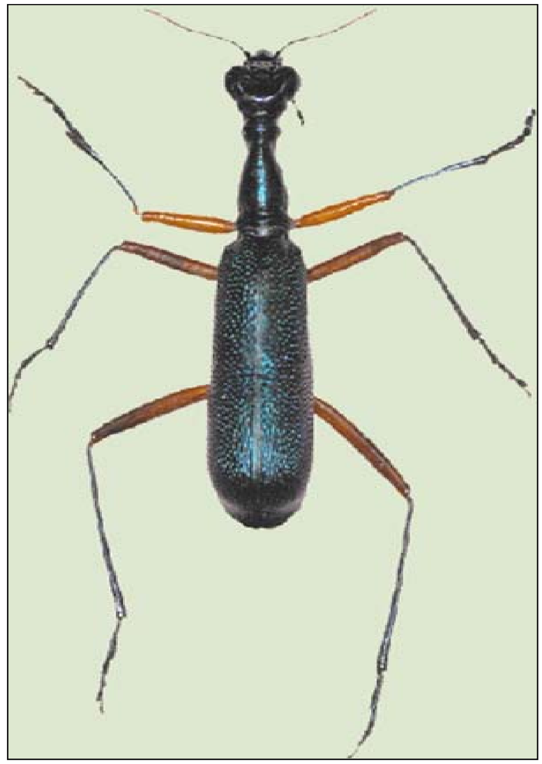
14. *Lophyra (Spilodia)* striolata (Illiger)

Diagnostic characters

- Length 10-15 mm; Head is coppery, with greenish reflection, blue and green behind eyes laterally, slightly raised in middle between eyes; antennae with four basal segments metallic rest blackish and dull.
- Pronotum is with a more or less distinct coppery reflections, with the sides bright green and coppery, and with two short blue lines between



Neocollyris saphyrina



Neocollyris bonellii

Heptodonta pulchella

Calochroa bicolor

- Plate 7 –

- the eyes, about as long as broad, with the sides more or less rounded with distinct short and scanty setae at the sides.
- Elytra with sides sub-parallel, velvety black, with a basal spot, two juxta-sutural spots, a discal spot joined to a submarginal spot by a narrow line, and a subapical, usually interrupted lunule [extending up to middle band].
- Legs and underside metallic, coppery green and cyaneous.

15. *Jansenia crassipalpis* (Horn)

Diagnostic characters

- Length 10-12 mm; Head is predominantly green and violaceous with vertical striations, greenish reflection in front, and metallic green laterally and behind the eyes; eyes are prominent with metallic blue tinge; antennae with the first four basal segments with metallic greenish blue reflection, rest maroon red.
- Pronotum is bright green and metallic blue laterally, strongly rounded at base, constricted near apex and base with very little setae.
- Elytra are with brilliant blue margins and suture; maculations include two yellow spots on shoulder, two minute red spots near the margin in the middle, and three big, conspicuous yellow spots at the margin on each elytron, the surface being uniformly pitted with moderately deep punctures.
- Legs are black, with blue-green reflections, trochanters are red, and underside is brilliant blue with very little pubescence.

16. *Jansenia chloropleura* (Chaudoir)

Diagnostic characters

- Length 10-12 mm; Head is predominantly coppery, with greenish reflection in front, green laterally behind the eyes, rather long, somewhat excavate and strongly striate between the eyes, which are moderately prominent; antennae with the first four basal segments black with greenish reflection, rest black.
- Pronotum is bright coppery, green and blue laterally, strongly rounded at base, constricted near apex and base.
- Elytra are dull coppery red or olivaceous with brilliant blue or green

margins and suture, and with two white spots on each, just touching the marginal colour, one at middle and other at apex, surface with small moderately deep punctures.

- Legs are black, with coppery and greenish reflection, trochanters are red, and underside is brilliant green or deep blue with very little pubescence.

17. *Cylindera (Ifasina) bigemina* (Klug)

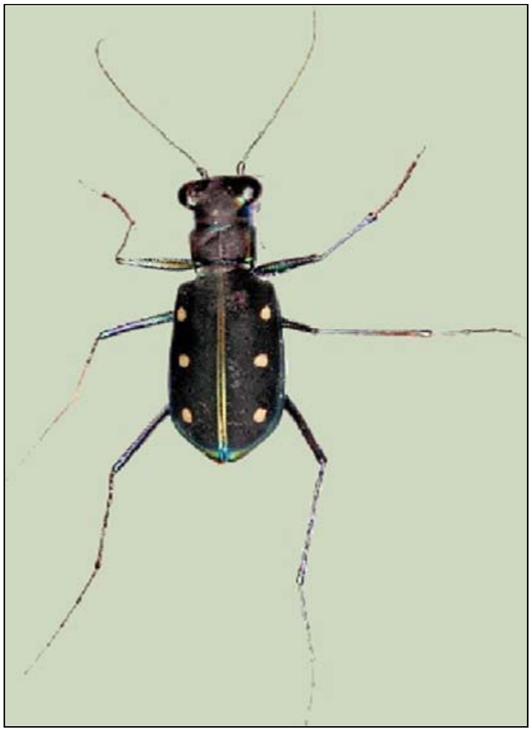
Diagnostic characters

- Length 9-10 mm; Head is coppery, with green reflection and its surface is striated between eyes; antennae are black, four basal segments have greenish reflection. Genae and clypeus glabrous.
- Pronotum is coppery, slightly narrowed towards base, with straight sides. Female coupling sulci a broad shallow groove.
- Elytra with sides sub-parallel, shoulders sub-rectangular, extreme margins greenish-metallic dull, uniformly and thickly punctured. Each elytron has a whitish yellow spot at the shoulder, two on the disc and a sinuate middle band (acutely bent at middle), as well as an apical lunule.
- Legs are metallic, trochanters black; underside deep blue or greenish, coppery in front, with much thicker pubescence.

18. *Cylindera (Ifasina) subtilesignata* (Mandl)

Diagnostic characters

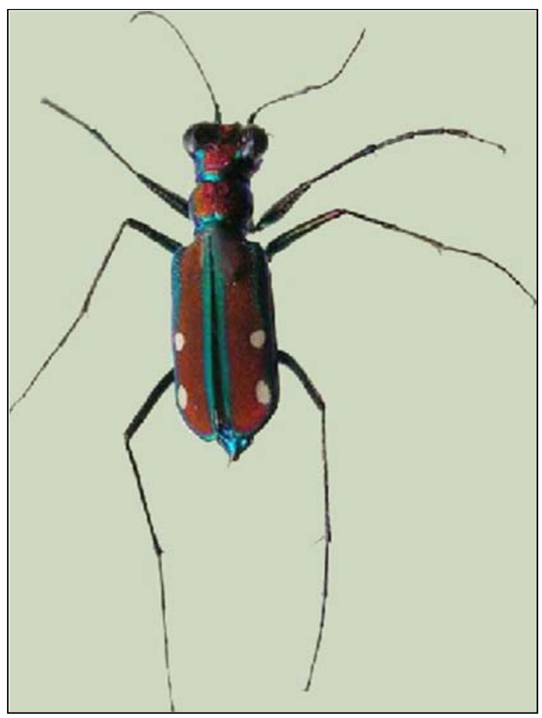
- Length 7-8 mm; Head green, blue, coppery and golden, finely striated longitudinally between eyes, and finely rugose at other places, glabrous.
- Antenna with four basal segments greenish-black, rest pitchy; scape with one pre-apical seta.
- Pronotum coppery with margins green, sometimes entirely greenish, sub-quadrate, slightly narrowed towards base. Its surface is finely rugose (having wrinkles), covered with few white setae laterally.
- Elytra slightly widened behind basal one-fourth with shoulders sub-rectangular. Each elytron is coppery with a green strip extending marginally from shoulders to basal one-fourth and then sub-



Calochroa flavomaculata

Lophyra striolata

Jansenia crassipalpis



Jansenia chloropleura

- Plate 8 -

marginally up to basal three- fourth, suture and base green; markings whitish and comprise of a humeral spot, a discoidal spot and a small sub-marginal spot.

- Abdominal sternites dark blue green, six basal segments in ♂ five in ♀.
- Legs blue, green, and coppery, with trochanters reddish.

19. *Cylindera (Ifasina) spinolae* (Gestro)

Diagnostic characters

- Length 7-8 mm; Head is small, black, striated between the eyes, glabrous (without setae); antennae with four basal segments metallic with red-green lustre, rest segments dull black coloured.
- Pronotum is small, with bluish margins, rugose, coppery, and transverse striations along median line.
- Elytra surface is uniformly pitted; brown coloured, shoulders are bluish green, coppery metallic. Each elytron with two conspicuous whitish yellow spots near the posterior half on the margin, and two minute yellowish spots roughly in the centre on either side of the elytra.
- Legs with trochanters are red-green metallic while rest segments are black dull, tarsi green ending in two claws.

20*. Cylindera (Ifasina) viduata* (Fabricius)

Diagnostic characters

- Length 7-8 mm; Head is short, striated vertically between the eyes, coppery green; antennae with four basal segments with greenish red lusture, rest are dull black.
- Pronotum is short, elongated, coppery green, transversely striated, the apical sides are bluish green, feebly setose.
- Elytra with shoulders are flat, elytra is uniformly densely pitted. Each elytron with three whitish spots in lower half, one elongated at margin in the middle, one round spot near 2/3rd portion of body along mid-elytral suture, one at the lower end [is crecentric-like].
- Legs are with trochanters dull greenish coloured and tarsi are dull black.

21. *Cylindera (Eugrapha) grammophora* (Chaudoir)

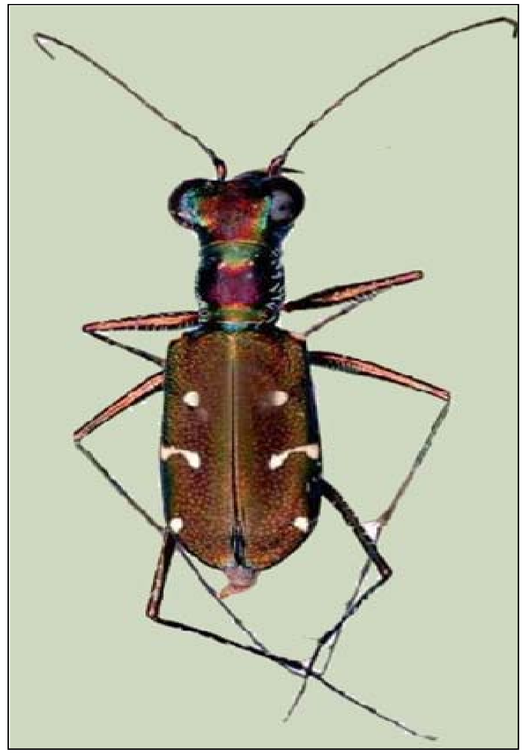
Diagnostic characters

- Length 8-8.5 mm; Head is blue, green, coppery and black, flat between the eyes, surface with broad and deep striations; antennae with four basal segments greenish, rest black.
- Pronotum coppery, greenish laterally, with sides straight and parallel surface is rugose covered with few white setae laterally.
- Elytra is dull, dark usually with more or less distinct greenish reflections at base, with sides sub-parallel, shoulders sub-rectangular, surface shallowly punctuate. Margins are mostly white testaceous, being interrupted before the basal and apical markings the white markings consist of a large crescent –shaped spot at the shoulders, a central inverted V-shaped marking springing from the marginal patch, with the inner lines produced and dilated towards the suture.
- Legs metallic trochanters red, underside, head, and genae, thickly set with tomentose pubescence.

