

MOEF PROJECT NO. 22/6/2010-RE, dt. 28.10.2010

Principal Investigator: Prof. A.J. Solomon Raju

ALL INDIA COORDINATED RESEARCH PROJECT

REPRODUCTIVE BIOLOGY OF FOUR RARE ENDANGERED AND THREATENED (RET) TREE SPECIES NAMELY, *HILDEGARDIA POPULIFOLIA* (ROXB.) SCHOTT. & ENDL., *ERIOLAENA LUSHINGTONII* DUNN (STERCULIACEAE), *SYZYGIIUM ALTERNIFOLIUM* (WT.) WALP. (MYRTACEAE) AND *SHOREA ROXBURGHII* (DIPTEROCARPACEAE) OF ANDHRA PRADESH

### Executive Summary of the Project

Reproductive ecology of four tropical tree species, namely, *Hildegardia populifolia* (Roxb.) Schott. & Endl. (lat. 14°06'N and long. 78°09'E), *Eriolaena lushingtonii* Dunn. (Sterculiaceae) (long. 16°02'N, lat. 78°57'E), *Syzygium alternifolium* (Wight) Walp. (Myrtaceae) (lat. 13°42'N and long. 79°20'E) and *Shorea roxburghii* Don. (Dipterocarpaceae) (lat. 13°40'N and long. 79°19'E) were investigated in the Eastern Ghats of Andhra Pradesh State, India. Of these, *H. populifolia* is treated as an endangered species, *E. lushingtonii* as a vulnerable species while the other two tree species as globally endangered species. *S. alternifolium* is also an endemic species while *S. roxburghii* is also a keystone species.

*Hildegardia populifolia* is a deciduous tree species. All phenological events fruit dispersal, leaf shedding, flowering, leaf flushing and fruiting occur, one after the other during dry season. The flowering lasts 7-8 weeks at population level and 20-36 days at tree level. It is morphologically andromonoecious due to occurrence of male and bisexual flowers but functionally monoecious due to abortion of male function in bisexual flowers. It produces strikingly male-biased male and bisexual flower ratio; it is self-incompatible and obligately outcrossing. The flowers are nectariferous and the nectar has hexose-rich sugars, some essential and non-essential amino acids. *Trigona* bee and *Rhynchium* wasp were the exclusive foragers; their foraging activity does not promote cross-pollination. Male flower number, the pollen output, pollen characteristics and placement of anthers on the top of androphore conform to anemophily. The natural fruit set does not exceed 5%. The fruit is 5-follicled with 1 or 2 seeds. The low fruit set is compensated by the production of more 2-seeded follicles. The fruit characteristics such as wing-like follicles, membranous follicle sheath and very light weight characterize anemochory. Seeds with hard coat do not germinate readily during rainy season and their germination depends on the soil chemical and nutrient environment. The soil is deficient in nitrogen, potassium and phosphorous.

*Eriolaena lushingtonii* is distributed in dry and moist deciduous areas in the southern Eastern Ghats of Andhra Pradesh. Leaf flushing occurs during late dry season and flowering during early wet season. Fruit maturity and seed dispersal events occur during February-March. The flowers are either solitary or few-flowered cymes, borne in axillary position and do not stand out very prominently against the foliage and usually go unnoticed by the flower visitors due to the flowering pattern characterized by the production of a few flowers per day at tree level and emergence of herbaceous flora and leaf flushing in deciduous tree species following rainfall in June. The floral characteristics such as morning anthesis, exposed dehiscent anthers presenting pollen and exposed flower base presenting nectar after anthesis indicates that they are adapted for day-active flower foragers for pollination. Certain co-occurring and co-flowering nectariferous and polleniferous herbaceous plant species attract a variety of insects in the habitat of *E. lushingtonii* and in effect the latter species receives reduced rates of foraging visits which contribute to both self- and cross-pollination.

In *E. lushingtonii* with hermaphroditic sexual system and weak protandry facilitates both self- and cross-pollination. The ability to fruit through both modes of pollination is adaptive but both are essentially insect-dependent since the extension of the stigmatose style beyond the height of stamens and the sticky nature of pollen grains which is further dampened by the high humidity during wet season preclude the occurrence of autogamy. The fruit set rate is low but it is partly compensated by the production of several seeds in *E. lushingtonii*. Seed dispersal is characteristically anemochorous. Since the dry season with high winds contribute to top soil erosion in the absence of all herbaceous flora on the slopes, the germinated seeds in the early rainy season struggle to establish and in effect, a few eventually establish and grow slowly. Therefore, the rocky and nutrient-poor soils, the pollinator limitation, bud and anther predation, seedling establishment problems and local uses collectively contribute to the endemic and endangered status of *E. lushingtonii* in the Eastern Ghats.

*S. alternifolium* is not an annual flowerer. The flowering intensity varies during the years of flowering. The flowering is either massive or sparse; in case of sparse flowering, the flowering is confined to a few branches

only. The floral traits suggest a mixed pollination syndrome involving entomophily and anemophily together called ambophily. Further, the floral traits suggest generalist pollination system adapted for a guild of pollinating insects. The plant is self-incompatible and obligate out-crosser. The flowers are many-ovuled but only a single ovule forms seed and hence fruit set and seed set rates are the same. Natural fruit set stands at 11%. Bud infestation by a moth, flower predation by the beetle, *Popillia impressipyga* and bud and flower mounds significantly limit fruit set rate. The ability of the plant to repopulate itself is limited by the collection of fruits by locals due to their edible nature, short viability of seeds, high seedling mortality due to water stress, nutrient deficiency, erratic rainfall or interval of drought within the rainy season. Therefore, *S. alternifolium* is struggling to populate itself under various intrinsic and extrinsic factors.

