

3. Biodiversity Conservation and Ecological Security

Biodiversity is the variety of life on earth and, a steady stream of ecosystem services supported and maintained by it is essentially required for the ultimate benefit of human welfare and survival. ICFRE is actively engaged in a variety of activities in the area of biodiversity conservation and ecological security including participation in national and international workshops, meetings, symposia, seminars etc, observing International Biodiversity Day, capacity building through trainings, awareness and extension programmes on biodiversity and its conservation, organizing seminars/workshops on biodiversity related issues, publication of biodiversity related books/brochures, etc.

3.1 Biodiversity Conservation

Studies on Taxonomy of the Family Eulophidae (Hymenoptera: Chalcidoidea) present in National Forest Insect Collection (NFIC) except Doon Valley.

NFIC holds a lot of unidentified parasitoid fauna reared from various forest insect pests and general sweep collection both in dry and wet conditions. Alcohol preserved collections were sorted out for eulophids. In the present work, wet collections from Uttarakhand, Punjab and Karnataka were studied. Specimens were air dried and card mounted; taxonomically important parts of specimens like antenna and wings were dissected and permanently slide mounted in Canada balsam. Identification work on species collected from Sitabani (Ram Nagar) and Mandal localities in Uttarakhand was carried out and following species identified as *Aprostocetus* spp. *Pediobius* spp., *Tetrastichus tunicus* and *Tetrastichus* spp. From Punjab, parasitic eulophid material was identified as *Diglyphus* sp.1 and *Diglyphus* sp. 2. Identified new species of *Aroplectrus* collected from Karnataka and its antenna and wings were mounted on a slide. Its head, thorax, propodeum, wings and antenna were photographed for taxonomic details, using automontage imaging system.

Parasitic Hymenoptera collected from the tree canopy of *Vateria indica*, preserved in alcohol was air dried and 30 specimens of Eulophidae were card mounted and labelled. Ten Eulophid species collected from Tamil Nadu were also card mounted and identified as *Elachertus* spp, *Tetrastichus* sp., *Pediobius elasmii*, *Pediobius* sp.1, *Pediobius* sp. 2, *Platyplectrus* sp., *Aroplectrus* sp., *Euderus* sp. and *Aprostocetus* spp. Following 39 holotypes and paratypes of Eulophidae were studied at Western Ghat Regional Station of Zoological Survey of India, Calicut, Kerala: *Elachertus adimalicus*, *E. malabaricus*, *E. lanotus*, *E. nedumbassericus*, *E. kashmiricus*, *E. propodiatu*s, *E. dericus*, *E. kainophanestus*, *E. nuperus*, *E. jurus*, *Euplectrus stoms*, *E. umbrocaxatus*, *E. yaloticus*, *E. zammoorini*, *E. mangericus*, *Cirrospilus acadicus*, *C. abalus*, *C. brevicorpus*, *Notanisomorphella manjaerica*, *Pnigalio anoti*, *Platyplectrus baricus*, *P. ericatus*, *P. daricus*, *P. nilumburicus*, *Hemiptarsenus orizae*, *H. banati*, *H. aditu*, *Sympiesis acicus*, *S. kazmii*, *S. hiplopsis*. *Aroplectrus contheylae*, *Deutereulophus tunctatus*, *Diglyphomorphomyia ebifurcata*, *D. kairali*, *D. sholayarica*, *D. plodica*, *D. scolofronta*, *D. nexius* and *D. sringeriensis*.

Studies on Taxonomy of the Family Encyrtidae (Hymenoptera: Chalcidoidea) present in National Forest Insect Collection (NFIC) except Doon Valley

Described a new genus and three new species of Encyrtidae: The new genus *Noyesencyrtus* was compared with *Acerphagoidea* and found different from it. It was also compared with the identified material of *Zaommoencyrtus submicans* obtained on loan from Natural History Museum, London and was found different from it. *Noyesencyrtus brachyoculus* was the type species of this new genus. Another species, new to the science, *Psyllaephagus kundapurensis*, was compared with *P. Mesohomotomae* Singh and found to be completely different species. Third species, *Ooencyrtus hayatii* sp. nov. was

compared with closely related species *O. macula* and *O. nanus* and was found different from both. Following species of encyrtids identified: *Blepyrus insularis*, *Trechnites aligarhnsis*, *Syrphophagus* sp., *Leptomastix* sp. and *Encyrtus* sp. from the collection from Tamil Nadu; *Psyllaephagus garuga*, *Psyllaephagus phacopteron*, *Trechnites aligarhensis* and *Metaphycus zabratus* from Uttarakhand *Psyllaephagus viridis*, *Syrphophagus aeruginorum* and *Copidosoma* sp. collected from Punjab *Psyllaephagus viridis* was a new record from India. They were dried, card and permanent slide mounted. Their photographs were also taken with automontage system.

Studies on thrips of forest and medicinal plants, problems caused by them and their management in Uttarakhand.

Survey of thrips was carried out from Gwaldam, Bageshwar, Karanprayag, Gaucher, Herbal Garden (Muni ki Reti), Rishikesh, Forests of Thano, Timali and Karvapani, Chiriyapur Nursery, Kalsi Nursery, Yamkeshwar (Pauri Garhwal), NWFP nursery and Botanical Garden F. R. I. Campus.

Thrips of forest tree species and medicinal plants were collected from various nurseries and forest plantations of upper, middle and lower Himalayas including Shivalik range of Uttarakhand. *Gynaikothrips uzeli* was collected from *Schefflera actinophylla*; *Sciotothrips dorsalis* and *Thrips tabaci* from *Plumbago*



Anaphothrips flavicinctus

zeylanica (Chitrak); *Thrips flavus* from *Ocimum sanctum*; *Mycterothrips ravidus* from Eucalyptus galls; *Thrips tabaci* from *Terminalia chebula*; *Haplothrips gowdeyi* and *Scirtothrips dorsalis* from *Aloe barbadensis*. *Lefryothrips lefroyi*, from *Tagetes erecta*. *Anaphothrips flavicinctus* from *Perilla frutescens*. *Taeniothrips major* from *Murraya koenigii* and *Ecacanthothrips sanguineus* from *Pterospermum acerifolium*. *Scirtothrips dorsalis* and *Hoplothrips gowdeyi* were collected from *Aloe barbadensis*, *Ginaikothrips uzeli* was collected from *Schefflera actinophylla* (Umbrella plant), *Scirtothrips dorsalis* & *Thrips tabaci* from *Plumbago zeylanica* (Chitrak), *Anaphothrips flavicinctus* (Karny) from *Perilla frutescens* (Bhanjeera), *Thrips tabaci* was carried out on *Terminalia chebula*, *Mycterothrips ravidus* was collected on Eucalyptus galls. Identification of thrips collected from the host plants, *Rhus cotinus*, *Calendula officinalis*, *Ocimum sanctum*, *Mimosa pudica*, *Calendula officinalis*, *Artemisia roxburghiana*, *Sida cordifolia*, *Pogostemon*, *Nerium indicum* and *Terminalia arjuna* is in progress.

Digitization of the type material (E-typing) present in National Forest Insect Collection, F.R.I., Dehradun, using Auto -Montage 3-D imaging system.

NFIC currently comprises about 1800 type species of different orders. Faisal *et al.* (2013) have documented buprestid type collections deposited in NFIC. Type collection of two other families, Carabidae and Cleridae, have also been updated and documented by Faisal & Singh (2014) and Faisal *et al.* (2014), respectively. Original descriptions of type species present in NFIC were collected from different sources including books, journals and monographs. The information that was available in the hard copy was first digitized using a scanner and then converted into PDF format and entered digitally into the database which was developed in windows application.

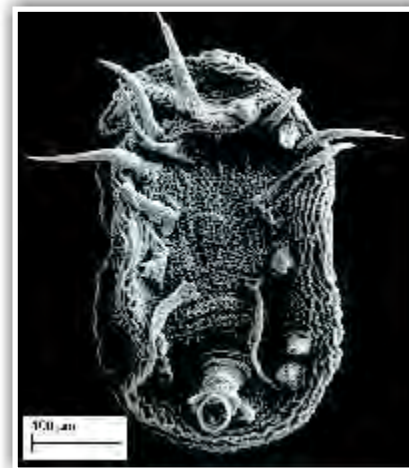
The various records of type specimens have also been entered into the database which

includes many relevant information such as name of species, its accession number, collection data, holotype/ paratype, male/ female, taxonomic position, hosts, collector, identifier etc, which were earlier hand written in various records like accession register record, index cards etc. The information on scientific name of the specimen, collection locality, collection date, collector name(s), etc given for each species was taken from original hand written labels and where ever necessary, corrected with original description or published articles. The digital photographs of type specimen were taken by Automontage 3-D imaging system mounted on Olympus SZX-16 stereozoom microscope. The pictures of these associated handwritten data labels of specimens have also been captured with the help of digital camera.