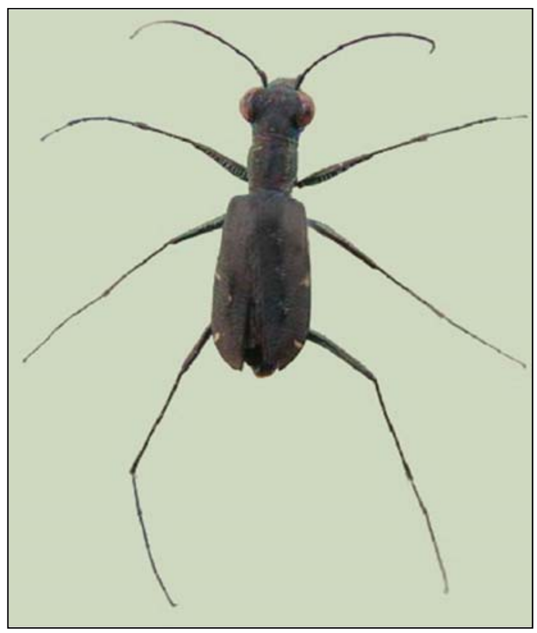
22. *Cylindera (Eugrapha) venosa* (Kollar)

Diagnostic characters

- Length 8-9 mm; Head greenish and coppery, broad and slightly raised between eyes, with a small depression on each side of raised area, its surface glabrous, very finely striated between eyes and in front.
- Antennae with four basal segments greenish, rest black. Its scape is with one stout pre-apical seta.
- Pronotum greenish and coppery, transverse with sides straight and parallel, its surface are with transverse striations along central line and almost smooth at other places, laterally covered with long white setae.
- Elytra slightly rounded at sides with shoulders slightly rounded, surface shallowly punctate with few basal punctures setigerous. Each elytron green and coppery with white maculation, which comprise of a complete white marginal line extending from shoulders to apex formed by fusion of a complete humeral and apical lunules and middle band.
- Abdominal sternites green, densely setose with glabrous areas in middle. Legs green with anterior and hind trochanters partially reddish.



Cylindera bigemina ***Cylindera subtilesignata***



Cylindera spinolae ***Cylindera viduata***

- Plate 9 -

23. *Myriochila (Myriochila) melancholica* (Fabricius)

Diagnostic characters

- Length 10 mm; Head is green and coppery, slightly raised between eyes, its surface is glabrous; antennae with four basal segments greenish black.
- Pronotum is coppery and green, sub–quadrate with sides slightly rounded, and narrowed at base.
- Elytra are slightly widened behind middle, with shoulders sub-rectangular, surface with few large deep punctures in middle near base. Margin of elytra broad and unevenly whitish testaceous; at the shoulders there is a crescent, produced behind into a sharp point, which almost joins a spot on the disc. A narrow band starts from the centre of margin and is strongly hooked ceases at the middle of the disc. Below the apex of this and near the suture is a white spot, the apical margin is white and produced at its upper end.
- Legs are reddish-testaceous with reddish trochanters.

24. *Myriochila (Myriochila) undulata* (Dejean)

Diagnostic characters

- Length 10-11 mm; Head is small, dull coppery with the apex and basolateral portions being bluish green and coppery, feebly striated between the eyes and with no setae; antennae with the first segment metallic rest are dull brown coloured.
- Pronotum is more or less with parallel sides and lateral margins with setae the lateral sides of apex are bluish green while rest of the pronotum is dull coppery coloured
- Elytra are uniformly pitted expanded towards the base, the antero-lateral margins being bluish green while the rest of the elytra are dull coppery coloured. The markings include a crecentric-shaped patch running towards base, two prominent circular white spots near the base and the baso-lateral margins have the dull white marking running some way towards apex along the margins.
- Legs are with greenish trochanters, metallic, setose while rest of the segments are brownish, tarsii brown ending in two claws.

25. *Cicindela fastidiosa* (Dejean)

Diagnostic characters

- Length 8-10 mm, Dorsal ground colour dull green with a mixture of blue on head and pronotum with several row of whitish setae.
- Elytra with lunulate maculation and numerous bluish punctures.

10.1.3 Butterflies

The open mixed scrub jungle around Pong Dam WLS had higher species richness when compared to mixed forests as in Naina Devi WLS, although it is comparable to the sal dominated forests in Simbalbara WLS. The species richness in each area is shown in Table 2. Fig. 12 gives the comparison between the average species richness per transect in each area. A checklist of the species in each area is given in Appendix II. The total species richness for an area was estimated using Estimate S software (Colwell, 2006). The Jackknife 1 estimates for butterflies from the sites are shown in Fig. 13. Jack1 estimates were selected because they were close to the cumulative richness and had very low standard error. Fig. 14 gives a comparison between the Jackknife estimate, cumulative species richness and check lists for the sites (Plates 11 to 14).

Table 2. Species richness of Butterflies across the study sites

Study sites	Butterflies	N	Mean	Min.	Max.
PWLS	30	6	5.7 (± 2.3)	3	10
NWLS	41	20	9.3 (± 3.3)	4	14
NRF	75	39	10.9 (± 6.2)	3	23
RWLS	48	2	41.5 (± 6.4)	37	46
SWLS	74	76	9.95 (± 4.2)	3	20
CWLS	55	12	8.6 (± 3.4)	5	32
Total	**116**	**143**	-	-	-

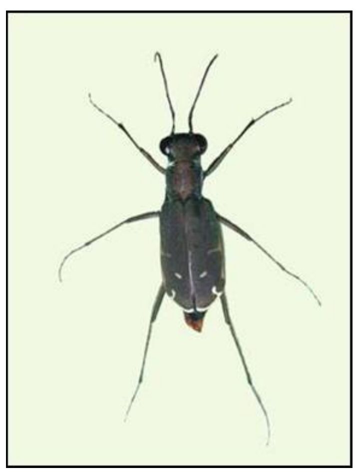
N - Number of transects (including pseudo replicates)

Myriochila melancholica

Myriochila undulata

Cylindera grammophora

Cylindera venosa



Cicindela fastidiosa

- Plate 10 -

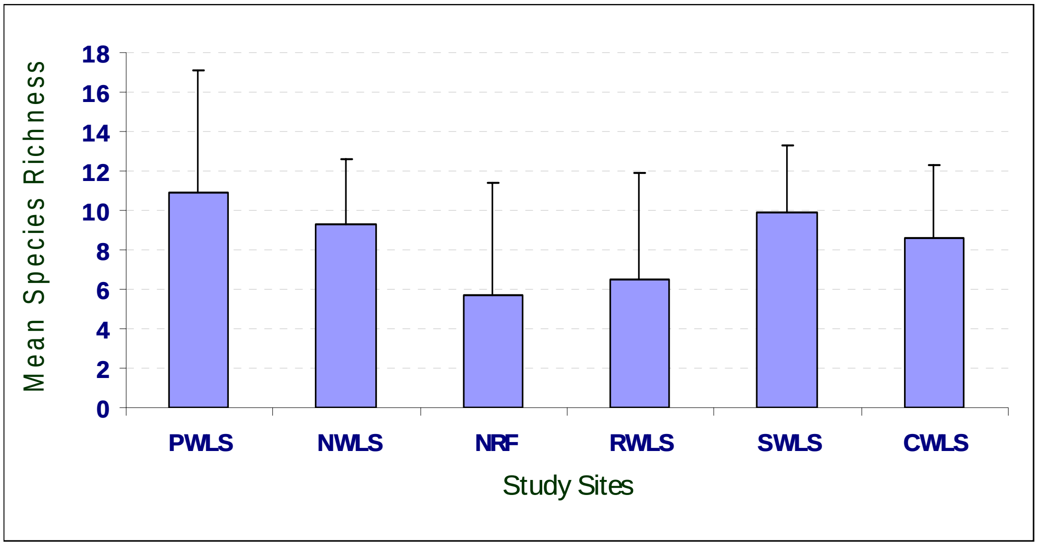


Fig. 12 Average number of Butterfly species encountered per transect walk.

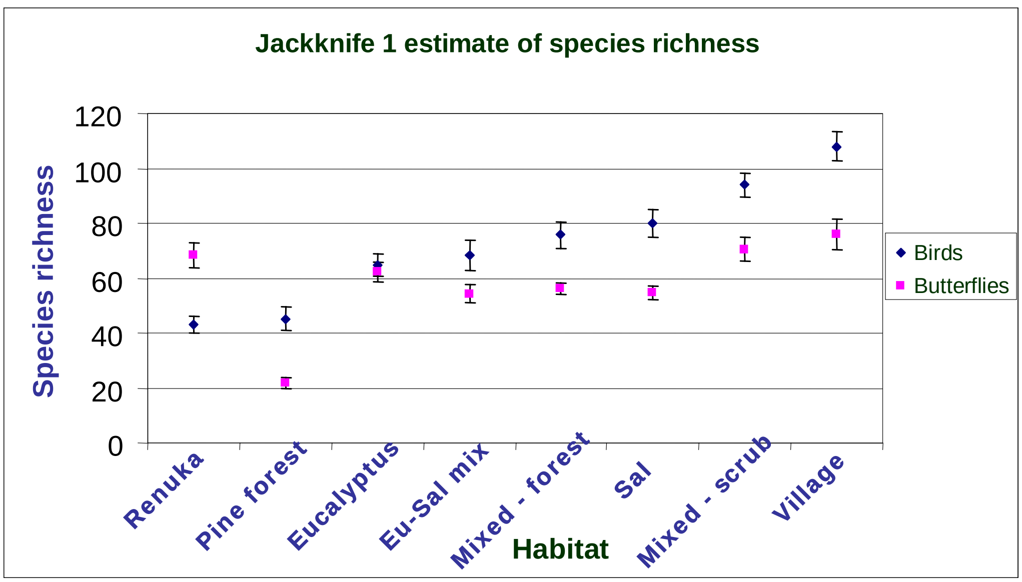


Fig. 13 Jack knife1 estimate for species richness of Birds and Butterflies across study sites.