In *S. roxburghii*, massive blooming, drooping inflorescence with pendulous flowers, ample pollen production, gradual pollen release as a function of anther appendage and aerodynamic pollen grains— all suggest anemophily. The characteristics of nectar secretion, hexose-rich sugars and amino acids in nectar are additional adaptations for entomophily. The plant is therefore both anemophilous and entomophilous; the existence of these two modes of pollination is referred to as “ambophily”. Since the plant is adapted also for entomophily, it attracts different insect species, bee, wasps, flies and butterflies. The nectar is a source of some of the essential and non-essential amino acids for insects. The ability to have both anemophily and entomophily is adaptive for *S. roxburghii* to set fruit to permitted level through cross-pollination. The natural fruit set does not exceed 15% despite the plant being ambophilous. Scarabaeid beetle by causing flower damage and bruchid beetle by using buds, flowers and fruits for breeding greatly affect fruit set rate and hence the success of sexual reproduction in this plant species. Anemochory is the mode of fruit dispersal but it is not very effective due to semi-closed nature of the canopy cover of the forest by the time the fruits mature. Seeds are recalcitrant, non-dormant, embryo is chlorophyllous while the fruits are on the plant. Healthy seeds germinate as soon as they reach the forest floor but their establishment is seemingly affected by the resource constraint due to rocky habitat. The study suggests that massive flowering for a short period, high bud/flower and fruit infestation rate, absence of seed dormancy and rocky habitat with nutrient-deficient soil disallowing seedling establishment collectively appear to be contributing to the endangered status of *S. roxburghii*.

In summary, all the four studied tree species play an important role in supporting insect fauna in deciduous forest ecosystem in the Eastern Ghats. *E. lushingtonii*, *S. alternifolium* and *S. roxburghii* are morphologically and functionally hermaphroditic while *H. populifolia* is morphologically andromonoecious but functionally monoecious. *E. lushingtonii* is primarily out-crossers while the other three species are self-incompatible and obligately outcrossing. *S. alternifolium* and *S. roxburghii* are ambophilous; the former is zoochorous while the latter is anemochorous. *H. populifolia* is primarily anemophilous while *E. lushingtonii* is entomophilous; both the species are obligately anemochorous. All the four tree species are nectariferous and offer pollen and nectar as floral rewards to pollinators.

The floral rewards in all the four tree species attract one or more than one class of insects - bees, wasps, flies, thrips and butterflies. The study clearly suggests that entomophily is effective, reliable and economical in terms of resource investment in the production of flowers and floral rewards. Anemophily functional in *H. populifolia* and *S. roxburghii* are effective. In *S. alternifolium*, both entomophily and anemophily function effectively. The buds and flowers of *E. hookeriana* and only flowers of *E. lushingtonii* are subjected to infestation by a beetle (not identified); the beetle uses the buds or flowers for feeding purpose only. In *S. alternifolium*, the buds are subjected to infestation by a moth (not identified); the moth uses the buds for breeding purpose only. The beetle in case of *E. lushingtonii* and moth in case of *S. alternifolium* have been considered to be natural controls to regulate the fruiting.

The study suggests that interactions between insect pollinators and the tropical tree species are important for the structural and functional integrity of the deciduous forest ecosystem. Further, flower and fruit predation and infestation by beetles and moth partly contribute to the endemic and endangered status of the studied tree species. Seed collection from natural areas and raising seedlings in experimental plots and nurseries for subsequent transplantation into natural areas seem to be imperative for expanding the population size of each of the studied tree species in the deciduous forest ecosystem with feasible soil nutrient amendments. The work reported here would form the most important information in order to take up further studies for effective conservation and management measures for the sustainability and restoration of population size of the studied tree species.

**EXECUTIVE SUMMARY OF THE PROJECT**  
**“Reproductive Biology of Five RET Species of Central and Western Himalaya”**

**Sanctioned to Prof. A. K. Bhatnagar (No. 22/2/2010-RE)**

The work was carried out on our RET species of Central and Western Himalaya namely *Pittosporum eriocarpum*, *Engelhardia spicata*, *Acer oblongum*, *Acer caesium* and *Ulmus wallichiana*. The major findings of the research work are presented below:

Populations of *E. spicata* comprise of staminate, pistillate and andromonoecious trees. Staminate trees bear only male flowers and pistillate trees bear only female flowers. Monoecious trees bears all the three types of flowers i.e. male, female, and bisexual flowers which are functionally male. Monoecious trees show reciprocal heterodichogamy with a proportion of trees showing protandry and other proportion showing protogyny. No sexual lability was observed in the gender expression of monoecious trees. Staminate trees bloom earlier than the pistillate and monoecious trees. However, the flowering is synchronized amongst sites. Trees of *E. spicata* are complete out-crossers and are wind-pollinated. Fruit set through open-pollination in pistillate trees is 28.46-30.35 % and in monoecious tree is 45.60-52.31 %. However, geitonogamy yields very low ( $9.96 \pm 3.34$ ) amount of fruit set. Thus, the species is mainly self-incompatible. Seeds are small, light-weight and winged. Seed dispersal occurs through wind and propagules were located up to 110 meters away from the source plant. Seeds require shady and moist places for germination, and thus high density of seeds was found germinated under the parent canopy. However, the seedling survival rate was almost negligible. Habitat fragmentation is having highly negative impact on the per cent fruit set and vigour of the seeds and seedlings. Regeneration in terms of seed germination and seedling survival is affected due to low viability of seeds, low germination and reduced survival of seedlings owing to lantana invasion and anthropogenic disturbances such as construction and farming in the under canopy areas. The tree is locally exploited for fire-wood, fodder and manuring.

Populations of *P. eriocarpum* comprise of staminate and pistillate trees. The flowers produced in staminate trees have cryptically functional pistillode. Gender ratios across all the sites were male biased. Trees show lability in gender expression with prominence of male to female transitions. Trees are complete out-crossers and are majorly pollinated by different pollinators at different study sites. A significant variation in the pollinator guild was also observed across study sites which was constant across seasons. The trees are mostly pollinated by bees in Uttarakhand and 77 by butterflies in Himachal Pradesh. The fruit set through open-pollination was 35.95 % and 56.42 % at Nainital and Kullu, respectively. Additionally, the seed set per fruit at both the sites was found to be pollen-limited due to the absence of major pollinator groups. However, no instances of apomixis or fruit set through wind were noted at any of the sites. The seed and fruit dispersal occur primarily through gravity and surface run-off and to a lesser extent through ornithochory (endozoochory) at all the study sites. Seeds dispersed through gravity are mostly (79.52 %) deposited under the canopy. However, the seeds dispersed through birds were found up to a distance of 3 kms. The dispersal was limited across all habitats due to the absence of the disperser agents in most of the diurnal hours. Under natural conditions, the seed germination requires scarification treatment in the birds gut for germination. Thus, both the seed germination and seedling recruitment are limiting factors for regeneration of the plant. Additionally, no instances of dispersal through nocturnal agents were recorded. A major barrier in regeneration of

the plant is the underlying morpho-physiological dormancy of the seed which requires a time-period of 7-8 months for overcoming dormancy under natural conditions. However, this time-period was successfully reduced to two weeks using gibberellic acid and temperature stratification treatments. Density of the trees is a factor in attracting pollinators as well as disperser agents was found to be crucial as fruit set owing to the contribution of the pollinators and dispersal through bird species was found to be significantly correlated with the density of flowering and fruiting trees. Anthropogenic disturbances in the form of habitat fragmentation, line quarrying, uprooting and pollarding of the plants for making highways, and usage of the plants as fodder in dry months are posing a threat to the species survival. Additionally, the tree is locally also exploited for fire-wood and manuring.