Morphological taxonomy of the family Aleyrodidae Westwood (Hemiptera: Sternorrhyncha) of India: revisions of the genera and species.-

A total of 120 plants infested with whitefly puparia were collected from natural forests of Uttar Pradesh and Uttarakhand. A total of 468 permanent mounts of whitefly puparia were prepared and remaining 45 samples were preserved in 80% ethanol and 10 on dry leaves. Three pest species i.e. *Aleurodicus dispersus* Russell, *Aleurolobus barodensis* (Maskell) and *Bemisia tabaci* (Gennadius) and adults (71 males, 18 females) of *Singhiella bicolor* (Singh) were also mounted. Thus twenty one species of whiteflies belonging to 13 genera were identified.

The genus, *Acanthaleyrodes* Takahashi was reported for the first time from India. A new species of the genus *Acanthaleyrodes* infesting *Bridelia retusa* has been described. The holotypes of 24 species of 8 genera, and 116 microscopic slides bearing unidentified whiteflies were taken on loan from NPC, New Delhi. Of these, one new species of the genus *Tetraleurodes* was described. Holotype was designated for *Dialeurolonga fici* David and Subramaniam. The type specimens (50 holotypes and 3 paratypes) of 51 species of the genera *Acanthaleyrodes* Takahashi, *Aleuroclava*



Scanning electron micrograph of ventral side of whitefly pupa, *Acanthaleyrodes* sp., found infesting leaves of *Bridelia retusa*

Singh and *Tetraleurodes* Cockerell were examined which include 16 species from National Forest Insect Collection - Forest Research Institute, Dehradun and 33 species from National Pusa Collection, IARI, New Delhi. A total of 223 Camera Lucida drawings of 51 species were made, which includes 51 major and 172 minor drawings of important taxonomic characters and a total of 230 microphotographs of 51 species were taken. In addition four species were taken on loan from Animal and Plant, Quarantine Agency, South Korea and 8 species from the Natural History Museum, London.

SEM studies have been carried out for eight species and their microphotographs taken. The studied species were: *Acanthaleyrodes* sp and *Crescentaleyrodes semilunaris* (Corbett), *Aleuroclava murrayae* (Singh), *Dialeuropora decempuncta* (Quaintance & Baker), *Viennotaleyrodes megapapillae* (Singh), two species of genus *Aleuroclava* and *Trialeurodes vaporariorum* (Westwood). Microphotographs of biological stages have been taken for two pest species, *Neomaskellia bergii* and *Aleuroclava jasmini* (Singh).

Butterfly diversity in relation to landscape changes in the Walayar Valley, at Palakkad Gap in the Western Ghats

The diversity of butterflies was studied in Walayar Valley, covering different forest types /landscape elements occurring both in Kerala and part Tamil Nadu. The forest types covered in Kerala part included semi-evergreen forests, moist deciduous forests, dry deciduous forests, riparian forests and grasslands. Teak was the major forest plantation species available in Kerala part of the valley, which was also taken up for the study. In Tamil Nadu part, the forest types covered were dry deciduous forests and thorny scrub. Tamarind was the major forest plantation species raised in Tamil Nadu part of the valley. Two limestone mine areas located in the valley within the forest areas and agricultural landscapes available adjoining the forest areas were also studied.

About 65 species of butterflies were recorded from moist deciduous forests, 41 species from semi-evergreen forests, 49 species from dry deciduous forests, 28 species from riparian forests, 24 species from grasslands and 22 species from thorny scrub forests. The teak plantations raised in the forest areas and the agricultural areas located in the forest fringes were found to harbour a good number (over 45) of species, while the Tamarind plantations contained about 35 species. The mined out areas were found to be very poor in butterfly diversity. Altogether, about 110 species of butterflies were recorded from the Walayar Valley. Occurrence of some of the endemic, rare and endangered species of butterflies like Malabar Tree Nymph (*Idea malabarica*), Southern birdwing (*Troides minos*), Malabar banded peacock (*Papilio budha*) and Great evening brown (*Melanitis phemida*) and several species included in the Schedules I & II of the Wildlife (Protection) Act 1972 in the study area, was very interesting.

Studies on the species diversity of whiteflies (Aleyrodidae: Homoptera) and their natural enemies in Mangrove habitats of India".

Surveys were conducted in mangrove habitats of south India viz., Muthupet (Tamil Nadu), Vypeen Island (Kerala), Udupi, Karwar and Honnawar (Karnataka), Coringa (Andhra

Pradesh) Chorao (Goa) and Thane (Maharashtra). 11 species of mangrove plants were found infested with whiteflies. All the whiteflies were identified at the genus level. In addition, 20 species of coccinellids and 13 species of spiders were found feeding whiteflies in the mangrove habitats.

Ecological studies on the distribution patterns and food plant resources of butterflies along altitudinal gradients in different forest ecosystems of the Eastern Himalaya (Arunachal Pradesh)

Surveys were carried out in forest areas of Arunachal Pradesh covering Namdapha and Pakke Tiger Reserves and Dibang Valley district during the year and data were collected on 60 more species of butterflies. Database being prepared on 365 species of butterflies sampled

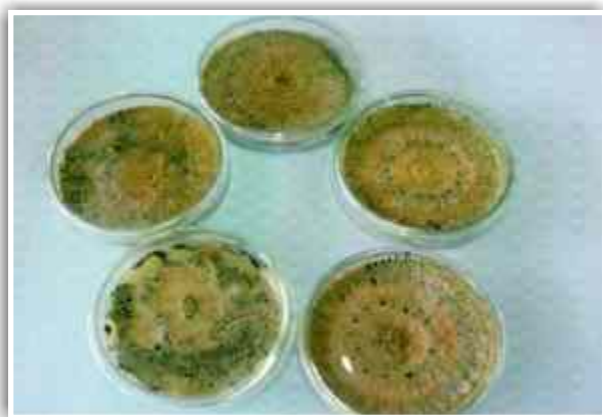


Field surveys being carried out in Namdapha Tiger Reserve (bottom) and the north-eastern endemic butterfly- the Jungle Glory, *Thaumantis diores* in Namdapha (top)

so far from different forest ecosystems in 13 districts of Arunachal Pradesh' and data for each species were being incorporated in the GIS platform at RFRI. As project extension component, a three days training programme was organized for Forest Officers of 6 North-Eastern states on "Identification, Ecological values of butterflies and potential of butterfly's inclusive ecotourism as a source of livelihood in north eastern India" from 3 to 5 March 2014. A poster entitled -'Butterflies of North-east India- Butterfly Inclusive Ecotourism', was prepared and published.

Genetic diversity of *Trichoderma* strains prevalent in Forest types of North Eastern India and Pure cultures of *Trichoderma* species isolated from different rhizosphere soil samples

Field tours to Mokokchung, Kohima and Meghalaya were conducted for the collection of rhizospheric and non rhizospheric soil samples. A total of 150 soil samples were collected. Using soil dilution plate technique, *Trichoderma* strains were isolated. The isolated *Trichoderma* species



Pure cultures of *Trichoderma* species isolated from different rhizosphere soil samples

were identified as *T. asperellum* and *T. harzianum* on the basis of microscopic studies. Isolated *Trichoderma* species was found effective against *Curvularia* species. and *Fusarium* species. in dual culture and field testing.

Screening, identification and preparation of a comprehensive check- list of the Lepidopteron fauna of Sasan Gir National Park of Gujarat state

Periodical surveys (six) had been conducted in the Gir Wildlife Sanctuary (GWS) in order to collect samples of butterflies and moths in hundred five locations. Light trapping method was followed for moth collection in the thanas of GWS. The checklist of the lepidopteron fauna recorded and identified from Gir showed that Pieridae was the most dominant family, followed by Nymphalidae, Papilionidae, Lycaenidae and Hesperidae in GWS. For the moth population, the most dominating family was Noctuidae, followed by Arctiidae, Geometridae, Sphingidae, Lymantridae, Limacodidae, Lasiocampidae, Hyblaeidae, Drepanidae, Uraniidae and Notodontidae. Identified 21 species of Nymphalidae, 34 species of Pieridae, 13 species of Lycaenidae, 14 species of Papilionidae, 5 species of Hesperidae as butterfly fauna. Whereas, 13 species of Noctuidae, 9 species of Arctiidae, 7 species of Geometridae, 6 species of Sphingidae, two species each of Lymantridae and Limacodidae and, 1 species each of Lasiocampidae, Hyblaeidae, Drepanidae, Uraniidae, Notodontidae have been identified as moth species from different Gir Wildlife Sanctuary. The host range in the form of nectar plant species and larval food plants, preferred by the butterflies and moths have been identified in sixty numbers. The most common plant species being *Tridax procumbens*, *Celosia argentea* and *Lantana camara*. Besides, plants of family Fabaceae and Asclepiaceae were frequently visited by the butterflies. Screening and listing of most important rare and endangered species of lepidopteron fauna showed that *Castalius rosimon* was enlisted in Schedule-I, *Hypolimnas misippus* in Schedule-I and II and *Euploea core* in Schedule-IV of the Indian Wildlife Protection Act, 1972 (red data list). Influence of abiotic factors causing changes in natural population of butterflies and food habits studied. and found that monsoon to late winters was the preferred season for the lepidopteron fauna. The interaction of host-plant species, species abundance, richness

and evenness were calculated for each habitat with grassland habitat was found the best.