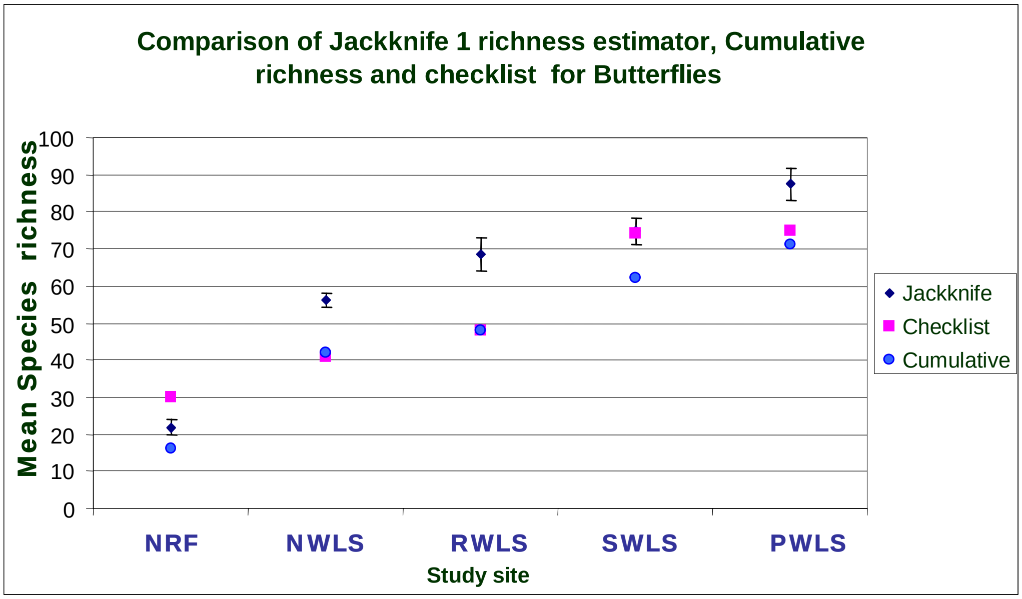


Fig. 14 Comparison between Jack knife1 estimates, Cumulative species richness

A total of 55 species of butterflies were recorded in five different habitat types of Chilla WLS. Sampling was conducted in winter, summer and monsoon. In summer season, butterfly richness and abundance was found to be highest followed by monsoon. This can be attributed to the fact that temperature plays an important role for the activity of butterflies and which was highest and suitable in summer season (Fig. 15).

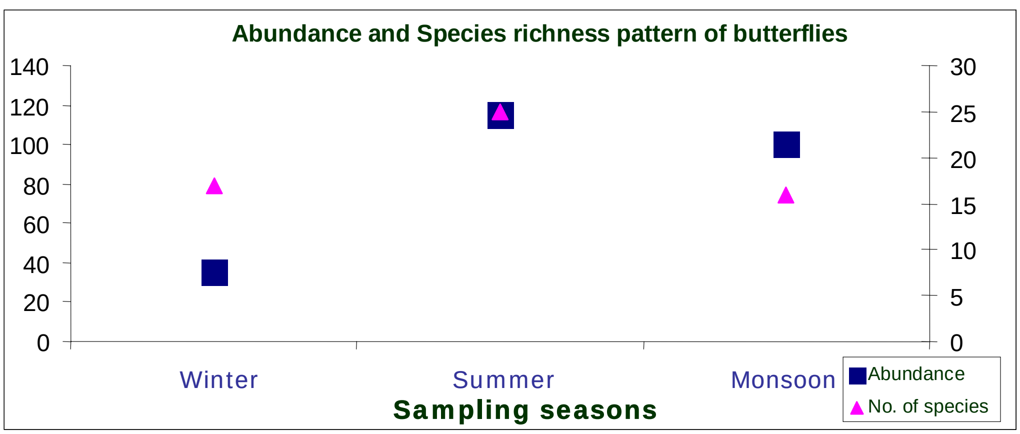


Fig. 15 Fluctuations in butterflies' diversity in different seasons

Diversity of butterflies in different habitat types including disturbed habitats in Chilla WLS showed that the most abundant group of butterflies

Common Butterflies of the Shivaliks of Himachal Pradesh and Uttarakhand


Peacock Pansy (*Junonia almana*)


Blue Admiral (*Kaniska canace*)


Common Map (*Cyrestis thyodamas*)


Rounded Pierrot (*Tarucus nara*)


Common Mormon (*Papilio polytes*)


Common Nawab (*Polyura athamus*)


Spotted Angle (*Caprona alida*)


Mottled Emigrant (*Catopsilia pyranthe*)


Common Leopard (*Phalanta phalantha*)


White Orange Tip (*Ixias marianne*)


Striped Tiger (*Danaus genutia*)


Common Hedge Blue (*Actolepis puspa*)


Indian Tortoiseshell (*Aglais cashmirensis*)


Common Jezebel (*Delias eucharis*)


Lemon Pansy (*Junonia lemonias*)

- Plate 11 -

Commander (*Moduza procris*)

Orange Oak Leaf (*Kallima inachus*)

Chestnut Tiger (*Parantica sita*)

Common Sailer (*Neptis hylas*)

Two-spot Swordtail (*Graphium nomius*)

Common Baron (*Euthalia aconthea*)

Baronet (*Euthalia nais*)

Common Lime (*Papilio demoleus*)

Common Bluebottle (*Graphium sarpedon*)

Painted Lady (*Cynthia cardui*)

Common Gull (*Cepora nerissa*)

Common Brimstone (*Gonepteryx rhamni*)

Common Grass Yellow (*Eurema hecabe*)

Peacock Butterfly (*Inachis io*)

Common Castor (*Ariadne merione*)

- Plate 12 -

Gaudy Baron (*Euthalia lubentina*)

Common Pierrot (*Castalius rosimon*)

Common Rose (*Pachliopta aristolochiae*)

Daniad Eggfly (*Hypolimnas misippus*)

Dark Blue Tiger (*Tirumala septentrionis*)

Great Eggfly (*Hypolimnas bolina*)

Indian Cabbage White (*Pieris canidia*)

Common Bushbrown (*Mycalesis perseus*)

Indian Skipper (*Spialia galba*)

Red Pierrot (*Talicada nyseus*)

Rustic (*Cupha erymanthis*)

Striped Blue Crow (*Euploea mulciber*)

Water Snow-flat (*Tagiades litigiosa*)

Pioneer (*Anaphaeis aurota*)

Zebra Blue (*Syntarucus plinius*)

- Plate 13 -


Crimson Rose (*Pachliopta hector*)


Crimson Tip (*Colotis danae*)


Common Cerulean (*Jamides celeno*)


Glassy Tiger (*Parantica aglea*)


Grey Pansy (*Junonia atlites*)


Common Emigrant (*Catopsilia pomona*)


Plum Judy (*Abisara echerius*)


Red Admiral (*Vanessa indica*)


Pale 4-line Blue (*Nacaduba hermus*)


Tawny Coster (*Acraea violae*)


Tiny Grass Blue (*Zizula hylax*)


Grass Demon (*Udaspes folus*)


Common Redeye (*Matapa aria*)


Blue Pansy (*Junonia orithya*)


Spotless Oakblue (*Narathura fulla*)

- Plate 14 -

was Nymphalidae accounting for almost 50 % of the all species. This was followed by Pieridae (22 %) followed by Papilionidae (12 %) Lycaenidae (11%) and Hesperiidae (5%) (Fig. 16).

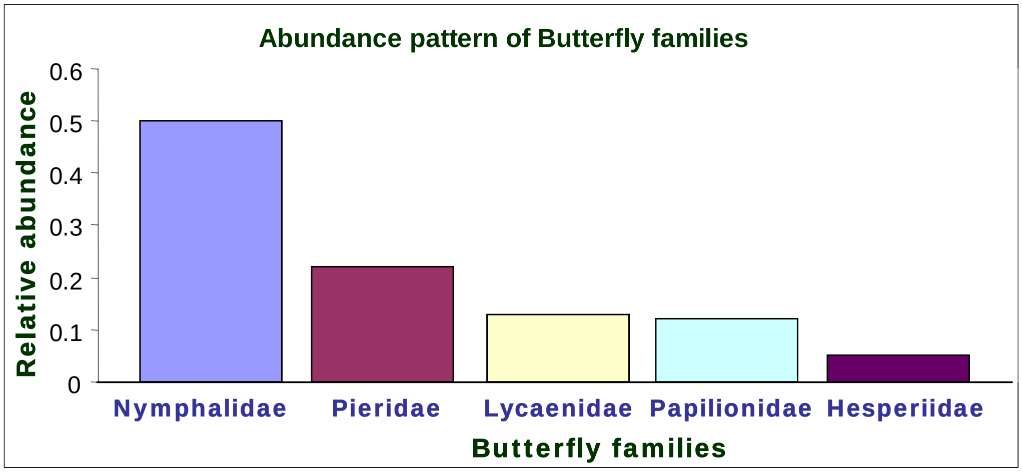


Fig. 16 Abundances of various families of butterflies

Riverine habitat was found to be most rich in species. This can be attributed to the fact that due to availability of water, and mineral, salts. Most of the butterflies were seen in mud-puddling state during the observation period. A large proportion of butterflies were also observed in the degraded (human settlement) habitat. This can be because of availability of complex habitat structure *viz.* grassland-woodland-agricultural land, which supports wide variety of host plants for sustenance of butterflies (Fig. 17).