*Acer oblongum* is an andromonoecious tree species due to the presence of male and bisexual flowers but exhibits cryptic monoecy since each type is functionally either male or female. Tree bears three types of flowering morphs: Male Type I, hermaphrodite and Male Type II. Male Type I flowers bloom early in March during the beginning of the flowering season and are meant primarily to attract pollinators and sustain them (mainly bees) till the blooming of hermaphrodite and Male Type II flowers. However, the phenology of shade oriented trees of *A. oblongum* varied with those growing in sun. Flowers of *A. oblongum* promote outcrossing since the bisexual flowers which set fruit have indehiscent anthers. Pollen from Male Type II flowers pollinates the co-flowering hermaphrodite flowers. So, mode of pollination is facultative xenogamous. *A. oblongum* shows mixed syndromes of anemophily in pollen characteristics and entomophily in floral structure. In *A. oblongum* natural fruit set is found to be 33-40%. However, this is primarily due to pollen limitation and high pollen sterility. Also wing loading in seeds of *A. oblongum* sometimes results in formation of hollow fruits. Mature fruits do not invariably indicate presence of mature seed inside. In *A. oblongum* seed germination and seedling establishment do not pose any problem since seeds do not require any pre-treatment but insect infestation of seeds was observed in few trees. This species prefers growing in slightly acidic to neutral soil (pH ranges from 6.0-7.0) and grows well in moist soil. The tree is commercially exploited for its valuable timber and leaves are used for manuring.

*Acer caesium* is dioecious, with distinct male and female trees in the population. The natural populations show male-biased sex ratio i.e. presence of larger number of male trees than female trees in a population. The presence of focal female tree ensures the larger number of pollen donor male individuals in a population which effects the seed set and regeneration. The inflorescence of *Acer caesium* is cymosely branched terminal corymb. Floral structure promotes wind pollination as the presence of sticky papillate stigma is well exposed to wind and the male flowers have exerted stamens. The pollen grains have all characteristics of wind pollination. The mode of pollination is majorly by wind but insect visitors also contribute to pollination. Pollen limitation is observed within populations as pollen supplementation experiments resulted in higher fruit and seed set. The fruit set is very high as a result of successful pollination process but mortality of flowers at different post-pollination developmental stages reduces the successful seed set percentage. At maturity, the pericarp colour turns dark brown. The change in fruit colour corresponds to a change in seed colour. The outer structure of the *A. caesium* samara attains full size within two months after anthesis, but its inner cavity requires an additional five months for seed fill. Mature fruits started dispersing through wind as a diaspore from late October to December. Maximum distance travelled by the diaspores was 130 meters by wind. In its natural habitat, the samara is dispersed in late autumn and undergoes stratification when it is

covered with snow. Physiological dormancy of different levels is found in seeds from different populations. Seed germination requires prolonged chilling and pricking of pericarp and testa in natural conditions. Seedling establishment rate is very low at forest floor as some of the seeds are not mature and get degraded by pest infestation under seed bank and many of them lose their viability. Successful regeneration needs artificial germination and seedling establishment in the nurseries and introducing the sapling to forest floor after hardening stage.

Flowers of *Ulmus wallichiana* are hermaphrodite arranged in lateral racemes. The anthesis time largely varies due to morning temperature. The flower structure promotes wind pollination. Insect visitation is insignificant and wind pollination is responsible for maximum fruit-set. Breeding experiments reveal that seed set is higher in manual pollination. Effective pollination time is 0700 to 1200 hrs. Fruit set is very high but the number of infertile or hollow fruits is very high which is due to high rate of abortion and mortality during seed maturation. *U. wallichiana* diaspore is flat, obovate and with membranous reticulate wing completely surrounding the seed. The winged diaspore is primarily dispersed by wind. The maximum dispersal of seeds is 180 meters. Seeds are orthodox and lose viability and germinability within a few months under natural conditions after dispersal. Seeds can be stored under low temperature and specific moisture content for long artificially. Regeneration rate is very low in forest floor. Seedlings survival rate is relatively high at higher altitude populations. Deliverables: The investigated tree species belong to RET category. The reason behind their scarce distribution and lack of regeneration in their natural habitats needs to be understood. Reproductive data indicates that the investigated species show low numbers due to pollinator constraints and low rate of fruit/ seed set. The rate of seed abortion is high. Seed germination rate is also very low indicating inbreeding depression.

## Executive Summary

### All India Coordinated Project on Reproductive Biology of RET tree species

PI: Dr. Rajesh Tandon, Professor, Department of Botany, University of Delhi, Delhi – 110007.

Title: Reproductive Biology of Rare, Endangered and Threatened (RET) Tree Species namely: *Anogeissus sericea*, *Salvadora oleoides*, *Tecomella undulata* and *Wrightia tomentosa* in Rajasthan.