Appias nero galba
(Pieridae)



Junonia iphita
(Nymphalidae)



Celaenorrhinus asmara
(Hesperiidae)



Zetides sarpedon teredon
(Papilionidae)



Tridrepana albonotata
(Drepanidae)



Hippotion boerhaviae
(Sphingidae)

Diversity of butterflies in Sasan Gir National Park of Gujarat

Study on grasses of Uttarakhand and Himachal Pradesh

Exploration-cum-collection tours were conducted to collect the grass specimens in the Kangra and Chamba Districts of Himachal Pradesh and Khirsu and Pauri in Uttarakhand. Ca. 250 grass specimens were collected from the visited areas. Identification of the collected specimens was in process. Some of the identified specimens prevalent in the study area were *Apluda mutica*, *Andropogon monticola*, *Arundinella benghalensis*, *A. nepalensis*, *Arundo donax*, *Avena fetua*, *Coix lacrym-jobi*, *Cymbopogon distans*, *Digitaria ciliaris*, *D.*

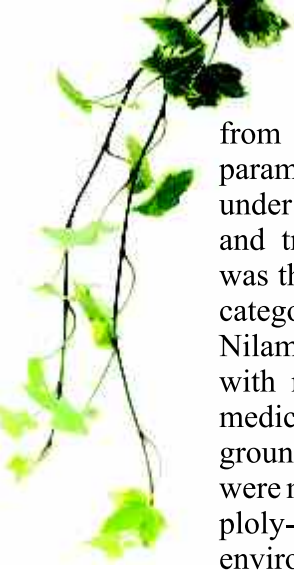
sanguinalis, *D. stricta*, *Echinochloa colonum*, *E. crus-galli*, *E. procera*, *Eleusine compressa*, *Eragrostis nigra*, *E. tenella*, *E. unioloides*, *E. ciliansis*, *E. minor*, *E. trimula*, *Setaria sphacelata*, *S. viridis*, *S. glauca*, *Isachne albens*, *Poa pratensis*, *Pennisetum purpureum*, *Cenchrus ciliaris*, *Bromus unioloides*, *Paspalum flavidum*, *Thysoleana maxima*, *Heteropogon contortus*, *Hemarthria altissima*, *Rottboellia cochinchinensis*, *Eleusine indica*, *Phalaris minor*, *Dactylis glomerata* etc. 250 herbarium specimens are prepared and others were in the process.

The study of biology and conservation of endemic plants of Kalakad Mundanthurai Tiger Reserve, Tamil Nadu

Intensive field surveys were carried out to locate five endemic species and to study their distributions, association, population and phenological status by repeated perambulation in the Kalakad Mundanthurai Tiger Reserve (KMTR), Tamil Nadu. Phenological observations, distribution and recording of plant associations for the species *Eugenia singampattiana*, *Phyllanthus singampattianus*, *Palaquium bourdillonii* and *Sonerilla kanyakumariana* were carried out. Only few individuals could be recorded in case of *Sonerilla kanyakumariana* in KMTR. Vegetative propagation and seed germination trials were also conducted and among the species tried, only *Phyllanthus singampattiana* showed successful rate for root formation. Seed germination trials were conducted repeatedly but no encouraging results obtained for any of the species tried. Soil samples were collected and analyzed for various physical and chemical properties in addition to phytosociological analysis of the associated species.

Impact of Forest plantation on ground flora diversity under soil characteristics including the prescription of management practices

Enumerated ground flora diversity in two teak plantations in Sadivayal, collected soil samples and analyzed them for soil micro flora and fauna soil properties. Analyzed the data ground flora



from all the plantations for phytosociological parameters. A total of 47 species were enumerated under different categories such as herbs, shrubs and tree regeneration. *Oplismenus compositus* was the dominant herb species found under the category. Teak plantations in Sadivayal and Nilambur supported good number of ground flora with more than 60% of them having good medicinal values. The study indicated that if the ground flora and regeneration under plantation were managed properly, it could be converted into poly-crop stand especially in protected areas for environmental services.

Structure, diversity and regeneration studies in permanent preservation plots in moist deciduous and evergreen forests of Western Ghats in Karnataka

This study was undertaken to throw some light on structure, diversity and regeneration status in permanent preservation plots of tropical Wet Evergreen Forests in Kotlekan, Uttar Kannada district and in moist deciduous forests of Western Ghats in Karnataka in Karka, Bhagavati, and Kuligi in Dharward and Belgaum districts. Secondary data in PPP records of these five sites was utilized as baseline data and past data on history and management. Parameters related to structure, diversity and regeneration were quantified. Each plot (between 3.0 and 3.7 ha. in size) was completely enumerated. Later, secondary data recorded since 1936 at periodical intervals, were collated and compared. Trends revealed considerable changes in tree density, basal area and girth increment. There were discernible and unique changes in the diversity as revealed by various indices such as Species richness, Shannon's index, Evenness index, Similarity index and species composition. Dominance relationship between species, with respect to density and basal area, also changed within this time frame. Constraints in the establishment of regenerates at pole stage in some species were noticed. Overall changes in species composition, over the past 75 years could not be attributed to normal vegetational succession trends alone. If these trends truly reflect the current status of forests in Western Ghats, it could well be a cause for concern.

Investigation on floristic diversity in teak plantation of various age groups in Barnwapara Project division, Raipur, Chhattisgarh.

Plantations promote understory regeneration by shading out grasses and other light demanding species, changing under storey microclimates, improving soil properties and increasing vegetation structural complexity. Studies were carried out to determine the changes in plant diversity and soil properties in teak plantations of different ages. Phyto-sociological studies were undertaken in teak plantations by laying out quadrats in 25 compartments of Rawan, Raikera and Sirpur Range of Barnawapara Project Division, Raipur Chhattisgarh. 48 trees, 12 shrubs and 36 species of herbs were recorded from these plantations.

The results indicated species richness and diversity in tree layer of the plantations increasing with the age of plantations. The dominant trees of Rawan range were *Tectona grandis*, *Lagerstroemia parviflora*, *Cleistanthus collinus*, *Terminalia tomentosa*, *Buchanania lanzan*, *Pterocarpus marsupium*, *Madhuca indica*, *Diospyros melanoxylon*, *Anogeissus latifolia*, *Bridelia retusa*, *Semecarpus anacardium*, *Schleichera oleosa*, *Lannea coromandelica*, *Terminalia bellerica*, *Careya arborea*, *Cassia fistula*, *Grewia tiliifolia*, *Ziziphus xylopyra* and *Bauhinia purpurea*. In Raikera Range, dominant tree species were *Tectona grandis*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Diospyros melanoxylon*, *Cleistanthus collinus*, *Madhuca indica*, *Chloroxylon swietenia*, *Lannea coromandelica* and *Wrightia tinctoria*. In Sirpur Range, dominant species were *Tectona grandis*, *Chloroxylon swietenia*, *Lagerstroemia parviflora*, *Terminalia tomentosa*, *Anogeissus latifolia*, *Madhuca indica*, *Cleistanthus collinus*, *Gardenia latifolia* and *Bridelia retusa*

Species richness and diversity in herb layer was found to be higher in younger plantations. Physico-chemical properties of soil showed no significant changes under different aged plantations, This completed project is under writing.



Team at work in Barnwapara Forest Division



Lasiosiphon eriocephalus



Teak plantation with under growth in Barnwapara



Maytenus rothiana

Monitoring the impact of Climate variables on plant diversity in Bhimashankar permanent plot of Sub-tropical Hill Forest of Maharashtra

One of the goals of the ecology is to study the succession in the forest community and predict future trends. Permanent preservation plots provide such an opportunity. Studies were therefore conducted on vegetation parameters in Bhimashankar permanent preservation plot of Sub-tropical Hill Forest of Maharashtra. Enumeration of vegetation was carried out in three permanent preservation plots. 30 quadrats of 20x20 m by laying. 120 quadrats of 5mx5m size were laid out for the study of shrubs and saplings along with invasive species and 120 quadrats of 1m x 1m for herbs and grasses .