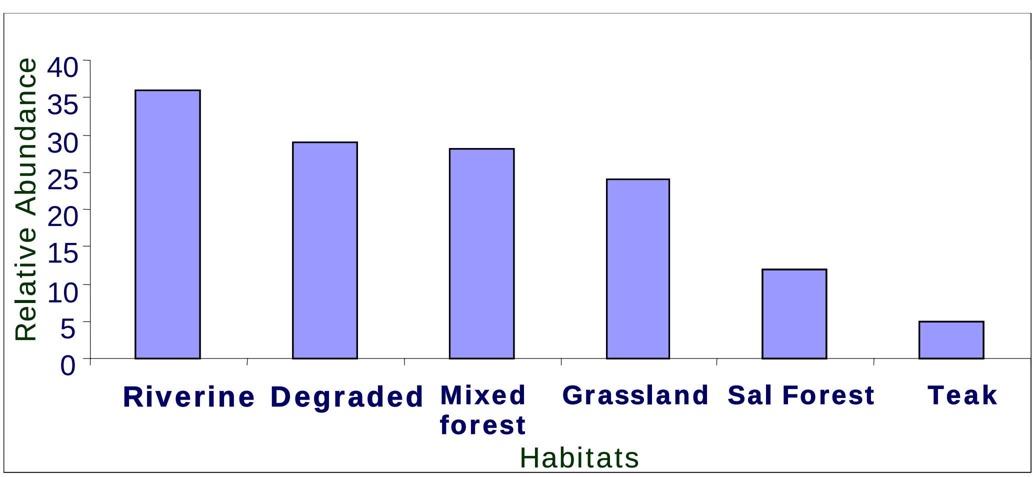


Fig. 17 Relative abundances of butterflies across different habitats

10.1.4 Birds

The mixed scrub jungle around Pong Dam WLS was found to have an overall high species richness of birds as well as a higher number of species that were seen per transect (Fig. 18). These birds did not include the wintering water birds that use the lake area. Table 3 gives the bird species richness across the study sites. A checklist of species seen in the different sites is given in Appendix III. Jackknife 1 for bird species is shown in Fig. 19 and a comparison of the estimate with cumulative richness and checklist data is illustrated.

Table 3. Species richness of Birds across the study sites

Study site	Birds	N	Mean	Min.	Max.
PWLS	42	6	11.5 (± 3.88)	7	16
NWLS	55	15	16.3 (± 5.59)	7	23
NRF	138	30	23.3 (± 6.66)	14	39
RWLS	32	2	25 (± 4.24)	22	28
SWLS	126	51	10.4 (± 4.32)	4	23
CWLS	86	12	8.9 (± 3.22)	3	20
Total	**161**	**104**	-	-	-

N - Number of transects (including pseudo replicates)

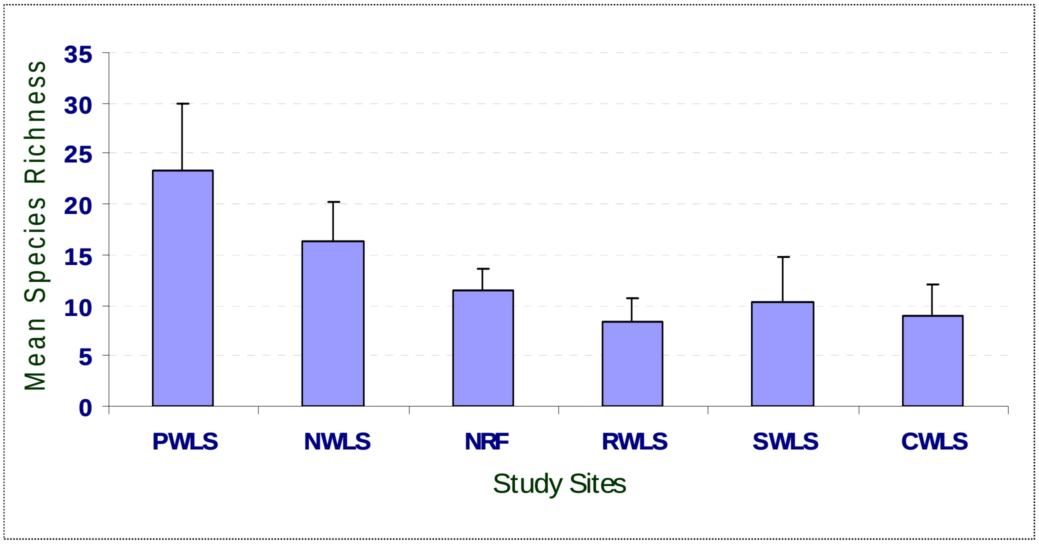


Fig.18. Average number of Bird species encountered per transect walk.

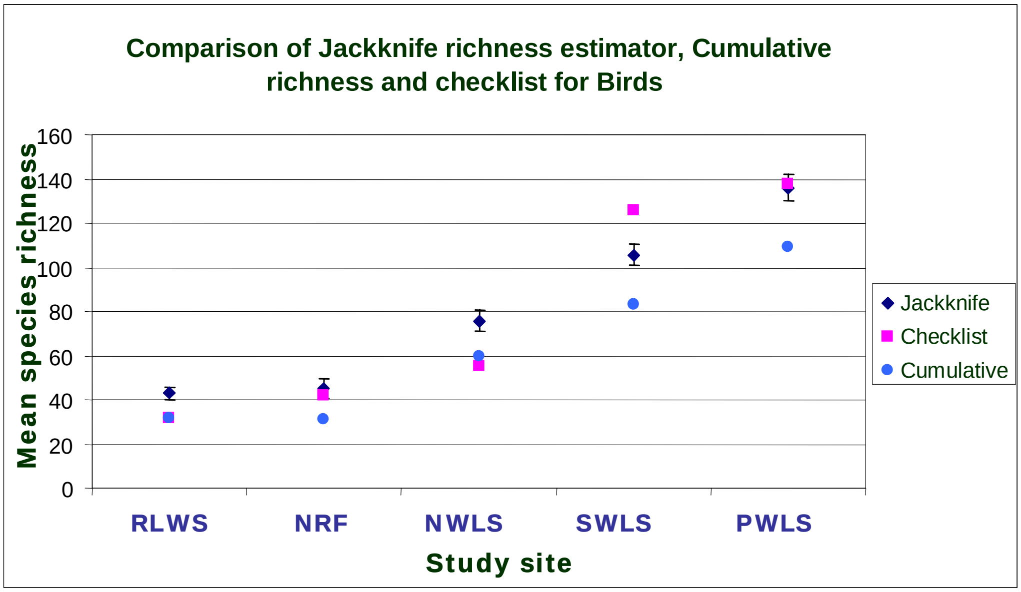


Fig.19. Comparison between Jack knife1 estimate, Cumulative species richness

10.2 Response to habitat characteristics

The forest patches in which transects were laid at Simbalbara and Pong Dam WLS were divided into disturbed areas and relatively undisturbed areas. In Simbalbara the undisturbed areas were in sal dominated (6) forests and the disturbed areas (7) were in *Eucalyptus* plantations and *Eucalyptus* - sal mix patches, two of which were near the adjoining village and were subjected to regular lopping and grazing. In Pong Dam WLS the relatively undisturbed transects were in Mixed scrub forest (5) and the disturbed transects were laid in villages (2). Species richness (cumulative) for these areas was compared using T- tests and Mann - Whitney U test (used in case of butterflies in Pong Dam WLS because of unequal variances) (SPSS 8.0). Only bird species richness showed a significant difference between disturbed and undisturbed areas (Fig. 20).

SWLS	Sal	Disturbed	Test	p - value
Butterflies	45	56	t-test	0.118 (NS)
Birds	57	64	t-test	0.713 (NS)
PWLS	**Mix-Scrub**	**Disturbed**		
Butterflies	57	55	Mann-Whitney U	0.141 (NS)
Birds	75	82	t-test	0.004 *

* - significant

Fig. 20 Comparison for species richness of birds and butterflies between disturbed and undisturbed areas in Simbalbara and Pong Dam.

10.2.1 Birds

The disturbance data (discussed in methods) for each plot was added and averaged for each transect to get the over-all averaged disturbance in the area. The village transects in Pong Dam WLS could not be sampled for vegetation and thus were not included in the analysis. Birds showed a significant negative correlation to disturbance (Fig. 21 and 22). No significant correlation was seen between bird species richness and canopy openness (Fig. 23).

Correlations

		DISTURBN	BIRDS
DISTURBN	Pearson Correlation	1.000	-.475*
	Sig. (2-tailed)	.	.019
	N	24	24
BIRDS	Pearson Correlation	-.475*	1.000
	Sig. (2-tailed)	.019	.
	N	24	24

*. Correlation is significant at the 0.05 level (2-tailed).

Fig. 21 Correlation of birds with disturbance

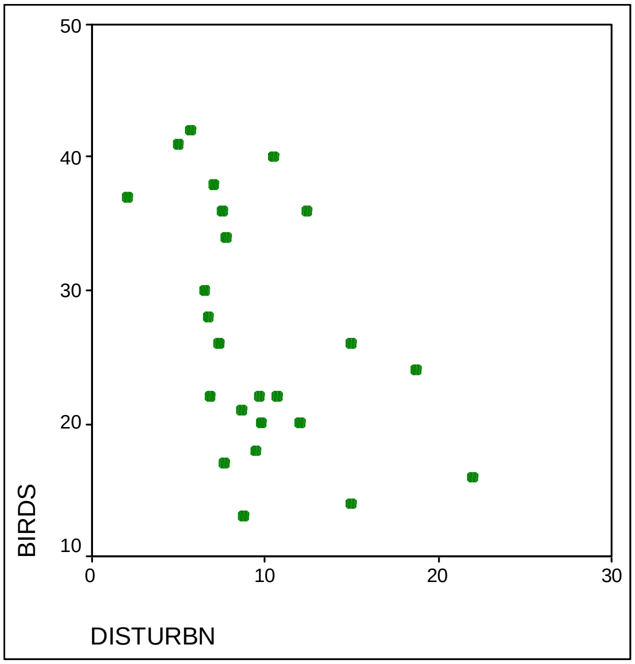


Fig. 22 Bird species showing a significant negative correlation to disturbance.

Correlations

		CANOPY	BIRDS
CANOPY	Pearson Correlation	1.000	.002
	Sig. (2-tailed)	.	.991
	N	24	24
BIRDS	Pearson Correlation	.002	1.000
	Sig. (2-tailed)	.991	.
	N	24	24

Fig. 23 Correlation of birds with canopy openness

10.2.2 Butterflies

Butterfly species richness did not show significant correlation with both disturbances nor with canopy openness (Fig. 24 and 25).

		CANOPY	BUTTERFL
CANOPY	Pearson Correlation	1.000	.283
	Sig. (2-tailed)	.	.180
	N	24	24
BUTTERFL	Pearson Correlation	.283	1.000
	Sig. (2-tailed)	.180	.
	N	24	24

Correlations

Fig. 24 Correlation of butterflies with disturbance

Correlations

		DISTURBN	BUTTERFL
DISTURBN	Pearson Correlation	1.000	.065
	Sig. (2-tailed)	.	.762
	N	24	24
BUTTERFL	Pearson Correlation	.065	1.000
	Sig. (2-tailed)	.762	.
	N	24	24

Fig. 25 Correlation of butterflies with canopy openness

10.3 Cross Taxa Correlations

Investigation of cross taxa correlation between bird and butterfly species richness was tested at two spatial scales. One at a habitat level using the Jack knife 1 estimate and another with richness pooled for each site.