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The selected tree species have been worked out for the first time. The base-line information would be useful in conservation of the tree species. The information would be of immense importance for government agencies heading the forestry and agroforestry departments and the agri-farm owners. Specifically the information generated on the reproductive strategies of the tree species would help in (i) species reintroduction, and (ii) designing their conservation at the community level, as their survival is highly dependent on ecosystem service provided by the legitimate pollinators. Importantly, three out of the four tree species exhibit specialized pollination syndrome. During the preliminary survey it was noticed that there were two varieties of *Anogeissus sericea* viz. var. *sericea* and var. *nummularia*. Therefore, both the varieties were included in the investigation. Both the taxa were self-compatible; excessive autogamy in the variety *nummularia* incurs considerable amount of inbreeding depression. However, var. *sericea* remained unaffected by inbreeding depression. Pollinator limitation was more prominent in the var. *sericea* than in var. *nummularia*. *Salvadora oleoides* is a self-compatible tree species. Although a large number of fruits are produced in nature, natural seedling establishment was negligible. Some of the main factors for poor regeneration this species are inbreeding depression, poor seed viability and germination. In Rajasthan, *Wrightia tomentosa* is represented by only one population, where only a few individuals produce flowers. Thus, ineffective population size of mature trees may be one of the factors for poor natural regeneration in the species in addition to overexploitation for its white textured wood. This may be due to inbreeding depression and low seed viability. 'Roheda' or *Tecomella undulata* is an obligate self-incompatible and ornithophilous. The flowers are frequently robbed of their nectar by nectar robber birds. Intense nectar robbing influences the pollinators to visit additional flowers and trees thereby increasing the female fitness. The natural recruitment of this threatened species requires optimal nutrients in the initial stages of establishment. For this, the practice to grow them as

agroforestry tree species on the seasonally cultivated plots would not only continue to profit the farmers but would also safeguard its conservation in moisture limited environment.

### *Key recommendations based on the work*

The present work demonstrates that heterogeneity at the population level is crucial for the reproductive success in *Tecomella undulata*. The other three tree species are self-compatible but definitely not autonomous. Thus fruit set is facilitated by the essential requirement of pollinators. This information underlines the importance of species organization in ecosystem context. For establishing new populations, the unrelated young plants/genets should be introduced from different regions. Monoculture of a tree would be ineffective as the pollinators presence in the community should persist in the community through continued availability of resources. Any effort to reintroduce the species in new habitats should consider interplay of plant-pollinator interaction network at the community level for the sustenance of the tree species investigated. Tree density is a crucial issue at least in the varieties of *Anogeissus* as they are pollinated by dipteran flies which are slow foragers and their activity is highly restricted. Also, to avoid the neighbourhood effect that often leads to inbreeding depression, reintroduction of unrelated sibs is crucial. The site at *Kewde ki naal* in Udaipur needs to be protected from grazing pressure as the flowering individuals are very few in number. To circumvent the effect of founder effect, the other age-groups of the tree must be guarded to become reproductively active. The survival of trees needs to be monitored at the site.

Dr. S. Muralidharan, SACON

**Executive summary of the project**

Colonial water birds, one of the vital components of many a wetland ecosystem, serve as an excellent indicator of wetland health. Indiscriminate use of man-made chemicals has resulted in accumulation of residues in food and animal tissues causing environmental and ecological impact. As birds occupy different trophic levels in different food chains, they are exposed to different concentrations of contaminants. In India information on the ill effects of pesticides on wildlife, especially birds (colonial birds) is limited. Although, some information is available on the levels of pesticide residues in eggs of fish-eating and insectivorous birds in India, we do not have studies assessing the impact of pesticides on the breeding outcome and eventually on the population. The present work was conducted with the following objectives; identify the heronries in Tamil Nadu, monitor the population and study breeding ecology of colonial nesting birds in select locations, document the residue levels of organochlorine pesticides in fishes, eggs and tissues of colonial nesting birds and assess their impact.

Survey was conducted to identify the heronries in the state. Direct count method was followed to estimate the number of species and individuals. Breeding ecology of select colonial nesting birds was studied using focal animal sampling technique. Samples, namely fishes, dead birds and eggs were collected as per standard operating protocols. Soxhlet extraction was followed with suitable solvents and cleaned up for estimating organochlorines using Gas Chromatograph.

**Preliminary field survey**

Distribution of 41 heronries in 14 districts showed that not all the districts in Tamil Nadu have ideal breeding locations for the colonial nesting birds. Little Egret, Little Cormorant and Indian Pond Heron were found in nearly twenty heronries in Tamil Nadu. Distribution of Black Ibis and Woolly-necked Stork was restricted only to two locations. Based on preliminary survey, Vedanthangal Bird Sanctuary, Vettangudi Bird Sanctuary and Koonthankulam Bird Sanctuary were selected for detailed studies.

**Population and breeding ecology of colonial nesting birds**

Between Oct '07 and Mar '10, 18 species of fish-eating birds were observed in Vedanthangal Bird Sanctuary. Population was the maximum (30,551) during March 2010 and minimum (118) during September 2009. Of which Cattle Egret, Glossy Ibis, Painted Stork, Spot-billed Pelican, Indian Cormorant and Little Cormorant were predominant. White-throated Kingfisher and Pied Kingfisher were only a few. Out of 18 species found in the sanctuary, 12 were observed breeding. However, we monitored eight species, namely Spot-billed Pelican, Asian Openbill, Black-headed Ibis, Painted Stork, Grey Heron, Little Cormorant, Little Egret and Eurasian Spoonbill. Number of nests recorded was the maximum (3,185) during 2009-10 and the minimum (2,819) during 2007-08. Among the species the maximum number of nests was of Spot-billed Pelican (887) followed by Painted Stork (576). Nests of Darter and White-throated Kingfisher were only a few.

In Koonthankulam Bird Sanctuary, total population comprising 21 species of fish-eating birds was the maximum (28,190) during March 2010 and minimum (52) during October 2009. Of all the species, Cattle Egret, Glossy Ibis, Painted Stork, Spot-billed Pelican, Indian Cormorant and Black-headed Ibis were the predominant species. White-throated Kingfisher and Pied Kingfisher were only a few. Out of 21 species found in this sanctuary, 11 species were observed breeding and we monitored six species. Maximum number of nests (3,650) was recorded during 2009 - 2010 and the minimum (2,169) during 2007-08. Among the breeding birds, Painted Stork (1,861) was the most predominant bird followed by Spot-billed Pelican (877).

Population and number of species in Vettangudi Bird Sanctuary were relatively lower than the other two. It was the maximum (3989) during December 2008 and minimum (17) during March 2010. Out of seven species of birds nested in the sanctuary, we monitored four species. Asian Openbill (326)

was the most predominant. Density of colonial nesting birds among the study sites, species, families, and between seasons was significantly different ( $P < 0.05$ ).

In Vedanthangal Bird Sanctuary, most of the nests were found on *Acacia nilotica* and *Barringtonia acutangula*. In Koonthankulam, Painted Stork, Little Egret, Intermediate Egret and Indian Pond Heron preferred *Prosopis juliflora*, while Indian Cormorant, Spot-billed Pelican and Darter used *Acacia nilotica*. Many of the birds breeding in Vettangudi preferred *Acacia nilotica*.