Callicarpa tomentosa



Xantolis tomentosa
Prominent flora found in compartment 200A of Bhimashankar

Vegetation change matrix, determining temporal change in the structure and composition of the vegetation in preservation plots of Bhimashankar was prepared. 14 new species (with no historical record) were recorded from the preservation plots. Regeneration status of dominant trees was determined using size class distribution curves. Based on the study, succession trend and future trends in vegetation pattern of the preservation plot was determined. The completed project is under the process of writing.

Impact of *Prosopis juliflora* on biodiversity, rehabilitation of degraded community lands and source of livelihood for people Rajasthan

Extensive studies were carried out in Bhilwara, Dholpur, Jhalawar, Jodhpur, Kota, Rajsamand and Sawai-madhopur districts of Rajasthan to study the impact of *P. juliflora* on biodiversity, rehabilitation of degraded lands and source of livelihood. 42 exotic & indigenous floral diversity found associated with *P. juliflora*. Thirty five species of invertebrates including, seed bruchids were found feeding on *P. juliflora*. Eighty two species of vertebrates were also found associated and dependent on *P. juliflora*. The main utilization of *P. juliflora* in the region as fuel wood & for bio-fencing. Pods are utilized by herbivores as food. Leaves were eaten by Hanuman Langurs. The trees utilized by aves including 29 species of raptors for perching. Studies on plant species revealed that both exotic as well as indigenous tree species were growing in the areas of *P. juliflora*. Some of the important tree



Avian species using *P. juliflora* for perching



Prosopis juliflora as a source of fuel wood

Ecological and economical (source of firewood) uses of *Prosopis juliflora*

species documented were; *Acacia nilotica*, *Albizia lebbeck*, *Azadirachta indica*, *Anogeissus pendula.*, *Butea monosperma*, *Dalbergia sissoo*, *Ficus bengalensis*, *Prosopis cineraria*, *Salvadora* spp., *Acacia tortilis* and *Leuceana leucopholea*.

Documentation of sacred groves of Rajasthan and assessment of biological diversity in some of them for improved management and people's livelihoods

Sacred groves (Oran in western Rajasthan) are scattered and do not enjoy protection via a federal legislation. While these lands have not even been declared as forest lands, effective legislation can not be applied in the case of offenders. Developmental activities and encroachments affects community forests. In view of the above, this project has been taken up: (i) to document and assess floral diversity of the important 'sacred groves' in different districts of Rajasthan; (ii) to identify and record faunal diversity countered in the above-mentioned 'sacred groves'; and (iii) to suggest suitable management strategies to increase, diversity and productivity for improved local benefits and climate change adaptation.

A total 118 sacred groves throughout Rajasthan (all districts) were surveyed and their plant and animal diversities recorded. In addition, people's perceptions was also recorded about the

problem and to act up on it. Calculation of diversity variables and Importance Value Index (IVI) indicates that these sacred groves represent varying subgroup of forests. Some of them were not even available in forests. *Salvadora oleoides*, *Capparis decidua*, *Anogeisus serecea*, *Acacia leucophloea*, *Prosopis cineraria*, *Ziziphus* spp. were dominating in arid areas, whereas, *Tectona grandis*, *Anogeissus pendula*, *Acacia nilotica*, *Holoptelia integrifolia*, *Phoenix sysvestris* were dominating in semi-arid regions. Some of the sacred groves were of mixed vegetation category like; *Acacia nilotica* and *P.cineraria* or *Holoptelia integrifolia*; whereas, others were of pure patch of single species like *Anogeisus pendula* in districts covering Aravalli. A combination of *S.oleoides*, *Azadirachta indica*, *Acacia leucophloea* and *P. cineraria* spp. was also observed in Alwar district.

Some of the sacred groves were important habitats even for the birds and wildlife. For example, at village Kala kho (Kalu Das Ji ki Dungari) in Dausa districts, *Anogeissus pendula* was the dominant species. Its over aged trees facing towards up hills have developed cracks. Other interesting observation was availability of large population of parakeets with their nest/ burrow in more than 80% of the trees (burrow ranging from 1- 4 in numbers). Lots of threats are there putting pressures on these valuable common resources that needs effective management with people participation.



Anogeissus pendula sacred grove covering a hill in Dausa



Anogeissus pendula-Daar Devi Oran, Kota

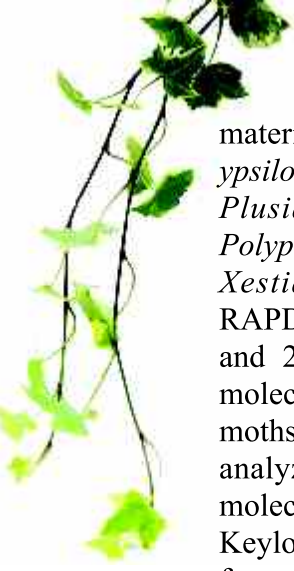


Acacia nilotica species in Alwar

Taxonomy and Molecular Analysis (through RAPD-PCR) of moths (Lepidoptera) of Cold Deserts (Spiti and Leh) of Indian Himalayas

After finalization of the sites for collection of identified faunal elements at Keylong, Pooh, Tabo, Kaza and Leh, necessary ecological observations were recorded and moths were collected, stretched and stored for permanent preservation. Some duplicate specimens were also kept at -20°C for RAPD-PCR study. Morphological study of moths was carried out for their taxonomy and identification.

During the year, remaining data, collected in the past were analyzed including wing preparation. Genitalia of 25 species was also carried out in the laboratory from the preserved



material. Species identified includes i. e. *Agrotis ypsilon*, *G. operculella*, *Y. rorella*, *S. litura*, *Plusia orchalsea*, Diamond back moth, *Polyphaenis confecta*, *Helicoverpa armigera*, *Xestia C-nigrum*, *Ochropleura vallesioca*. RAPD-PCR analysis continued in the laboratory and 20 specimens of moths were treated for molecular analysis. Work on the PCR analysis of moths is in progress including new initiative of analyzing the moths of Cold Deserts for molecular characterization. All four sites i.e. Keylong, Pooh, Tabo, Kaza and Leh were visited for collection of moths. Data on vegetation & environmental factors were also collected. Moths has been collected and stretched and stored for permanent preservation. Some duplicate specimens have been kept at freezing temperature for PCR study.

It was found that all the three species showed the band variance when applied with OLA6 primer whereas, when applied with OLA7 only *Helicoverpa armigera* produced bands. The others did not produce the variance. The results reflects OLA6 as much better primer to carry out the RAPD-PCR studies.

Morphological studies of moths were carried out for taxonomy and identification of moths. A total of 170 specimens of moth (Lepidoptera) species were collected from various localities of cold deserts of Leh and Spiti. 10 species moths identified as *Agrotis ipsilon*, *G. operculella*, *Y. rorella*, *S. litura* *Plusia orchalsea*, Diamond back moth, *Polyphaenis confecta*, *Helicoverpa armigera*, *Xestia C-nigrum*, *Ochropleura vallesioca*. All these species were identified taxonomically and a comparative data of the genetic variance established through RAPD-PCR.

Ecological diversity of Kawal Tiger Reserve in Andhra Pradesh-A benchmark study

Field tours for ecological monitoring of the project site was conducted along with tree inventory study and for preparing check list of

flowering plants, grasses legume fodders and other fodder species. Similarly, direct and indirect evidence of macro fauna population was estimated using standard procedures which were identified. Photographic evidence of specimens collected was done wherever possible.

Networking Projects on Restoration and Reclamation on degraded site (Nodal:FRI)

Monitoring of the changes in flora and fauna in the Reserved Forest along the Thellavagu Nallah, Kothagudem, and A.P was undertaken.

Among tree species, *Pongamia pinnata* was the dominating plant species occurring in the study area with higher IVI. Other tree species found in the area were *Prosopis juliflora*, *Mimosa himalayana*, *Simarouba galuca*, *Syzygium cumini*, *Holoptelea integrifolia*. Among herbs, shrubs and trees *Aristida setacea*, *Waltheria indica*, *Hyptis suaveolens* were dominating in the study area. Various birds such as weaver birds, parrots, grey francholin, koyal, myna were observed during the entire part of the project period. Monkeys, monitor lizard (*Veranus* sp.), Butterflies (*Lepidopteran* sp.) were cited directly. The presence of wild boars was noticed through the symptoms of soil disturbance. The present study showed that, among the plant species, the number of herbaceous species, shrubs and trees had increased to indicate ecological improvement and increased plant diversity.