There is a significant correlation between butterfly and bird species richness at the habitat level (Fig. 26 and 27). The sampling at the pine forest at Nahan was included in this analysis. Even if we consider the pine forest as under-sampled and do not include this in the analysis, the correlation was still seen to be significant (Fig. 28 and 29). Pooled species richness for sites showed significant correlation between tiger beetles, butterflies and birds (Fig. 30).

Correlations

		BUTTERFL	BIRDS
BUTTERFL	Pearson Correlation	1.000	.886**
	Sig. (2-tailed)	.	.008
	N	7	7
BIRDS	Pearson Correlation	.886**	1.000
	Sig. (2-tailed)	.008	.
	N	7	7

**. Correlation is significant at the 0.01 level (2-tailed).

Fig. 26 Correlations - Jackknife estimate all habitat types

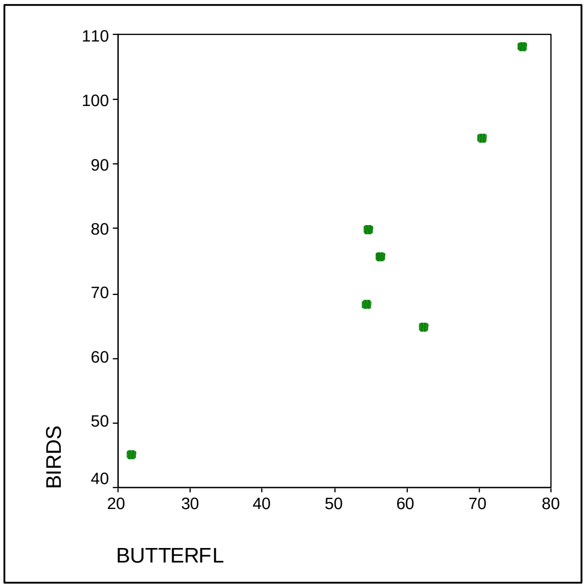


Fig. 27 Correlations - Jackknife estimate all habitat types

Correlations

		BUTTERFL	BIRDS
BUTTERFL	Pearson Correlation	1.000	.826*
	Sig. (2-tailed)	.	.043
	N	6	6
BIRDS	Pearson Correlation	.826*	1.000
	Sig. (2-tailed)	.043	.
	N	6	6

*. Correlation is significant at the 0.05 level (2-tailed).

Fig. 28 Correlations - Jackknife estimate without pine forest

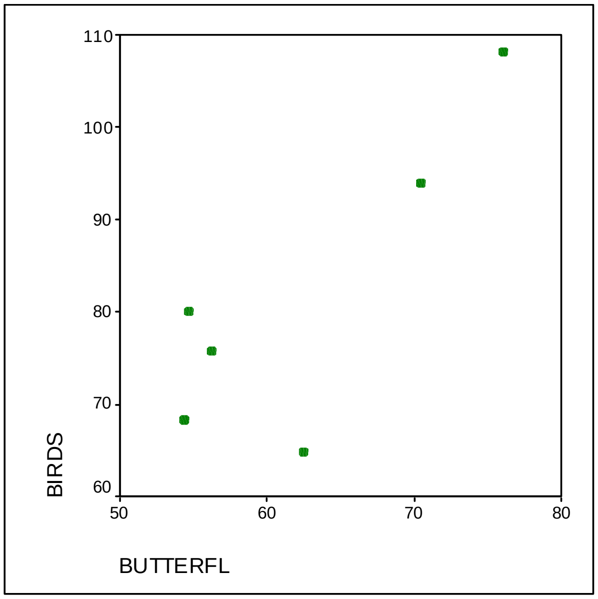


Fig. 29 Correlations - Jackknife estimate without pine forest

Correlations

		Birds	Butterflies	Beetles
Birds	Pearson Correlation	1.000	.916*	.897*
	Sig. (2-tailed)	.	.029	.039
	N	5	5	5
Butterflies	Pearson Correlation	.916*	1.000	.839
	Sig. (2-tailed)	.029	.	.075
	N	5	5	5
Beetles	Pearson Correlation	.897*	.839	1.000
	Sig. (2-tailed)	.039	.075	.
	N	5	5	5

*. Correlation is significant at the 0.05 level (2-tailed).

Fig. 30 Correlation between tiger beetle, butterfly and bird species richness across study sites.

11. Discussion and Conservation Implications

11.1 Species distributions

To study species distributions it is important to cover most of the area that one intends to sample. Due to the large expanse of the Shivalik landscape this was a difficult task. Again, the same transects may not be suited for all taxa. For example tiger beetles were found to be most easily sampled by walking along forest trails from past studies (Pearson and Vogler, 2001) and observations during this study. Transect sampling may not be very appropriate for beetles. Another aspect that could have caused a sampling bias is that tiger beetles have restricted micro-habitats. There are species that are only found on river banks and those that are mostly found on forest floor and some are arboreal. Placing of transects in forests will bias the sampling towards forest species.

In Pong Dam WLS most of the species were found as opportunistic sightings while searching at the banks of the lake, sand bars of rivers or small streams and very few were actually seen on transects. Methods need to be developed to enumerate river bank and stream bed species which aggregate in large numbers. Large aggregations of beetles were seen in Simbalbara from July end to September, which included mainly two species i.e. *Cicindela angulata* and *C. plumigera macrograptina*. This also holds true for butterfly sampling. Many of the species prefer dry to moist riverbeds which also provide forest edges, puddling areas and open space.

Transects placed close to riverbeds would most certainly show a higher diversity of butterflies when compared to transects that are away from river beds, even if they have the same vegetation. Transect sampling was most suited for enumerating birds, but again forest edges have an effect here too. Seasonality plays an important role in sampling species distributions. All the three taxa considered here respond to seasonal changes and needed regular seasonal monitoring. Bird species diversity differs between summer and winter due to seasonal migrations; butterflies are abundant in the pre and post monsoon and tiger beetle species composition and abundance changes with the advancing monsoon.

11.2 Response to habitat characteristics

The positive response of bird species richness to disturbances indicates that birds are sensitive to disturbance and habitat changes. However the number of species of birds in disturbed habitats was more than the relatively undisturbed mixed scrub forest in Pong Dam WLS. This could be because the villages that were sampled were close to forest patches and detection of birds could have been easier here, being relatively open habitats. Birds also correlated significantly with disturbance summed for each plot and averaged for each transect. Although, one reason of caution could be that vegetation sampling was carried out only in the first year and the bird data is a cumulative richness over the entire sampling period. The disturbance values should be taken as a very coarse value. Birds did not seem to respond to canopy openness possibly because there are very evident compositional changes in diversity when we move from forests to scrub vegetation, even without much difference in species richness.

Butterflies are sensitive to habitat changes and also show changes in species composition along a gradient of vegetation structure from forests to scrub vegetation. This could be one reason why their species richness did not show any response to canopy openness. Richness could remain relatively unchanged but with stark differences in composition and abundances. For this further investigations would be necessary. Butterflies also visit open areas with some disturbance like grazed sited having dung piles for mud pudddling for minerals and areas infested with flowering weeds for nectar eg. *Lantana camara, Ageratum* sp. and thus may not show a difference in richness across a disturbance gradient.

11.3 Cross Taxa Correlations

The use of indicators for assessing biodiversity is valid only if the species richness of the indicator correlates with the diversity of other taxa (Oertli et. al. 2005). Many studies (Carrol and Pearson, 1998; Beccaloni and Gaston, 1995; Bilton et. al. 2006; Blair, 1999; Pearson and Carrol, 1998; Pearson and Cassola, 1992; Singh and Pandey, 2004 and Vanclay, 2004) have used species richness as a criterion for indicator taxa. Species richness however is not the only component of diversity. Other aspects such as abundance and species composition also need to be considered when the response of a taxonomic group to environmental factors is considered.

Bird and butterfly species richness showed a significant correlation across all habitat types. However, other aspects such as their correlation in diversity patterns need to be explored. Tiger beetles, butterflies and birds also showed significant correlations when the data was pooled for study sites (checklist data). The data suggests that each of the three groups could act as surrogates for species richness in the study area. Tiger beetle richness could be a good indicator to predict the richness of butterflies and birds. Nevertheless, further investigations in other sites with varied disturbance criteria and improved sampling techniques need to be carried out to be conclusive.

Biodiversity is complex and to assess it surrogates such as sub-sets of species, species assemblages and habitat types have to be used as measures of biodiversity. Identifying such surrogates would be the first step for systematic conservation planning (Margules and Pressey, 2000). Under the conditions of constant change in our environment, in the conservation context both inventorying and monitoring programmes cannot be exhaustive and thus the use indicator species and indicator assemblages seems practical (Kremen et. al. 1992).

11.4 Role of Tiger Beetles as Bioindicators

Bioindicators are used to monitor the health of an environment or ecosystem. They are any biological species or group of species whose function, population, or status can be used to determine ecosystem level or environmental integrity. Such organisms are monitored for changes (chemical, physiological, or behavioural) that may indicate a problem within their ecosystem. An increase or decrease in an animal population may indicate damage to the ecosystem caused by pollution. For example, if pollution causes the depletion of important food sources, animal species dependent upon these food sources will also be reduced in number. An insect taxon can also be used to identify the state or changes in the landscape or to find out how certain insect taxa are affected by a possible or an inevitable modification to the landscape. Insects in general are particularly suited for monitoring landscape change because of their abundances, species richness, ubiquitous occurrence and importance in the functioning of the natural ecosystems.

The family of tiger beetles (Cicindelidae) is an appropriate indicator taxon for determining regional patterns of biodiversity because (1) its taxonomy is stabilized; (2) its biology and general life history are well understood; (3) individuals are readily observed and manipulated in the field; (4) the family occurs world-wide and in a broad range of habitat types; (5) each species tends to be specialized within a narrow habitat; (6) patterns of species richness are highly correlated with those of other vertebrate and invertebrate taxa; and (7) the taxon includes species of potential economic importance. Logistical advantages provide some of the strongest arguments for selecting tiger beetles as an appropriate indicator taxon. Species numbers of tiger beetles are relatively well known for the various countries of the world. Eight countries alone account for more than half the world total of over 2600 known species. The tiger beetle species numbers can be reliably determined within fifty hours on a single site, compared to months or years for birds or butterflies, and the advantage of using tiger beetles in conservation biology is thus evident.