Totally 1583 nests belonging to five families, namely *Ardeidae*, *Pelecanidae*, *Ciconiidae*, *Phalacrocoracidae* and *Threskiornithidae* were followed for assessing breeding success. In Vedanthangal, Black-headed Ibis and Spot-billed Pelican showed the highest breeding success (100%) during 2007-08, while the same species had the least success (58.5%) during 2009-10. In Koonthankulam, Spot-billed Pelican and Painted Stork had the highest success rate, while Intermediate Egret had the least. Among the four species of birds studied in Vettangudi Bird Sanctuary, Little Cormorant was the most successful breeder.

#### OCP residues in fishes

Towards assessing the magnitude of pesticide contamination, three hundred individuals comprising nine species of fishes were collected seasonally from the study sites. Among the organochlorines analyzed, HCH was most frequently detected followed by Heptachlor epoxide, Endosulfan and DDT. It is noted that the  $\Sigma$ -DDT concentrations recorded in two species of fishes, namely *Cirrhimis mirigala* (17.40 ng/g) and *Oreochromis mossambica* (41.72 ng/g) collected from Vedanthangal are closer to the levels responsible for gill damages. Among DDT metabolites, p,p'-DDT had the highest percentage of occurrence. Among the cyclodiene insecticide residues, Endosulfan was detected in more than 60% of the fishes.

#### OCP residues in birds

Among various organochlorine pesticide residues analyzed in 76 individuals belonging to 14 species of birds, HCH was the maximum (981 ppb) in muscle of Indian Cormorant. Heptachlor epoxide,  $\Sigma$  Endosulfan and  $\Sigma$  DDT ranged from BDL to 963 ppb, BDL to 637 ppb and BDL to 208.6 ppb respectively. Concentration of  $\Sigma$  DDT, Dieldrin and heptachlor epoxide significantly ( $P < 0.05$ ) varied among the locations while  $\Sigma$  HCH,  $\Sigma$  Endosulfan and Dieldrin significantly ( $P < 0.05$ ) varied among the species. On the whole, levels of organochlorine residues detected were higher in the tissues of wading birds (Cattle Egret, Little Egret and Grey Heron) than in swimming birds (Little Cormorant and Indian Cormorant). HCH, the most predominantly detected contaminant in all the birds can be expected to create harm, if the birds are continuously exposed. Similarly, DDT and its metabolites are also capable of creating abnormalities, especially reproductive failures, if exposure level increases or even continues.

#### OCP residues in eggs of birds

Among the 12 species of birds studied, Painted Stork, Spot-billed Pelican and Black-headed Ibis are the near threatened birds. Egg measurements and eggshell parameters including shell index of all the species of birds were calculated. Thickness showed negative correlation with organochlorine residues. Among the isomers,  $\gamma$ -HCH contributed more than 50% to the  $\Sigma$ -HCH. Among the metabolites, p,p'-DDE had higher accumulation in the eggs of all species studied. Concentration of  $\Sigma$  DDT, HCH, heptachlor epoxide and endosulfan in the eggs significantly ( $P < 0.05$ ) varied among the species. Levels of OC residues in the eggs currently studied are well below the threshold levels (4 - 8  $\mu\text{g/g}$  wet wt) associated with impaired reproduction. However, DDE concentration in eggs of Painted Stork (228.06 ng/g) and Black-headed Ibis (72.74 ng/g) may be associated with effects on survival rate of young ones of these species, if exposure continuous.

Based on the information collected on ecological and pesticide contamination perspectives, site-wise recommendations are proposed for conservation of fish-eating birds.

**FORMAT FOR EXECUTIVE SUMMARY OF THE RESEARCH PROJECTS FUNDED BY THE  
MINISTRY OF ENVIRONMENT & FORESTS**

(not more than 02 to 03 pages)

1	Title of the Project	: Inventory of vegetation with special reference to medicinal and aromatic plants and documentation of traditional knowledge in the Walayar Valley, Western Ghats
2	Name of Members of Research Team and their designation	: Dr. V.S. Ramachandran Scientist and PI Mr. A. Venkatachalapathi (RF: Jun. 2012 to Jul. 2014) Mr. Sekar Shanmuganathan (RF: Oct. 2014 to Feb. 2015) Mr. S. Jagathes Kumar (FA: Jun. 2012 to Jun. 2013) Mr. L. Kathirvel (FA: Mar. 2014 to Feb. 2015)
3	Number and date of Sanction letter	: No. 23/8/2009-RE dated 31 Jan. 2012
4	Duration	: 3 years
5	Total outlay	: ₹ 11,92,250/-
6	Date of start	: 01 Mar. 2012
7	Date of completion	: 28 Feb. 2015
8	Objectives	: a) To make an assessment of the plant resources of Walayar Valley, with special reference to medicinal and aromatic plants b) To make a quantitative assessment of the medicinal plants collected from the Walayar Valley and to identify their threats (such as over exploitation) and seek probable remedial measures c) To document scientifically the traditional knowledge of ethnic and folk communities of the area
9	Methodology	: The vegetation was studied using samples of 0.1 ha (50 m x 20 m), within each plot all plants ≥10 cm girth at breast height (gbh) were enumerated. Herbaceous forms were studied in samples of size 5 m X 5 m plots were all plants were counted and recorded. Phytogeographic and conservation status of the plants were found out, structural attributes such as density, frequency and relative dominance were computed for each species following standard phytosociological practices, for species diversity Fisher's α. Detailed ethnobotanical surveys were conducted for a period of three years from April