3.2 Forest Botany

Inventorization, characterization and conservation strategies of selected rare and endangered plant species of India

Rare and threatened species of Uttarakhand were selected for project. Species like, *Ilex pseudo-odorata*, *Catamixis baccharoides*, *Sophora mollis* and *Pittosporum eriocarpum* were studied. Herbarium was consulted to trace location of occurrence of above rare and threatened species. Extensive field survey was carried out in Mussoorie, Jhari Pani, Hathi Paon,

Rishi Kesh and adjoining areas, Rajaji National park etc. Belt transect method was used in the study. *Pittosporum eriocarpum* was found in the Jhari Pani and Hathipaon areas. Population of the species was very much less in the area and were found in the slopy terrain from where seeds of the plants were collected. *Ilex pseudo-odorata* was found in the Hathipaon, only 5 trees could be traced in whole Mussoorie and adjoining areas. *Sophora mollis* was found in the Sahastradhara area but the population was very less. Flowering was observed in the month of March. Seed and stem cutting of above species were collected and planted in polybags in the Botanical Garden for *ex-situ* conservation. Population structure and regeneration potential of *Indopiptadenia oudhensis* was carried out in Champawat Division of Uttarakhand and adjoining areas. Overall good regeneration was observed in the area.

3.3 Ecology & Environment

Ecological study of watershed in Mussoorie Hills (Dehradun)

The study was conducted in protected plantation, degraded plantation, degraded natural forests of Mussoorie area and protected natural forests during summer, rain and winter seasons to understand phytosociological attributes of herbaceous species. Grasses diversity was observed maximum in degraded landscapes. Degraded natural forest was burnt during June 2013 and, therefore, impacted herbaceous plants diversity *vis-a-vis* infiltration capacity. Microclimatic data showed more relative humidity (%) and less temperature (°C) under protected plantation and protected natural forest than that under open land data. For determination of soil moisture in all landscapes, soil samples from the depth of 0-30 cm and 30-60 cm were collected. Results revealed that soil moisture (%) under 0-30 cm depth, from all landscapes, except protected natural forest were more, than that under 30-60 cm depth whereas under protected natural forest it was vice-versa. Infiltration study

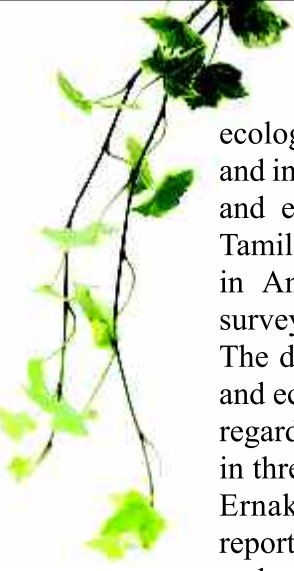
under protected plantation, degraded plantation, degraded natural forest and protected natural forest were carried out during winter season. The rate of infiltration capacity was found in the order of protected natural forest > plantation > degraded natural forest > degraded plantations. Due to forest fire under degraded natural forest during summer, infiltration capacity, during winter got reduced manyfold in comparison to spring season. Hourly infiltration capacity revealed that in 1st hour, infiltration under protected natural forest was 39.17%, 563.58% and 219.80% more than in the protected plantation, degraded plantation and degraded natural forest, respectively whereas during 2nd hour it was 13.17%, 583.13% and 241.57% and during 3rd hour it was 21.67%, 610.98% and 259.67%. Results showed that during 3rd hour the infiltration capacity under protected natural forest was rapid in comparison to 2nd hour and than in the protected plantation, degraded plantation and degraded natural forest. Result also showed that protected natural forest was hydrologically more sound as compared to other forests.

Impact of human induced disturbances on regeneration and population structure of *Rhododendron arboreum* and *Myrica esculenta* in mid-hills of Garhwal Himalaya

Seed germination of *R. arboreum* and *M. esculenta* was recorded higher under open exposed sites than that under thick canopy cover in the field. Seeds of *Rhododendron arboreum* were collected from the field, and stored in laboratory to develop storage protocol. Seed viability of *R. arboreum* was found declining over the years from the date of seed collection. The germination percentage of *R. arboreum* was also found declining from 80-90% to 40-50% over the years from the date of collection /storage of seeds.

Identification of extent of forest lands in forest fringe villages

The major components of the projects were socio economic survey of the selected villages,



ecological survey of the forests area, data storage and interpretation. Therefore, the socio economic and ecological survey work in 10 districts of Tamil Nadu, one district in Kerala and one district in Andaman was done. The data of all the surveyed districts was entered in the Web portal. The draft report with respect to socio economic and ecological survey also has been prepared. As regards Kerala state, the survey has been initiated in three districts viz. Malappuram, Palakkad and Ernakulam. Ecological and socioeconomic reports for 12 districts have also been prepared and sent to FRI.

Study on beneficial microbial interaction with trees in heavy metal polluted sites in Tamil Nadu

Reclamation and rehabilitation of polluted sites is very much essential to save life on the earth. It is necessary to apply an integrated approach, involving suitable chemical and biological amendments such as plants and beneficial microbes, for the successful remediation of heavy metal contaminated soils. In the present study, attempts were made to investigate diversity status of different plant species occurring in and around different industries. Among different plants, the herbaceous plants were found very common in all the study sites, followed by shrub species. Among shrub species, *Calotropis gigantea*, *C. procera* and *Prosopis juliflora* were found in all the study locations. In tannery effluent treatment area at Dindugal, *Suaeda maritima* was found to grow well in the sludge and in the surrounding areas. Status of heavy metal elements was found high in non-rhizosphere soil samples rhizosphere ones in afforested site at Tirupur. Among different study locations, tannery effluent treatment site showed maximum amounts of heavy metals. In this study, total of 137 isolates of PGPRs and other heterotrophic bacteria were isolated from different polluted sites and maintained in the germplasm bank of IFGTB. PGPR isolates, producing highest growth hormone (IAA) and showing maximum phosphate solubilization were

selected for molecular characterization. Genus and species level identification of different PGPR isolates was also done. The sequences of all these isolates were submitted to European Molecular Biology Laboratory (EMBL) and accession numbers obtained. Some of the PGPR isolates viz., *Achromobacter xylosoxidans*, *Micrococcus luteus*, *Bacillus subtilis*, *Azotobacter vinelandii* and *Azospirillum lipoferum* showed maximum production of IAA, ammonia, catalase, P solubilisation and heavy metal tolerant potential under *in-vitro* condition. Efficacy of all the selected PGPR and AM fungi on growth of tannery sludge samples in nursery was also studied. The results of the study indicated that seedlings treated with PGPRs and AM fungi had better growth performance as compared to uninoculated ones (control). The seedlings of *Callophylum inophyllum* and *Casuarina equisetifolia* withstood the presence of tannery sludge samples treated with PGPRs as compared to other tree species. Among different treatments, combined application of PGPRs and AM fungi treated seedlings in tannery sludge samples showed maximum plant growth and survival as compared to other treatments.

Population structure, regeneration status and pollination ecology of *Dalbergia latifolia* and *D. sissoides*

The population status of Dalbergias was assessed in Salem Forest Division (Tamil Nadu) and Nemmara Forest Division (Kerala). In Salem Forest Division, which is situated in the Eastern Ghats, *D. latifolia* alone was present, but, its population was very sparse, with poor height and diameter. The regeneration was also very scanty. The habitats of the species in this Eastern Ghats portion were more or less rocky slopes of the hills. In Nemmara Forest Division, which falls in the Western Ghats, both *Dalbergia latifolia* and *D. sissoides* were found together, in almost equal numbers. There was a preponderance of mature trees of higher girth classes in all the locations studied, with very less number of pole stages and saplings. The regeneration was found scanty.

Phenological studies of both the species were also conducted in the area.

Development of Site Specific Regeneration Augmentation Plan for Potential Degraded Areas in Western Ghats

Experimental trials established at four sites in Attapaddy Reserve Forests (Siruvani, Pudur and Thathengalam) and Silent Valley National Park buffer zone (Panthanthodu) with selected pioneer and canopy species as given in the table.