Tiger beetles (Cicindelidae) are thus an indicator group for identifying areas for biodiversity conservation. Tiger beetles are well known, their biology well understood, occur over a broad range of biotope types and geographical areas and also exist in remnant patches of appropriate biotopes thus they are particularly useful as “fast bioindicators” for determining regional patterns of biodiversity. There are over 2,600 species of tiger beetles worldwide, 220 in India (with 114 or 51% endemics). In the protected areas of Shivalik Landscape, 25 species were recorded from different protected areas with a mean altitude of 300m to 1400 m above msl in Himachal Pradesh *viz.* Pong Dam WLS, Naina Devi WLS, Nahan RF, Renuka WLS, Simbalbara WLS and Chilla WLS.

The species showed a high degree of habitat specialization and were found in one or few microhabitats owing to unique climatic and trophic characteristics and resource partitioning. These in turn form the prime character for a bioindicator taxon for which tiger beetles are well known. Thus, monitoring these species in future will give precise idea about changes in microclimatic conditions, if the anthropogenic disturbance increases. Tiger beetles also provide a background for identifying centres of species richness and abundance with the protected areas as their spatial abundances correlate with the other vertebrate taxon such as birds and with the invertebrate taxon such as butterflies. Tiger beetles are thus excellent candidates for bioindicators in long term monitoring of forest ecosystems, ecosystem health and its application in a variety of landscapes.

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11.6 Appendix I

Presence Absence matrix of Tiger Beetle species (Cicindelidae) found during sampling period (Including casual sightings)

S.No.	Species	PWLS	NWLS	NRF	RWS	SWLS	CWLS
1.	*Calochroa bicolor*	-	-	-	-	*	*
2.	*Calochroa flavomaculata*	*	-	-	-	-	-
3.	*Calomera angulata*	*	-	-	-	*	*
4.	*Calomera chloris*	*	-	-	-	*	*
5.	*Calomera plumigera macrograptina*	*	-	-	-	*	*
6.	*Cicindela erudita*	-	-	-	-	*	-
7.	*Cicindela fastidiosa*	*	-	-	-	-	*
8.	*Cicindela multiguttata*	-	-	-	-	-	*
9.	*Cicindela parvomaculata*	-	-	-	-	-	*
10.	*Cicindela vigintiguttata*	-	-	-	-	-	*
11.	*Cosmodela intermedia*	*	*	*	*	*	*
12.	*Cylindera bigemina*	*	-	-	-	*	-
13.	*Cylindera grammophora*	*	-	-	-	*	-
14.	*Cylindera spinolae*	-	-	-	-	*	-
15.	*Cylindera subtilesignata*	*	*	*	*	*	-
16.	*Cylindera venosa*	-	-	-	-	*	*
17.	*Cylindera viduata*	-	-	-	-	*	-
18.	*Heptodonta pulchella*	-	*	-	-	-	-
19.	*Jansenia chloropleura*	-	*	*	-	-	*
20.	*Jansenia crassipalpis*	*	-	-	-	*	-
21.	*Lophyra striolata*	-	-	-	-	*	-
22.	*Myriochila melancholica*	*	-	-	-	*	-
23.	*Myriochila undulata*	*	-	-	-	*	*
24.	*Neocollyris bonellii*	-	-	-	-	*	-
25.	*Neocollyris saphyrina*	-	*	-	*	*	-
	Grand Total	10	6	4	3	16	12

11.6 Appendix II

Presence Absence matrix of butterfly species found during sampling period (Including casual sightings)

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
	Family – Papilionidae							
1.	Common Blue Bottle	*Graphium sarpedon*	-	-	-	*	-	*
2.	Common Mime	*Papilio clytia dissimilis*	*	-	-	*	*	*
3.	Common Mormon	*Princeps polytes*	*	-	*	*	*	*
4.	Common Rose	*Pachliopta pandiyana*	*	-	-	-	-	*
5.	Crimson Rose	*Pachliopta hector*	-	*	-	-	-	*
6.	Glassy Blue Bottle	*Graphium cloanthus*	-	*	-	-	-	-
7.	Lime Butterfly	*Papilio demoleus*	*	-	*	*	*	*
8.	Peacock Butterfly	*Inachis io*	-	-	*	*	-	-
9.	Two-Spot Swordtail	*Pathysa nomius*	-	-	-	-	*	*
	Family – Pieridae							
10.	Common Brimstone	*Gonopteryx rhamni*	-	-	*	*	-	-
11.	Common Emigrant	*Catopsiila pomona*	*	*	*	*	*	*
12.	Common Grass Yellow	*Eurema hecabe*	*	*	-	*	*	*
13.	Common Gull	*Cepora nerissa*	*	*	-	-	*	*
14.	Common Jezebel	*Delias eucharias*	*	*	-	-	*	*
15.	Indian Cabbage White	*Pieris canidia*	*	-	*	*	*	*
16.	Large Cabbage White	*Pieris brassicae*	*	-	-	*	-	*
17.	Mottled Emigrant	*Catopsilia pyranthe*	*	-	*	*	*	*
18.	Pioneer	*Anaphaeis aurota*	*	-	*	-	*	*
19.	Common Psyche	*Leptosia nina*	-	-	*	-	*	*
20.	Small Grass Yellow	*Eurema brigitta*	*	-	*	*	-	*

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
21.	Small Orange Tip	*Colotis etrida*	-	-	-	-	*	-
22.	Spotless Grass Yellow	*Eurema laeta*	*	-	-	-	*	*
23.	Striped Albatross	*Appias libythea*	*	-	-	-	-	-
24.	Three Spot Grass Yellow	*Eurema blanda*	*	*	-	*	*	*
25.	White Orange Tip	*Ixias marianne*	*	*	-	-	-	-
26.	Yellow Orange Tip	*Ixias pyrene*	*	-	-	-	-	-
	Family –Nymphalidae							
27.	Bamboo Tree Brown	*Lethe europa*	-	*	-	-	-	-
28.	Banded Tree Brown	*Neope puleha*	-	-	*	*	-	-
29.	Baronet	*Euthalia nais*	*	-	-	-	*	*
30.	Blue Admiral	*Kaniska canace*	-	-	-	*	*	-
31.	Blue Pansy	*Junonia orithya*	*	-	-	-	*	*
32.	Blue Tiger	*Tirumala limniace*	*	-	-	*	*	*
33.	Chestnut Tiger	*Parantica sita*	-	*	-	-	-	-
34.	Chocolate Soldier	*Precis iphita*	*	*	*	*	*	-
35.	Club Beak	*Libythea myrrha*	*	-	*	*	-	-
36.	Commander	*Moduza procris*	-	-	-	-	*	*
37.	Common Baron	*Euthalia aconthea*	-	-	-	-	*	-
38.	Common Beak	*Libythea lepita*	-	-	-	-	*	*
39.	Common Bush Brown	*Mycalesis perseus*	*	*	*	*	*	*
40.	Common Castor	*Ariadne merione*	*	-	-	*	-	-
41.	Common Crow	*Euploea core*	*	*	*	*	*	*
42.	Common Evening Brown	*Melanitis leda*	*	*	-	*	*	*
43.	Common Four Ring	*Ypthima huebneri*	*	*	*	-	-	*
44.	Common Lascar	*Pantoporia hordonia*	*	*	-	*	*	*

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
45.	Common Leopard	*Phalanta phalantha*	*	*	*	-	*	*
46.	Common Map	*Cyrestis thyodamas*	-	-	-	*	*	-
47.	Common Nawab	*Polyura athamas*	-	-	-	-	*	*
48.	Common Palmfly	*Elymnias hypermnestra*	-	-	-	*	*	-
49.	Common Sailer	*Neptis hylas*	*	*	-	*	*	*
50.	Common Three Ring	*Ypthima asterope*	-	-	-	*	-	*
51.	Common Tiger	*Danaus chrysippus*	*	*	-	*	*	*
52.	Common Tree Brown	*Lethe rhoria*	*	*	-	-	-	-
53.	Danaid Eggfly	*Hypolimnas misippus*	-	-	-	-	*	*
54.	Gaudy Baron	*Euthalia lubentina*	-	-	-	-	*	-
55.	Glassy Tiger	*Parantica aglea*	*	*	*	*	*	*
56.	Great Eggfly	*Hypolimnas bolina*	*	-	-	-	*	-
57.	Himalayan Five Ring	*Ypthima sakra*	*	-	-	*	-	-
58.	Indian Red Admiral	*Vanessa indica*	-	-	-	*	-	-
59.	Indian Tortoiseshell	*Aglais cachmirensis*	*	-	-	*	-	-
60.	Large Oak Blue	*Arhopala amantes*	*	-	-	-	*	-
61.	Lemon Pansy	*Precis lemonias*	*	*	*	*	*	*
62.	Orange Oakleaf	*Kallima inachus*	*	*	-	*	*	*
63.	Painted Lady	*Cynthia cardui*	*	-	*	-	*	*
64.	Peacock Pansy	*Precis almana*	*	-	-	-	*	*
65.	Plain Tiger	*Danaus genutia*	*	-	-	-	*	*
66.	Rustic	*Cupha erymanthis lotis*	-	-	*	*	*	*
67.	Small Leopard	*Phalanta alcippe*	-	-	-	*	*	-
68.	Spotless Oakblue	*Narathura fulla*	*	-	-	*	*	*
69.	Striped Blue Crow	*Euploea mulciber*	-	-	-	*	*	*

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
70.	Tawny Coster	*Acraea violae*	-	-	-	*	-	*
71.	Yellow Pansy	*Junonia hierta*	*	-	*	-	*	*
	Family – Lycaenidae							
72.	Acacia Blue	*Surendra sp.*	-	-	-	-	*	-
73.	Angled Sunbeam	*Curetis dentata*	*	*	-	-	*	-
74.	Broad Tail Royal	*Camena cleobis*	-	-	-	-	*	-
75.	Common Cerulean	*Jamides celeno*	*	*	-	*	-	*
76.	Common Gem	*Poritia hewitsoni*	-	-	-	-	*	-
77.	Common Hedge Blue	*Acetolepis puspa*	-	-	-	*	*	*
78.	Common Pierrot	*Castalius rosimon*	*	-	-	-	*	*
79.	Common Red Flash	*Rapala irabus*	*	*	-	-	*	-
80.	Common Silverline	*Spindasis vulcanus*	*	-	-	-	-	-
81.	Dark Grass Blue	*Zizeeria karsandra*	*	-	-	*	-	-
82.	Golden Sapphire	*Heliophorus brahma*	*	-	-	-	-	-
83.	Gram Blue	*Euchrysops cnejus*	*	-	-	-	*	-
84.	Grass Jewel	*Freyeria trochylus*	*	-	-	*	*	-
85.	Margined Hedge Blue	*Lycaenopsis marginata*	-	-	-	-	-	*
86.	Pale Grass Blue	*Pseudozizeeria maha*	*	*	-	*	*	*
87.	Pea Blue	*Lampides boeticus*	*	-	-	-	*	-
88.	Plains Cupid	*Edales pandava*	-	-	-	-	*	-
89.	Plum Judy	*Abisara echerius*	*	*	-	-	*	-
90.	Red Pierrot	*Talicada nyseus*	-	-	-	-	*	*
91.	Sapphire	*Heliophorus sp.*	-	-	*	-	-	-
92.	Silverline	*Spindasis sp.*	-	-	-	-	*	-
93.	Six-Line Blue	*Nacaduba sp.*	*	*	-	-	-	-