		<p>2012 to January 2015. The field studies were carried out in different seasons of the year and field days varied from seven to fifteen days in a month and closely interacted with the tribal people. Ethnobotanical and socioeconomic tools such as personal interviews, Rapid Ethnobotanical Appraisal (REA) and Participatory Ethnobotanical Appraisal (PEA), Field Walk, Plant Walk were used to gather information on plants. A total of 259 people were interviewed. The herbarium of voucher specimens pertaining to ethnobotanical uses were prepared as per standard herbarium methods and kept in Centre for environmental studies herbarium, Amrita Vishwa Vidyapeetham University, Ettimadai, Coimbatore.</p>
10	Output	<p>One MS in Review  One research report  2 MS under preparation</p>
11	Outcome	<ol style="list-style-type: none"> <li>1. Plant wealth of Walayar was hitherto unknown. We have recorded 291 species of plants and among this, 121 species were herbs and 116 were trees, followed by climbers and shrubs</li> <li>2. We have documented a plant <i>Elytraria acaulis</i> (L.f.) Lindau, a new record to the region, an addition to the State flora of Kerala and this documents western extension of the distribution boundary of the plant in the peninsular India</li> <li>3. Though forest of the region is highly disturbed and still in active regeneration, the area nurtures 16 plants which are endemic to the Western Ghats and four plants in Vulnerable and 2 plants in Low Risk/Near Threatened category of IUCN.</li> <li>4. Traditional knowledge on the use of plants of the region has been brought out. The tribal people of the area use 176 species of plants for their various needs. Out of 176 plants 163 have medicinal uses, followed by 23 edible plants and others</li> <li>5. Using these 163 medicinal plants the tribal people cure/treat 72 common</li> </ol>

			<p>ailments.</p> <p>6. The use of <i>Dipteracanthus prostratus</i> as a food plant is not recorded anywhere in the literature and this is new to science.</p> <p>7. The whole plant of the four species <i>Pseudarthria viscida</i>, <i>Desmodium velutinum</i>, <i>Desmodium pulchellum</i> and <i>Sida rhombifolia</i> var. <i>retusa</i> were collected extensively from the area for commercial purpose.</p> <p>8. The collection of seeds of silk cotton tree, <i>Bombax insigne</i>, can be a cause for forest fire and can be harmful in long run.</p>
12	Deliverables	:	NIL
13	Name of the Agencies by whom the results can be utilized	:	<ol style="list-style-type: none"> <li>1. State and Central Forest Departments</li> <li>2. Research Institutes and Academic Organisations</li> <li>3. Medicinal Plant Board</li> <li>4. Tribal Welfare Department</li> </ol>
14	The manner in which the finding will be utilized	:	<ol style="list-style-type: none"> <li>1. Information on the plant diversity of Walayar can be used to update local and regional floras and other databases</li> <li>2. Information on the use of plants can be used to update the existing database on the use of plants</li> <li>3. Further studies can be initiated in the plants with new or unknown uses</li> <li>4. Regulation can be brought in the collection of the herbaceous plants which are currently collected as a whole plant in very large quantities</li> <li>5. Finding out alternate sources of livelihood for the tribal people of the area during lean months so as to reduce pressure on plant wealth and to improve their standard of living.</li> </ol>
15	Recommendations and their implementation	:	<ol style="list-style-type: none"> <li>1. <i>Dipteracanthus prostratus</i>, a potential edible plant deserves further in depth study in the phyto-chemical and nutritional aspects for its wider use among rural community, especially economically backward people.</li> <li>2. The collection of the whole plant of <i>Pseudarthria viscida</i>, <i>Desmodium velutinum</i>, <i>Desmodium pulchellum</i> and <i>Sida rhombifolia</i> var. <i>retusa</i>. to be brought</li> </ol>

under control. Regulation is recommended to prevent its extinction in local flora.

3. Collection of seeds of silk cotton tree, *Bombax insigne*, which has been started recently, can be stopped in order to save the forest from fire. The seeds have no medicinal value but are collected for some other purpose, which the people of the area don't know.
4. There is scope for a detailed floristic study in the forests of Walayar as in our ecological study itself we have found that *Elytraria acaulis* is a new record from the region and addition to the flora of Kerala. Identity of a few species is not yet complete. Our preliminary observation says that there is scope for addition of a few species to the Flora of Palakkad (Palghat) District.
5. Micro ethno-botanical studies like this has to be initiated, which will bring to science the knowledge of ethnic people of the area before they get wiped off for ever. The lifestyle of tribal people is changing very much and the younger generation is neither interested to know about the uses of plants from the older generation nor interested to go to the forest.



Signature of the Principal Investigator

*Dr. V. S. Ramachandran*  
Scientist (CES) & Principal Investigator  
Amrita/Proj./ CES/MoEF/IMAPDTKW/53  
Amrita Vishwa Vidyapeetham  
Coimbatore - 641 112. Tamil Nadu



Registrar/Head of the Institution

*Dr. S. Krishnamoorthy*  
Registrar  
Amrita Vishwa Vidyapeetham  
Amrita Nagar, COIMBATORE - 641 112

## EXECUTIVE SUMMARY

RESEARCH PROJECT FUNDED BY THE MINISTRY OF ENVIRONMENT, FORESTS & CLIMATE CHANGE

1. Title of the project: **Ecological investigation of woody vegetation and nest tree use by birds in the riverine forests of Athikadavu Valley, Western Ghats**

2. Name of the members of Research team and their designation: Dr. P. Balasubramanian  
Principal Scientist  
Mr. P. Manikandan, SRF

3. Number and date of Sanction letter: No. 23/12/2010-RE dated 20 January 2012.

4. Duration : Three Years  
5. Total outlay : Rs.10,72,250/-  
6. Date of start : March 2012  
7. Date of completion : March 2015

8. Objectives:

- i. Quantify the woody vegetation and estimate the abundance of trees in the riverine forests of the Athikadavu Valley, Western Ghats,
- ii. Find out the nest trees used by cavity-nesting birds, assess the characteristics of nest trees and identify preferred nest tree species
- iii. Find out the nest trees used by stick-nesters, especially raptors and assess the nest tree features and identify preferred nest tree species,
- iv. Assess the human impacts on riverine vegetation and suggest conservation measures.

9. Methodology:

Quantification of vegetation: Woody vegetation along river banks was enumerated by repeated walks along river banks. Quantification of woody vegetation of the riverine forest was done by belt-transect method. Sampling was done in two belt transects, each measuring 1 ha (1000x10m). To understand the vegetation composition in the adjoining mixed dry deciduous forests, 1 ha was sampled. All the stems measuring >20 cm gbh (girth at breast height) were enumerated.

Observations on cavity-nesters and nest tree and cavity characteristics: Bird census was carried out by Line Transect Method. Birds were observed using a pair of 10 x 50 binoculars. Nest trees were located by making repeated walks along river banks. Data on nest characteristics and nest-sites were collected. Nest tree parameters such as height of the tree, height of the nest location, placement and orientation of the nest and cavity dimensions were recorded. Nest tree preferences of cavity nesting birds were assessed by using Ivlev's Index.