Wet site (Siruvani & Panthanthodu)	Moist site (Thathengalam)	Dry Site (Pudur)
Pioneer species		
<i>Maesa indica</i>	<i>Helicteres isora</i>	<i>Tarennia asiatica</i>
<i>Macaranga peltata</i>	<i>Macaranga peltata</i>	<i>Dodonaea viscosa</i>
<i>Clerodendrum viscosum</i>	<i>Clerodendrum viscosum</i>	<i>Clausena dentata</i>
<i>Olea dioica</i>	<i>Holarrhena pubescens</i>	<i>Mundulea sericea</i>
<i>Syzygium cumini</i>	<i>Glycosmis mauritiana</i>	<i>Glycosmis mauritiana</i>
Canopy species		
<i>Palaquium ellipticum</i>	<i>Terminalia bellirica</i>	<i>Holoptelia integrifolia</i>
<i>Dimocarpus longan</i>	<i>Haldina cordifolia</i>	<i>Azadiracta indica</i>
<i>Mesua ferrea</i>	<i>Gmelina arborea</i>	<i>Chloroxylon sweitinia</i>
<i>Prunus ceylanica</i>	<i>Xylea xylocarpa</i>	
<i>Euodia lunu-ankenda</i>	<i>Pterocarpus marsupium</i>	

Better survival of pioneer species, *Syzygium cumini* (67%), *Olea dioica* (56%) and *Maesa indica* (70%) in wet sites; *Helicteres isora* (63%) and *Macaranga peltata* (52%) in moist site; *Tarennia asiatica* (64%) and *Dodonaea viscosa* (55%) in dry site was observed. Among canopy species planted, very few individuals of *Melicope lunu-ankenda* and *Dimocarpus longan* in wet site; *Xylea xylocarpa*, *Terminalia bellirica* and


Gmelina arborea in moist site; *Chloroxylon sweitinia* in dry site survived. Growth performances of these species indicate that certain canopy species can be utilized for speeding up of eco-restoration measures in similar degraded forests for the first time. Information on seed handling of different pioneer species has been generated.

Pollination entomology: Dynamics and role of insect pollinators in fruit set of species of Sonneratiaceae and Avicenniaceae in Mangroves of Karnataka

Surveys were conducted in different selected sites located in three forest divisions namely, Karwar, Kundapura and Mangalore on a bimonthly basis during 2011-13 & floral morphology, flowering season, different floral phenomena and pollination biology were studied. Flower visiting insects were collected from five major mangrove species namely *Avicennia officinalis*, *A. alba* and *A. marina* (Avicenniaceae) and *Sonneratia caseolaris* and *S. alba* (Sonneratiaceae), processed and identified. In the present study, a total of 72 species of flower visitors were documented.

Detailed studies were conducted in two species, one from Avicenniaceae (*A. officinalis*) and one from Sonneratiaceae (*S. caseolaris*). The experiments revealed that *A. officinalis* can reproduce through both cross pollination and selfing, with preference for cross pollination. Twenty three species of flower visiting insects belonging to 15 families of four insect orders were found to visit the flowers of *A. officinalis*. The peak insect foraging time was recorded between 6.30 a.m. and 11.30 a.m. Ants were recorded to spend maximum time while foraging whereas as Lepidopterans visited flower for a very short time. Percentage of stigma contact during foraging was found higher in case of Dipterans and visitors belonging to Apidae (Hymenoptera).

S. caseolaris peak flowering was encountered in the months of January, February and March (39%, 62% and 29% respectively). Insect exclusion resulted in very less fruit set in



S. caseolaris. The study revealed that *S. caseolaris* offered both nectar and pollen to the visitors. Eight species of insects belonging to 4 families of 3 orders were recorded as flower visitors of *S. caseolaris*. The peak insect foraging time was recorded between 6.30 a.m. and 10.30 a.m. *Popilla propinqua* spent maximum time while foraging whereas as *Allobaccha amphithae* visited flower for very short time. *Apis dorsata* was found to forage for moderate stretch of time. Percentage of stigma contact during foraging was found higher in case of *Apis dorsata* and *Xylocopa* sp.

Assembling all the information in view of the selected key attributes of flowers and insect visitors, plant- wise major pollinating insects were determined for the selected major Mangrove species of Karnataka coast. A detailed study was done on pollination biology and the role of insects in fruit setting in two major species, *Avicennia officinalis* and *Sonneratia caseolaris* of families Avicenniaceae and Sonneratiaceae. Reproductive biology experiments clearly indicated outcrossing mode of reproduction in both *A. officinalis* and *S. caseolaris*. *A. officinalis* has trace amount of nectar and pollen to attract the visitors. Availability of copious rewards as pollen and nectar helped *S. caseolaris* to attract visitors within short floral life. Members belonging to Diptera and two species of Hymenopterans namely *Trigona* sp. and *Amegilla* sp. were found to be most frequent visitors of *A. officinalis*. Stigma contact was found higher for these species in comparison to the other flower visitors. *Apis dorsata* Fabr. was found one of the chief pollinators of both *A. officinalis* and *S. caseolaris*. *Xylocopa* sp. was recorded as the chief pollinator of only *S. caseolaris*. The project completion report has been submitted.

Population dynamics of threatened medicinal plants species growing in buffer and transition zones of Tadoba –Andheri Tiger Reserve

Matrices have emerged as an important tool to study age structured populations. Simulation and elasticity analysis for population projection matrices help us predict the fate of populations.

The population dynamics of endangered species will help in devising effective conservation strategies. The study was undertaken on population dynamics of two vulnerable species growing in the buffer region of Tadoba Andheri Tiger Reserve.

For the selection of species, surveys were conducted in the villages of buffer zone of Tadoba-Andheri Tiger Reserve. Medicinal plants, harvested by the villagers and local traditional healers were enlisted. Information on the availability of the medicinal plants was also gathered. Based on the survey, two medicinal plants viz., *Uraria picta* and *Andrographis paniculata* were selected for the study. Density of these species in the study area was determined using adaptive cluster sampling. Populations were identified for the study purposes. Permanent plots were marked in belt transect along the gradient in the identified populations. Five permanent quadrats were laid in each population (9 populations). All the individuals in the sample were marked, and monthly growth data were recorded from each quadrat. Seed production of marked individuals in the population was determined, soil samples collected and analyses done for the physicochemical properties. Experiments to determine seed viability and soil seed banking carried out. The population growth rate will be determined with the use of matrix projection models



Marking of permanent plots for the study



Collection of growth and survival data

Conservation, management and utilization of selected rattans of Assam.

Six species of rattans of Assam were selected for the study survey, inventorization and documentation of rattan diversity of Assam; studies on population dynamics and demography; standardization of nursery techniques for multiplication of canes; correlation of soil characters with growth parameters; nutritional analyses of rattan shoots which were duly carried out. Rattan germasm bank and rattan nursery were also established at Rain Forest Research Institute, Jorhat.

During 2013-14, field survey for rattans in North Cachar Hills, Karbi Anglong, Manas National Park and Guwahati Forest Division were carried out and recorded information on the distribution of species, phenology and population dynamic. Herbarium sample collected, were processed. Soil samples (40 no.) collected during survey were analyzed for physical properties-pH, texture, bulk density and chemical properties-macro and micro nutrition.

The nutritional analysis of shoots of *Calamus flagellum* and *C. floribundus* revealed the presence of proteins, carbohydrates, minerals, calories, and dietary fibres in higher amounts in comparison with other leaf vegetables and bamboo shoots, as reported in other edible rattan species. The low level of sodium, negligible amounts of fat, and the presence of high levels of vitamin B complex make rattan shoot more

nutritious. Rattan shoots, used for consumption in India are at present, mostly extracted from the wild. As most of the species were facing severe declines in their natural populations, the cultivation of rattan on farm land and shifting cultivation land not only aids in their conservation but also generates additional sources of income to the rural populace.

Identification of soil-vegetation relations and indicator species for assessment and rehabilitation in lower Aravalli.

Five forest blocks namely, Trisulia, Motimori, Bara Nandra Kho, Sabalia and Borvad situated in Banaskantaha and Motimori districts in Gujarat and Banaswara, Rajasmand and Pali districts in Rajasthan, respectively with annual average



Wrightia tinctoria in Trisulia forests of Ambaji Palanpur, Gujarat



Tectona grandis + *Nyctanthes-arbor-tristis* forest in Motimori in Sabarkantha



Indigofera astragalina at Bara Nandra Kho, Banswara



Anogeissus pendula + *Rhus mysorensis* at Borwad site, Pali

rainfall of 988 mm, 961 mm, 950 mm, 568 mm and 424 mm respectively were studied with objectives: (i) to study physical properties and nutrient status of soil derived from different parent material, and (ii) to study vegetation structure and indicator species on dominant soil types. Based on IVI values, these sites were found dominated by *Wrightia tinctoria*, *Tectona grandis*, *Lanea coromadelica* and *Anogeissus pendula* among tree species and *Nyctanthes arbor-tristis*, *Lantana camara*, *Rhus mysorensis* and *Euphorbia caudicifloia* among the shrubs, respectively. Alph-diversity for herbaceous vegetation for the respective site in 2013 was however, 82, 89, 89, 80 and 60 in which *Hyptis suaveolens* (IVI=29.9), *Apluda mutica* (IVI=57.9), *Apluda mutica* (IVI=76.8),

Heteropogon contortus (IVI=74.5) and *Tetrapogon tenellus* (IVI=54.8) dominated at the respective sites. Gama-diversity of the herbaceous vegetation were however, 142, 144 and 171 in 2011, 2012 and 2013, respectively.