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
94.	Striped Pierrot	*Tarucus nara*	*	-	-	-	-	-
95.	Tailed Punch	*Dodona eugenes*	-	-	*	-	-	-
96.	Tiny Grass Blue	*Zizula hylax*	*	-	*	*	-	-
97.	Zebra Blue	*Leptotes plinius*	*	-	-	-	-	-
	Family- Hesperiidae							
98.	Banded Awl	*Hasora chromus*	-	-	-	-	-	*
99.	Blank Swift	*Caltoris kumara*	-	*	*	-	-	-
100.	Chestnut Angle	*Odontoptilum angulata*	-	-	-	-	*	-
101.	Common Dart	*Taractrocera sp.*	-	*	-	-	-	-
102.	Common Grass Dart	*Taractrocera maevius*	*	-	-	-	*	-
103.	Common Redeye	*Matapa aria*	*	-	-	-	*	*
104.	Common Small Flat	*Sarangesa dasahara*	-	-	*	-	-	-
105.	Common Spotted Flat	*Celaenorrhinus leucacera*	-	*	-	-	-	-
106.	Common Dart	*Taractocera sp.*	*	-	-	-	-	-
107.	Fulvous Pied Flat	*Coladenia dan*	-	*	-	-	-	-
108.	Grass Demon	*Udaspes folus*	*	*	-	-	-	*
109.	Indian Palm Bob	*Suastus gremius*	*	-	-	-	-	-
110.	Indian Skipper	*Spialia galba*	*	-	-	-	-	*
111.	Rice Swift	*Borbo cinnara*	-	-	-	*	-	*
112.	Small Common Flat	*Sarangesa dasahara*	*	-	-	-	*	-
113.	Spotted Angle	*Caprona agama*	-	-	*	-	-	-
114.	Spotted Demon	*Notocrypta fiesthameli*	-	-	-	-	*	-
115.	Tree Fritter	*Hyarotis adrastus*	-	-	-	-	*	-
116.	Water Snow Flat	*Tagiades litigiosa*	-	*	-	-	-	-
	Grand Total		67	35	27	44	63	55

11.6 Appendix III

Presence Absence matrix of bird species found during the sampling period (Including casual sightings)

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
1	Ashy Throated Warbler	*Phylloscopus maculipennis*	-	-	-	-	*	*
2	Asian Barred Owlet	*Glaucidium cuculoides*	*	-	-	-	*	*
3	Asian Koel	*Eudynamys scolopacea*	*	-	-	*	*	*
4	Asian Paradise Flycatcher	*Trepsiphone paradisi*	*	-	-	-	*	-
5	Bank Myna	*Acriditheres ginginianus*	*	-	-	-	-	*
6	Bar-tailed Tree Creeper	*Certhia himalayana*	*	-	-	-	*	-
7	Bar-winged Flycatcher Shrike	*Hemipus picatus*	-	-	-	*	*	-
8	Baya Weaver	*Ploceus philippinus*	*	-	-	*	-	-
9	Black Bulbul	*Hypsiptes leucocephalus*	*	-	-	*	*	*
10	Black-chinned Babbler	*Stachyris pyrrhops*	*	-	*	-	-	*
11	Black-crested Bulbul	*Pycnonotus atriceps*	-	-	-	-	*	-
12	Black-crowned Night Heron	*Nycticorax nycticorax*	*	-	-	-	*	-
13	Black Drongo	*Dicrurus macrocerus*	*	*	*	-	*	*
14	Black-headed Cuckoo Shrike	*Coracina melanoptera*	-	-	-	-	*	*
15	Black-hooded Oriole	*Oriolus xanthormus*	-	-	-	-	*	*
16	Black Kite	*Milvus migrans*	*	-	*	*	-	*
17	Black Partridge	*Francolinus francolinus*	*	-	*	*	-	*
18	Black Redstart	*Phoenicurus ochruros*	*	-	-	-	-	*
19	Black-rumped Woodpecker	*Dinopium benghalense*	*	-	-	-	-	*
20	Blue-capped Rock Thrush	*Monticola cinclorhynchus*	-	-	*	-	-	-
21	Blue Rock Pigeon	*Columba livia*	*	*	-	*	*	*
22	Blue-tailed Bee Eater	*Merops philippinus*	*	-	-	-	-	*
23	Blue-throated Barbet	*Megalaima asiatica*	*	*	*	*	-	*
24	Blue-throated Flycatcher	*Cyornis rubeculoides*	*	*	*	-	*	-
25	Blue Whistling Thrush	*Myophonus caerulens*	*	-	-	-	*	-
26	Brahminy Starling	*Sturnus pagodarum*	*	-	-	-	-	-
27	Brahminy Kite	*Haliastur indus*	-	-	-	-	*	-
28	Brown-capped Pygmy Woodpecker	*Dendrocopos nanus*	*	-	-	-	-	-
29	Brown-fronted Woodpecker	*Dendrocopos auriceps*	-	-	*	-	-	-

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
30	Brown Hawk Owl	*Ninox scutulata*	-	-	-	-	*	*
31	Brown-headed Barbet	*Megalaima zeylanica*	*	*	-	-	*	*
32	Cattle Egret	*Bubulcus ibis*	*	-	-	-	*	*
33	Chestnut-bellied Nuthatch	*Sitta castenea*	-	-	*	-	*	*
34	Chestnut-headed Bee-Eater	*Merops leschenaulti*	-	-	-	-	*	*
35	Chestnut-shouldered Petronia	*Petronia xanthocollis*	*	-	-	-	*	-
36	Cinereous Vulture	*Aegypius monachus*	*	-	-	-	-	-
37	Common Hawk Cuckoo	*Hierococcyx varius*	*	*	-	-	*	-
38	Common Hoopoe	*Upupa epops*	*	-	-	-	-	*
39	Common Iora	*Aegithina tiphia*	*	-	-	-	*	*
40	Common Kingfisher	*Alcedo atthis*	-	-	-	*	*	*
41	Common Moorhen	*Gallinla chloropus*	-	-	-	*	-	-
42	Common Myna	*Acrodotheres tristis*	*	*	-	-	*	*
43	Common Tailor Bird	*Orthotomus sutotius*	*	*	-	*	*	-
44	Common Woodshrike	*Tephrodornis pondicerianus*	*	-	*	-	*	*
45	Coppersmith Barbet	*Megalaima haemacephala*	*	-	-	-	-	*
46	Crested Bunting	*Melophus lathami*	*	-	*	-	-	-
47	Crested Kingfisher	*Megaceryle lugubris*	-	-	-	-	*	*
48	Crested Serpent Eagle	*Spilornis cheela*	-	-	-	-	*	*
49	Crimson Sunbird	*Aethopyga siparaja*	*	*	-	-	*	-
50	Dusky Crag Martin	*Hirundo concolor*	-	-	-	*	-	-
51	Egyptian Vulture	*Neophron percnopterus*	*	-	-	-	*	*
52	Emerald Dove	*Chalcophaps indica*	-	-	-	-	*	-
53	Eurasian Black Bird	*Turdus merula*	-	*	-	-	-	-
54	Eurasian-collard Dove	*Streptopelia decaocto*	*	-	-	-	*	-
55	Eurasian Cuckoo	*Cuculus canorus*	*	*	*	-	*	-
56	Eurasian Golden Oriole	*Oriolus oriolus*	*	*	-	-	-	-
57	Eurasian Griffon	*Gyps fulvus*	*	-	-	-	-	-
58	Eurasian Tree Sparrow	*Passer montanus*	-	-	*	-	-	-
59	Fulvous-breasted Woodpecker	*Dendrocopos macei*	*	*	*	*	*	-
60	Golden-fronted Leafbird	*Chloropsis aurifrons*	-	-	-	-	*	*
61	Golden-spectacled Warbler	*Seicercus burkii*	-	-	-	-	*	-

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
62	Great Tit	*Parus major*	*	*	*	*	*	*
63	Greater Coucal	*Centropus sinensis*	*	-	-	-	*	*
64	Greater Flameback Woodpecker	*Chrysocolaptes lucidus*	*	-	-	-	*	*
65	Greater Yellow Naped Woodpecker	*Picus flavinucha*	-	-	*	-	-	-
66	Green Bee Eater	*Merops orientalis*	*	-	-	-	*	*
67	Grey-breasted Prinia	*Prinia hodgsonii*	*	*	*	*	*	-
68	Grey Bushchat	*Saxicola ferrea*	*	-	-	-	-	*
69	Grey-capped Pygmy Woodpecker	*Dendrocopos canicapillus*	*	-	*	-	*	-
70	Grey Francolin	*Francolinus pintadeanus*	*	-	-	-	-	-
71	Grey-headed Canary Flycatcher	*Culicapa ceylonensis*	*	-	-	-	*	-
72	Grey-headed Woodpecker	*Picus canus*	*	*	*	-	-	-
73	Grey-hooded Warbler	*Seicercus zanthoschistos*	-	*	*	*	*	-
74	Grey Hornbill	*Ocyceros birostris*	*	*	-	*	*	*
75	Grey Treepie	*Dendrocitta formasae*	-	-	-	-	*	-
76	Grey Wagtail	*Motacilla cineria*	*	-	-	-	*	-
77	Grey-winged Blackbird	*Turdus boulboul*	-	-	-	-	*	-
78	Himalayan Bulbul	*Pycnonotus leucogenys*	*	*	*	*	*	*
79	House Crow	*Corvus splendens*	*	-	-	-	-	*
80	House Sparrow	*Passer domesticus*	*	*	-	-	-	*
81	House Swift	*Apus affinis*	*	-	-	-	-	*
82	Indian Cuckoo	*Cuculus micropterus*	*	*	-	-	*	*
83	Indian Pitta	*Pitta brachyura*	*	-	-	-	*	*
84	Indian Robin	*Saxicoloides fulicata*	*	*	-	*	-	*
85	Indian Roller	*Coracias garrulus*	*	-	-	-	*	*
86	Jungle Babbler	*Turdoides striatus*	*	*	*	*	*	*
87	Jungle Owlet	*Glaucidium radiatum*	*	-	-	-	*	*
88	Khalij Pheasant	*Lophura leucomelanos*	*	*	-	-	*	-
89	Large-billed Crow	*Corvus macrorhynchos*	*	*	*	*	*	*
90	Large-pied Wagtail	*Motacilla maderaspatensis*	*	-	-	-	*	-
91	Large Tailed Night Jar	*Caprimulgus macrurus*	-	*	-	-	*	*
92	Large Woodshrike	*Tephrodornis gularis*	*	-	-	-	*	-
93	Laughing Dove	*Streptopelia senegalensis*	*	-	-	-	-	-