Observations on stick-nesters, nest tree and canopy features: Raptors (birds of prey) that use tree canopy and tree holes for nesting were studied. Stick-nests of raptors were located by making repeated walks and canopy scanning along river banks. Whenever raptor nest was located, name of the nesting tree, nest location, height, and canopy characteristics were observed and recorded. Nesting pairs were watched from nest construction to the fledgling leaving the nest. Weekly monitoring of nests was done. Ivlev's selectivity Index was used to find out the nest tree species preferences of the stick nesting raptors.

Threat Assessment: Potential human disturbances include cutting, lopping and Non-Timber Forest Produces collection. While sampling the woody vegetation, disturbance signs such as cutting and lopping and NTFP collection activities were recorded. Local people accompanying us in the field were interviewed to know the reasons for lopping/cutting etc. Based on the number of use values, individuals with disturbance signs, tree species were grouped into i) highly exploited ii) moderately exploited and iii. mildly used.

10. Output:

A Ph D Thesis by the project staff (SRF) under the guidance of Principal Investigator.

A research paper has been communicated and it will be published in Journal of Threatened Taxa.

Four research papers are under preparation.

Final Technical Report with research findings and recommendations.

A poster on Athikadavu Valley

11. Outcome:

Research work has brought out valuable scientific information on the following aspects of ecology of plants and birds in Athikadavu Valley, Coimbatore Forest Division, Western Ghats.

- Ecological analysis of riparian forest vegetation
- Bird community composition in the riparian forest
- Bird-tree relationships with reference to cavity nesting birds
- Nest tree utilization and nest tree species preferences of cavity nesting birds
- Nest tree utilization and nest tree species preferences of raptors
- Recommendation for the management of riparian forests of Athikadavu Valley

12. Deliverables: Not applicable

13. Name of the Agencies by whom the results can be utilized:

State Forest Department (Tamil Nadu, Kerala)  
Environmental conservation NGOs, Coimbatore  
Tamil Nadu State Electricity Board

14. The manner in which the finding will be utilized:

The Recommendations made by us based on research findings of the present study will be submitted to the State Forest Department. The Principal Investigator will make a briefing of the findings to the forest officials. The recommendations are likely to be included in their management plan. Once the suggestions/recommendations find place in the management plan, it is expected to be certainly implemented.

The State Electricity Board has its operations across the Athikadavu Valley by name, Kundha Power Project. Their operations extend from Kundha to Pillur, Parli and Athikadavu. Information on local biodiversity and its conservation significance could be spread to them for effective conservation. A



**FORMAT FOR EXECUTIVE SUMMARY OF THE RESEARCH PROJECTS  
FUNDED BY THE MINISTRY OF ENVIRONMENT & FORESTS**

**(not more than 02 to 03 pages)**

**1. Title of the Project:** "Diversity of Acridoidea (Orthoptera) in different parts of Western Ghats of India"

**2. Name of Members of Research Team and their designation:**

(i) Prof. Mohd. Kamil Usmani

Principal Investigator

(ii) Hirdesh Kumar

JRF

(iii) Md. Rashid Nayeem

JRF

**3. Number and date of Sanction letter:** No. 23/14/2010 – RE; Dt: 23.01. 2012

**4. Duration:** 3 years

**5. Total outlay:** Rs. 34,60,240/-

**6. Date of start:** 01.04.2012.

**7. Date of completion:** 31.03.2015

**8. Objectives:**

1. To undertake an extensive and intensive survey of Acridoid pests in Western Ghats to study the geographical distribution, diversity, frequency of occurrence and dominance of the locusts and grasshoppers.
2. To determine the host range of pests and to collect information on habitat, latitude and altitude.
3. To determine the pest-plant and plant-pest relationship and pest incidence in relation to ecological conditions.

## 9. Methodology:

1. Sites in the states of Kerala, Gujarat, Tamil Nadu, Karnataka, Maharashtra and Goa have been surveyed for sample collection. Data related to samples and sites like temperature, soil conditions, elevation etc. have been taken into account.
2. Insects were collected by sweep nets and were fixed using ethyl acetate in killing jars. Furthermore, they were transferred to 100 ml sterile vials containing ethanol (grade 70%) and carried back to laboratory.
3. Dry mounts were also prepared for better understanding of certain characters like size, color, texture etc. For this purpose, the specimens were first relaxed, stretched and later, they were pinned and labeled. Permanent collections of pinned specimens were kept in store boxes and cabinets for further studies on their morphological structures.
4. For a detailed study of the various components of genitalia, the permanent slides were prepared and examined under the microscope in order to make a detailed study of the genitalic structures. Protocols for genitalic slide preparation are as under:
  - 4.1. Apical one-fourth portion of the abdomen was cut-off and warmed in 10% KOH.
  - 4.2. The process was constantly monitored and when done, sample was transferred to cavity block.
  - 4.3. Washing of the same was repeatedly done to flush out excess KOH.
  - 4.4. Dissection was done using fine needles.
  - 4.5. Parts of interest were transferred to other cavity block.
  - 4.6. Dehydration was done using ascending alcohol grades (30% to absolute). Further, structures were mounted using DPX.
  - 4.7. Line drawing was done using Camera Lucida.
5. Species diversity, dominance and frequency (in concerned area) have been calculated employing various methods.

## 10. Output:

The geographic area under Western Ghats have been extensively surveyed and acridid samples have been collected. The collected specimens have been studied in detail and furthermore described taxonomically. Genitalic plates of many of the described taxa have been provided that complement the descriptions. New taxa has been described and documented. Color photographs of the taxa have also been added to the descriptions that ease the identification of the same. Ecological indices like Dominance, Evenness, Distribution, Diversity, Regression and Correlation based on acquired data till date have been calculated. Effects of various ecological abiotic parameters like rainfall, altitude, temperature, humidity and daylight on grasshopper

population have been interpreted through statistics. The study also predicts pest incidence in relation to ecological conditions. Host range has been provided along with distribution table. The work done is being progressed for publication.