Soil water content remained highest at Bara Nandra Kho site and lowest at Borwad site throughout the study period. Soil pH and electrical conductivity showed variations among the years. Soil organic carbon indicated an increasing trend from 2011 to 2013. Concentrations of $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$ and $\text{PO}_4\text{-P}$ showed variable trends due to variations in soil water availability, but increased to highest in 2013.

Phytoremediation of soil for productivity enhancement during land disposal of effluents

Survey was conducted of effluent disposal along Jojari river basin starting from Nandra Kurd, Doli in Jodhpur District and Bandi starting from Bumadra and ending Nehda Dam in Pali district (before monsoon) to document most efficient phytoremediation species. Thirty eight species were recorded, in the effluent disposal area, out of which 5 species of trees, 4 species of shrubs, 7 species of under shrub and 22 species of herbs.

A Lysimeter experiment (non-weighing type) was laid out in CRBD in 90 tanks of size 2 x 2 x 2 m³ with seven forestry tree species. This experiment was conducted, employing irrigation with treated industrial effluent water of Sangaria with 3 irrigation levels (0.5, 0.75 and 1.0) and control (0.5). Effluent water given for irrigation in lysimeter tank was, analyzed and maximum pH 5.7, EC 18.49 mScm⁻¹, alkalinity 20000 mg/l, Chlorine 204.75 mg/l and hardness 5200 mg/l were recorded. Preliminary observations indicated that *Azadirachta indica*, *Eucalyptus camaldulensis*, *Prosopis juliflora*, *Salvadora oleoides*, *S. persica* and *Tamarix aphylla* exhibited better growth under the influence of effluent water. *Prosopis cineraria* however, exhibited better growth performance in control (ground water).

Field trials were laid out at Jodhpur. Four hundred eighty plant seedlings of ten forestry tree



Gadwara Bandi river with effluent water



Jojari river having effluent water and association of *Argemone maxicana*



Lysimeter experiment for phytoremediation



Field experiment using ten selected tree species for phytoremediation

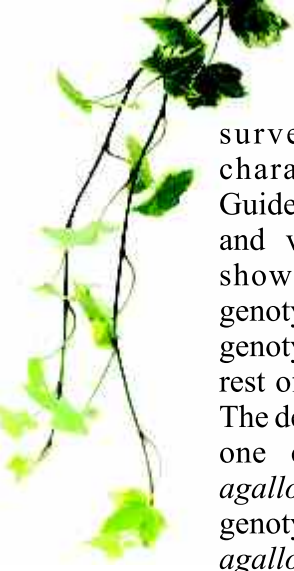
Phytoremediation studies on effluent water

species viz. *Acacia nilotica*, *Ailanthus excelsa*, *Azadirachta indica*, *Eucalyptus camaldulensis*, *Prosopis cineraria*, *Prosopis juliflora*, *Tamarix aphylla*, *Tecomella undulata*, *Salvadora oleoides* and *S. persica* at $3 \times 4 \text{ m}^2$ spacing were planted in Split Plot Design. One hundred fifty seedlings were planted in border row.

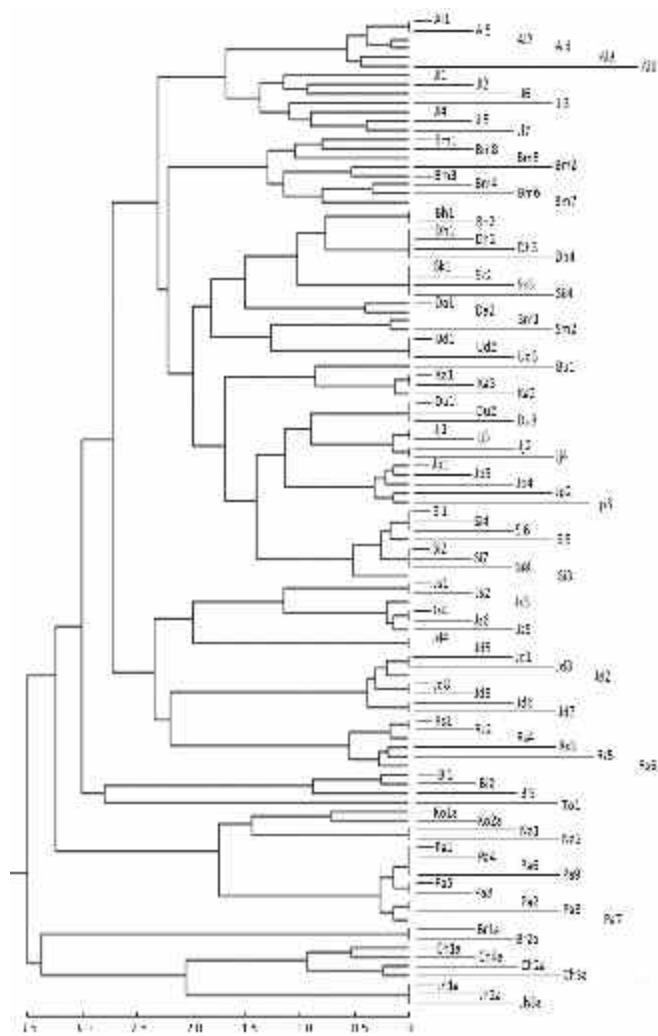
Assessment of guggul germplasm for studying population density, diversity, female-male plant's ratio for *in-situ* and *ex-situ* Conservation in Rajasthan.

Commiphora wightii (Guggal) is an important medicinal plant of arid region of Rajasthan & Gujarat. Many commercial products are marketed nationally and internationally. However, its ruthless exploitation and lack of cultivation practices of this species has led to decline in its population continuously making this plant vulnerable and category as 'data deficient' in assemblage of IUCN (2008). Government of India has included it under RET (Rare, Endangered, Threatened) category. Aim of this project was to study population density and assessment of genetic diversity in population for its conservation.

Selected genotypes from all over Rajasthan were vegetatively propagated and germplasm bank established in the fields of AFRI, Jodhpur. Left over area viz; Sariska and Bharatpur were



surveyed. Germplasm of Guggal was characterized by DNA marker studies. Guidelines were prepared for seed germination and vegetative propagation. The dendrogram shows genetic relationships among 109 genotypes of *Commiphora*. Out of these, 98 genotypes belong to *Commiphora wightii* and the rest of 11 genotypes to *Commiphora agallocha*. The dendrogram comprises of two major clusters: one cluster consisting 9 genotypes of *C. agallocha* and the other cluster having 98 genotypes of *C. wightii* and 2 genotypes of *C. agallocha*.



Genetic Distance by Jaccard's similarity coefficient

Dendrogram showing genetic distances amongst 98 genotypes of *C. wightii* and 11 genotype of *C. agallocha* genotypes.

Ecological Studies on Distribution Patterns and Food Plant Resources of Butterflies Along Altitudinal Gradients in Different Ecosystems of Western Himalayan Sub-Alpine Forests of Himachal Pradesh

Himalaya - one of the largest and youngest mountain chains in the world, covers roughly 10% of India's total land surface. Variations in terms of its size, climate and altitudinal ranges have created environments those were unique and characteristic to this region only. The diverse climate and the varied environmental conditions of Himalaya supports diverse habitat and ecosystems with equally diverse life forms. It provides an important habitat to the flora and fauna including 9,000 species of angiosperms and, hence, considered as the hot spot of biodiversity.

Areas in the defined eco-systems were surveyed and six sites for carrying out in-depth studies selected at Chansal (Shimla), Marhi (Manali), Kalatop (Chamba), Bhangal (Kangra), Hatu (Narkanda), Chitkul (Kinnaur). Three sites i.e. Chansal (Shimla), Marhi (Manali) and Hatu (Narkanda), were visited for collection of butterfly fauna during the year and 32 specimens of butterfly from Marhi, 37 from Chansal and 40 specimens from Hatu were collected. Faunal material, thus, collected was stretched and stored and some duplicate specimens kept at freezing temperature for further taxonomic studies. GPS coordinates were also recorded from selected sites. Host plant of butterfly species was collected and identified. Data was statistically analysed adopting standard methodologies.



Dark Clouded Yellow / *Colias Fieldii* (Menetries)



Apollo Butterfly

This species of butterfly has been collected from Hattu alpine forest of Western Himalaya. The species flies close to ground seen basking on rock beds and meadows of Hattu.