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
94	Lesser Kestrel	*Falco naumanni*	-	-	-	-	*	-
95	Little Cormorant	*Phalacrocorax niger*	*	-	-	-	-	*
96	Little Egret	*Egretta garzetta*	*	-	-	-	*	*
97	Long-billed Vulture	*Gyps indicus*	-	-	-	-	*	*
98	Long-tailed Minivet	*Pericrocotus ethologus*	-	-	*	-	*	-
99	Long-tailed Shrike	*Lanius schach*	*	-	-	-	-	-
100	Maroon Oriole	*Oriolus trailii*	-	-	-	-	*	-
101	Orange-headed Thrush	*Zoothera citrina*	*	-	-	-	-	-
102	Oriental Magpie Robin	*Copsychus saularis*	*	*	*	-	*	*
103	Oriental-pied Hornbill	*Anthracoceros albisrostris*	-	-	-	-	*	*
104	Oriental Scops Owl	*Otus sunia*	-	-	-	-	*	-
105	Oriental Turtle Dove	*Streptopelia orientalis*	*	-	-	-	*	*
106	Oriental White Eye	*Zosterops palpibrosus*	*	*	*	*	*	*
107	Pea Fowl	*Pavo cristatus*	*	*	-	-	*	*
108	Pied Bushchat	*Saxicola caprata*	*	-	*	-	*	*
109	Pied-crested Cuckoo	*Clamator jacobinus*	*	-	-	-	-	-
110	Plain Flowerpecker	*Dicaeum concolor*	-	-	-	-	*	-
111	Plum-headed Parakeet	*Psittacula cyanocephala*	*	*	*	-	*	-
112	Plumbeous Water Redstart	*Rhyacornis fuliginosus*	*	-	-	-	*	*
113	Puff-throated Babbler	*Pellorneum ruficeps*	*	*	*	*	*	*
114	Purple Sunbird	*Nectarina asiatica*	*	*	*	*	*	*
115	Red-billed Blue Magpie	*Urocissa erythrorhyncha*	-	*	*	-	*	-
116	Red-collard Dove	*Streptopelia tranquebarica*	*	-	-	-	-	-
117	Red-headed Vulture	*Sarcogyps calvus*	*	-	-	-	-	*
118	Red Jungle Fowl	*Gallus gallus*	*	*	-	*	*	*
119	Red-rumped Swallow	*Hirundo daurica*	-	*	-	-	-	*
120	Red-throated Flycatcher	*Ficedula parva*	-	-	-	-	*	-
121	Red-vented Bulbul	*Pycnonotus cafer*	*	*	*	*	*	*
122	Red-wattled Lapwing	*Vanellus indicus*	*	-	-	-	*	*
123	River Lapwing	*Vanellus duvauceilli*	*	-	-	-	*	*
124	River Tern	*Sterna aurantia*	*	-	-	-	-	*
125	Rose-ringed Parakeet	*Psittacula krameri*	*	*	-	-	*	*

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
126	Rufous-bellied Niltava	*Niltava sundara*	-	-	-	-	*	*
127	Rufous Treepie	*Dendrocitta vagabunda*	*	*	*	-	*	*
128	Rusty-cheeked Scimitar Babbler	*Pomatorhinus erythrogenys*	*	*	*	-	-	*
129	Scaly-breasted Munia	*Lonchura punctolata*	*	*	*	-	-	*
130	Scarlet Minivet	*Pericrocotus flammeus*	-	-	-	-	*	*
131	Shikra	*Accipiter badius*	*	-	-	-	*	*
132	Small Minivet	*Pericrocotus cinnamomeus*	*	-	-	-	*	-
133	Small Niltava	*Niltava macgrigoriae*	-	-	-	-	*	-
134	Small Partincole	*Glareola lactea*	*	-	-	-	-	-
135	Spangled Drongo	*Dicrurus hottentotus*	*	*	-	-	*	-
136	Speckled Piculet	*Picumnus innominatus*	-	*	-	-	-	*
137	Spotted Dove	*Streptopelia chinensis*	*	*	*	*	*	*
138	Stork-billed Kingfisher	*Halcyon capensis*	-	-	-	-	*	*
139	Streaked Laughing Thrush	*Garrulax lineatus*	-	-	*	-	-	-
140	Striated Prinia	*Prinia criniger*	-	-	*	-	-	-
141	Thick-billed Flowerpecker	*Dicaeum agile*	-	-	*	-	*	-
142	Tickle's Flycatcher	*Cyornis tickelliae*	-	*	-	-	*	-
143	Verditer Flycatcher	*Eumyias thalassina*	*	*	*	*	-	-
144	Wall Creeper	*Tichodroma muraria*	-	-	-	-	*	*
145	Wedge-tailed Green Pigeon	*Treron sphenura*	-	-	-	*	-	-
146	White-capped Water Redstart	*Chaimarrornis leucocephalus*	-	-	-	-	*	-
147	White-bellied Drongo	*Dicrurus caerulescens*	-	-	-	-	*	-
148	White-breasted Water Hen	*Amaurornis akool*	*	-	-	-	-	-
149	White-browed Fantail Flycatcher	*Rhipidura aureola*	*	-	-	-	*	*
150	White-browed Scimitar Babbler	*Pomatorhinus schisticeps*	*	*	*	*	-	-
151	White-browed Wagtail	*Motacilla maderaspatensis*	*	-	-	-	-	-
152	White-rumped Shama	*Copsychus malabaricus*	-	-	-	-	*	-
153	White-rumped Vulture	*Gyps bengalensis*	*	-	-	-	-	*
154	White-tailed Stonechat	*Saxicola leucura*	*	-	-	-	-	-
155	White-throated Fantail Flycatcher	*Rhipidura albicolis*	*	*	*	-	*	-
156	White-throated Kingfisher	*Halcyon smyrnensis*	*	-	-	*	*	*
157	White Wagtail	*Motacilla alba*	*	-	-	-	*	-

S.No.	Common Name	Scientific name	PWLS	NWLS	NRF	RWS	SWLS	CWLS
158	Wire-tailed Swallow	*Hirundo smithii*	*	-	-	-	*	*
159	Yellow-bellied Fantail Flycatcher	*Rhipidura hypoxantha*	*	-	-	-	*	*
160	Yellow-eyed Babbler	*Chrysomma sinense*	*	-	-	-	-	*
161	Yellow-footed Green Pigeon	*Treron phoenicoptera*	*	-	-	-	*	*
	Grand Total		111	47	42	31	107	86

Legends:

1. **SWLS**: Simbalbara Wildlife Sanctuary
2. **PWLS**: Pong Dam Wetland Sanctuary
3. **NWLS**: Naina Devi Wildlife Sanctuary
4. **NRF**: Nahan Reserve Forest
5. **RWS**: Renuka Wildlife Sanctuary
6. **CWLS**: Chilla Wildlife Sanctuary

*: Present
-: Absent

12. S&T benefits accrued:

(i) List of Research publications arising out of the Project:

Field Guide – One

Tiger Beetles – A Field Study in the Shivaliks of Himachal Pradesh.

Butterfly Posters - Two

Common Butterflies of the Shivaliks of Himachal Pradesh.

Paper – One

Swati Kittur, Padmawathe, R., Uniyal, V.P. and Sivakumar, K. 2006. Some observations on butterflies of Simbalbara Wildlife Sanctuary, Himachal Pradesh. *Indian Forester*, Vol. 132, December, 2006, No. 12 (a), 116-122.

Abstract Published in Conference Proceedings - Two

(a) Uniyal, V.P., Bhargav, V., Kittur, S and Sivakumar, K. 2006. Assessing Tiger Beetles (Cicindelidae) as Indicator in Protected Forest Areas of Shivalik Landscape. National Symposium on Role of Applied Zoology in Food Production and Human Health at MS College, Saharanpur, U.P. (23 December 2006).

(b) Bhargav, V.K. and Uniyal, V.P. 2007. Diversity Patterns of Butterflies (Lepidoptera) in protected areas of Shivalik Landscape, Himachal Pradesh. National Seminar on Bio-diversity of Himalayan States: With Special Reference to Uttarakhand at Department of Zoology and Environmental Sciences, Gurukul Kangri University, Haridwar, U.K.(18 March 2007).

(ii) Manpower trained in the project

(a) Research Scientists or Research Associates: -------------Nil---------

(b) No. of Ph.D. Registered – **One**

Thesis title "**Assessing the potential role of Coleoptera as bioindicators in Simbalbara Wildlife Sanctuary, Himachal Pradesh**" at Saurashtra University (Reg. no. **3430**) under supervision of Dr. V.P. Uniyal (Supervisor) and Dr. K. Sivakumar (Co-supervisor) at Wildlife Institute of India.

(c) Other Technical Personnel trained: - Two

(iii) Patents taken, if any:

13. Financial Position

S.No	Financial Position / Budget Head	Funds Sanctioned	Expenditure	% of Total cost
I	Salaries/ Manpower costs	6,44,800	4,62,105	33.46
II	Equipment	2,16,000	2,09,184	15.14
III	Supplies & Materials	50,000	1,41,191	10.22
IV	Contingencies	90,000	50,728	3.67
V	Travel	1,50,000	2,06,142	14.92
VI	Overhead Expenses	2,30,160	3,11,610	22.56
VII	Others, if any	-	-	
	Total	13,80,960	13,80,960	**99.97**

14. Procurement / Usage of Equipment

(a)

S. No.	Name of Equipment	Make / Model	Cost (FE / Rs.)	Date of Installation	Utilization Rate (%)	Remarks regarding maintenance / breakdown
1.	Binoculars (Two nos.)	Minolta (7X35)	12,000	-	100	None
2.	Triocular Stereo zoom Microscope (One no.)	Carton DSZ-45T	1,12,320	04 October 2004	100	None
3.	GPS-12 (One No.)	Garmin	16,120	25 August 2004	100	None
4.	Insect Cabinet and Boxes	Rescholar	47,156	01 October 2004	100	None
5.	Field Collection Items	-	21,588	-	100	None

(b) Plans for utilizing the equipment facilities in future: **Transferred to another DST Project.**

a.___________________________

b.___________________________ (Principal Investigator)

(Co-Investigator)