Natural regeneration studies of important tree species of Nallamalais, Seshachalam hills and Kaundalinya wildlife sanctuary of Eastern Ghats of Andhra Pradesh

Local communities were consulted for identifying their priorities for certain important species and their perception about natural regeneration; identified reasons for low regeneration; in an species which they felt was economically important species. The frequencies, density, basal area of all important species in each of the forests of Nallmalai were studied in permanent quadrates set up for the purpose. Quadrates of three sizes 1000sq m (31.6 x 31.6 m²) and 5 x 5m four plots for studying regeneration of seedlings and plots in each 1000 sq m quadrates were set up in all the four corners. The areas of Seshachalam and Koundinya are being tackled now.

Evaluation of performance of shola species of the Nilgiris under projected climate change conditions

Three sholas were identified for carrying out climatological, phenological and regeneration studies. Climate data for 20 years was consolidated for the purpose. Floristic diversity studies in progress. Phenological data and regeneration studies from the sholas identified for carrying out climatological studies is underway

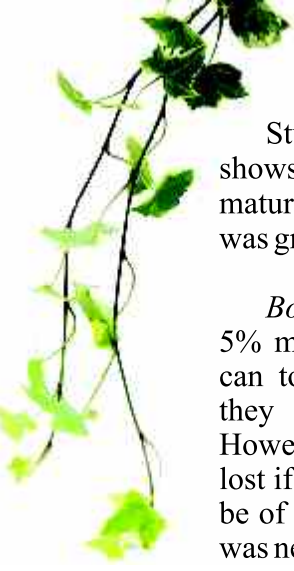
Impact of invasive species on plant diversity in selected forest sites of Uttarakhand, Haryana and Punjab

Species such as *Lantana camara*, *Ageratum conyzoides*, *Eupatorium adenophorum*, *Parthenium hysterophorum* etc. were selected for impact assessment. Floristic survey of Mussoorie and adjoining areas was carried out. Biomass of *Eupatorium adenophorum* was estimated. *Stevia obovata* was a new record of invasive species, from Mussoorie area. This species was the native of North America. Impact of invasive species in the Jhajra Range and Asharodi Range was carried out. Dominant species of the area was *Shorea robusta*. Area was heavily infested by *Lantana camara*. *Ardisia solanacea*, an associate of wet Sal was dominant in the Jhajra and Asharodi range. Species was posing great threat to other species. Quadrat study was carried out in control and *Lantana* and *Ardisia* infested areas. Biomass estimation of *Lantana camara* was also done. Vegetative analysis by quadrat method was carried out in Champawat (UK), Darpur and Kaleshar (Haryana) Forest. Invasive species like *Ageratum*, *Argemone*, *Parthenium* etc were found in the area. In all the areas *Lantana camara* was found as major threat to the indigenous species. Analysis of data was in progress. Potential of invasive species such as *Eupatorium adenophorum*, *Ageratum conyzoides*, *Parthenium hysterophorum* etc. for paper making was being analyzed.

3.5 Seed Science & Technology

Standardization of techniques for germination, collection and maintenance of maximum viability of four important tropical species: *Bridelia retusa*, *Sterculia urens*, *Boswellia serrata* and *Saraca indica*

Study on seed maturation of *Boswellia serrata* shows that germination was best after full maturation at 68 DAA, when the colour of the fruit was light brown and seed was brown with moisture content of about 2-3%.



Study on seed maturation of *Sterculia urens* shows that germination was best after full maturation at 75 DAA, when the color of the seed was grey with moisture content of about 16%.

Boswellia serrata seeds can tolerate up to 4-5% moisture content and *Sterculia urens* seeds can tolerate 2-3% moisture content; therefore, they can be considered as orthodox seeds. However, viability of seeds of *Saraca indica* was lost if dried to 20% moisture content. Seeds may be of recalcitrant category. Further investigation was needed.

Seeds of *Sterculia urens* stored at all conditions were viable; thereby no deterioration occurs till six months of storage.

Effect of temperature, light quality and type and depth of soil on germination of *Sterculia urens* was studied. It was observed that white light was best for germination of seeds of this species, the seeds can germinate at 25-40°C temperature. The seeds can germinate better on the surface of mixed type of soil.

Development of agro- techniques for organic cultivation of *Tribulus terrestris* L. and *Cissus quadrangularis* L.-medicinal plants extensively used in traditional system of medicine (Ayurveda, Unani and Chinese)

Seeds of *Tribulus terrestris* were collected from Uttarakhand Forest Dept. at Haldwani. The germination percentage of the seeds in nature was very poor. Efforts were made to increase the germination capacity of the seeds by physical and chemical means. The results of these experiments are awaited.

In case of *Cissus quadrangularis*, shoot cuttings have been obtained from plants growing in Chamranga Forests near Ranchi District. The survival rate of the cuttings was as good as 60%.

3.6 Eco- restoration

Development of model plantation/eco-restoration in coal mined areas of Bharat Coking Coal Ltd (BCCL), Dhanbad (Ongoing Externally Aided Project (Consultancy)

In a span of three years, 12,500 saplings of 17 tree species were planted, while seven shrubs, seven grasses, three herbaceous and three bamboo species were propagated by means of seed broadcasting, seed mixed with soil, stem cutting, bulbils and culm/slip. Species selection was based on the prevailing site condition, climate, nativity and multi uses. Periodical monitoring of the growth performance in terms of height, diameter and survival indicated tree species like *Dalbergia sissoo*, *Albizia procera*, *Albizia lebbeck*, *Bauhinia variegata* and *Phyllanthus emblica* were highly successful, while grasses like *Pennisetum pedicellatum*, *Pennisetum purpureum* *Panicum maximum*, *Cenchrus ciliaris*, *Cenchrus setigerus*, *Cymbopogon martini* and *Arundo donax* could also adapt well. Horticultural species mainly *Mangifera indica*, *Syzygium cumini* and *Psidium guajava* were found to be suitable in coalfields.

Identification and reclamation of 10 hectare of degraded land & bio diversity development at NCL, Singrauli

In the months of February 2014, top soil spread done on overburden dumps, as a part of physical measures to restore mined over burden dumps in project site.

Restoration ecology and species recovery studies in Tsunami impacted mangroves of Andaman Islands

Surveyed both the upliftment and submerged Tsunami impacted mangrove areas of South Andaman, Baratang, Middle Andaman and North Andaman. Sample plots in each island group were selected based on stratification and the damaged areas were stratified as heavily damaged, moderately damaged and less damaged. 15 sample plots were selected and demarcated on ground for restoration. Vegetation survey in the impacted areas and also in the adjoining undisturbed areas, have been also done. Studies on tidal fluctuations and vertical zonation of mangroves species in the affected areas are going on. Mangrove nurseries have been established in South Andaman and Middle Andaman. At each

site 2ha area was selected and floral composition of the sites was assessed. Nursery capable of 3000 seedling 10X5m was established at selected sites for raising seedling of available species. Nurseries were established in the following sites viz. Indira Nagar (*Rhizophora* sp, *Ceriops* sp), Shoal Bay (*Rhizophora* sp) Yerrata (*Rhizophora* sp, *Bruguiera* sp, *Ceriops* sp), Mohanpur (*Rhizophora* sp, *Bruguiera* sp), Parangra (*Rhizophora* sp, *Xylocarpus* sp). Transplanting the Nursery raised seedling to selected sites will be carried out on rotational basis. Supplementation of natural regeneration by introduction of seeds directly into the selected sites and collection of seeds and establishment of nursery for rare Mangroves species mentioned earlier will also be carried out.

Development of models for conversion of plantations into secondary forests in Andaman Islands

Seedlings of early colonizers were raised and planting was done in teak and Padauk plantations in Rangat division. Tending operations thinning, weeding and cleaning were done in sample plots of teak and Padauk plantation in Rangat and Diglipur.

Reclamation of laterite lands using beneficial microbes in Kasargode District

This project has been initiated in Apr 2013. Under this project, the study site was selected at Bhavikonam Range of Kasargode district and from there the laterite soil samples collected to analyse microbial and nutrient parameters. The microbial status was very low, however, Azospirillum, AM fung, and Phosphobacterium were isolated and cultured. The N, P and K status of laterite soils was very poor particularly the K was 0 in laterite soils. The primary colonizers *Crotalaria juncea* was broadcasted in the study site at Kasargode and established the primary colonization site. One truck load of laterite soil was collected, brought to the Institute for nursery experiments. Seedlings of *Butea monosperma*, *Swietenia macrophylla*, *Gmelina arborea*, *Ailanthus trypysa* and *Holoptelia integrifolia*

were grown in collected laterite soils (as potting media) and inoculated with beneficial microbes such as, Azospirillum, Phosphobacterium and AM fungi. The seedlings inoculated with these beneficial microbes, showed increased growth and biomass. The seedlings were being maintained in nursery for afforestation on laterite lands.



Butea monosperma (A) and *S. macrophylla* (B) grown in laterite soils inoculated with beneficial microbes