## 11. Outcome

It is not less than an achievement that the acridid fauna of such an area like Western Ghats have been studied in so much detail. Several visits to the fields were carried out in different seasons and the insects were studied interacting with their host plants. Insects concentration pockets are documented rather distribution has been chalked out. Host plants have also been listed along with the frequency of distribution of the concerned species. We also see Goa as much diverse state while Kerala has been documented with maximum number of species. Three taxa have been added new to the realm of science. Based on the gathered data, State as well as host wise distribution have been provided. Relation of abiotic factors to that of grasshopper population have also been studied in detail and it has been thereby clear from the statistical studies that abiotic factors exhibiting positive correlation affect insect population directly while those factors that are negatively correlated affect the population inversely. Concerned insects feeding on all three hosts i.e. rice, millet (ragi) and grasses show positive correlation with temperature. The values exhibit strong correlation in case of millet followed by rice and then grasses. The population in rice and grasses as host plants are negatively correlated to altitude while those in millet show weak positive correlation. Same is the case with daylight as insect population feeding on rice and grasses again are negatively correlated to daylight or photoperiod while the ones feeding on millet show weak positive correlation. The population of sampled insects in rice fields show strong correlation to relative humidity while those sampled from grasses exhibit medium correlation followed by the samples from millet with weak correlation. As far as precipitation is concerned, insect population sampled from rice show very weak positive correlation while samples from both other hosts are negatively correlated to this abiotic factor. It is very obvious that all the factors are interrelated as well as interdependent on each other but temperature, precipitation and humidity are very strongly linked. Further, it is very clear from the obtained data that these factors play a crucial role in supporting the rice crop and hence explained the sampled insect population from the crop. In case of grassland ecosystem, altitude and daylight are prime deciding factors as lack of canopy and exposure time to daylight maximizes the effect of the factors. Insect population of millet is very dependent on temperature followed by precipitation, since millet is a crop of semi-arid zones. Any factor that affects the host will indirectly affect the insect population supported by that host apart from direct effects that the population experiences while confronting the abiotic deciding parameters. Temperature alone is the key player in regulating the population of acridids, be it directly or indirectly. While the next position is jointly occupied by relative humidity and precipitation.

## 12. Deliverables

Several visits to the fields were carried out in different seasons and the insects were studied interacting with their host plants. Insects concentration pockets are documented. Host plants have also been listed along with the frequency of distribution of the concerned species. The data generated and the results achieved through these studies on diversity and ecological observations could be implemented to developing suitable control measures and applied in the field by researchers and govt. agencies.

## 13. Name of the Agencies by whom the results can be utilized

Various Govt. as well as Corporate Research & Development agencies

## 14. The manner in which the finding will be utilized

Commercial and Social

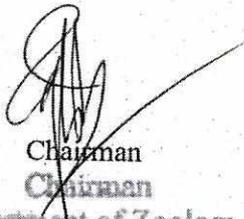
## 15. Recommendations and their implementation

The cultivation period for above mentioned crops should avoid a complete synchronization with the peak period of grasshopper (reported under the present work) activity. These crops must not be repeated at a locality and all the favourable crops should not be included in a one year cultivation scheme.

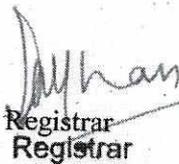


Principal Investigator

Dr. Mohd. Kamil Usmani  
(Principal Investigator)  
MOEF Major Research Project  
Department of Zoology  
A.M.U., Aligarh-202002



Chairman  
Chairman  
Department of Zoology  
A.M.U., Aligarh



Registrar  
Registrar  
Aligarh Muslim University  
Aligarh (U.P.) INDIA

03/08/15

Dr. K. K. Jha,

FORMAT FOR EXECUTIVE SUMMARY OF THE RESEARCH PROJECTS  
FUNDED BY THE MINISTRY OF ENVIRONMENT & FORESTS

1. Title of the Project: Distribution and Conservation Strategy of an Endangered Ornamental Fish Species  
*Chaca chaca* (Ham. – Buch.) in Arunachal Pradesh

2. Name of Members of Research Team and their designation:

1. Dr. Keshav Kumar Jha - Principal-Investigator
2. Prof. Tapan Kumar Ghosh -Co-investigator
3. Prof. Vibash Chandra Jha - Co-investigator
4. Shri Onang Tamuk – JRF
5. Shri Kumar Chetri – JRF
6. Shri Tamet Talom – F/A

3. Number and date of Sanction letter: 14/32/2008-ESR/RE & 7th July, 2010.

4. Duration: Three (3) year

5. Total outlay: Rs. 1673750/-

6. Date of start: 12-08-2010

7. Date of completion: 11-08-2013

8. Objectives:

- a. Survey was conducted in Arunachal Pradesh to explore the possibility of distribution of *Chaca chaca*.
- b. Studied the food and feeding habits of *Chaca chaca*.
- c. Studied the reproductive cycle of *Chaca chaca*.
- d. Studied the fishing methods applied by the residents of surrounding villagers of that locality.
- e. Created general awareness among the people about an endangered fish species
- f. Conservation Strategies.

9. Methodology:

The following methods were adopted:

A. To Study the structure of Tango Epong Stream:

a. For that all the information were collected from ground level of the Tango Epong stream.

B. For finding out the presence of *Chaca chaca* in the different districts of Arunachal Pradesh, the following methods were applied:

- i. The specimens *Chaca chaca* were produced before peoples of the areas.
- ii. The photographs of *Chaca chaca* were shown to the people.
- iii. Older people were contacted of those areas.
- iv. The fishermen were contacted of those areas.
- v. Different methods of fishing in the water bodies of Arunachal Pradesh for the collection of *Chaca chaca* were applied.
- vi. The employees of Fisheries Department, etc. were contacted.

To Study the Food and Feeding Habit of *Chaca chaca* :

To study the food and feeding habits of *Chaca chaca*, the fish specimens were collected from their natural habitat in each month from Tango Epong Stream and other places in Arunachal Pradesh. After taking the morphometric measurements the fish was anaesthetised with MS<sub>222</sub> and then the stomach was dissected. The gut contents were then fixed in small glass vials containing 70% alcohol. This is done to avoid further food digestion by digestive enzymes present in the fish gut. After dissecting out the alimentary canal the fish bodies were also preserved in 6 % formaldehyde solution for further investigation. In the laboratory, the gut content was observed under the Simple microscope, compound Microscope and research Microscope and observations were recorded.

The percentage of each food item was calculated by eye estimation method (Pearse, 1915, Job, 1940 and Pillay, 1952).

For quantitative feeding, gastrosmotic index was calculated by using the formula:

$$\text{Gastrosmotic Index} = \frac{\text{Weight of Food}}{\text{Weight of Fish}} \times 100$$

C. To Study the Reproductive Cycle of *Chaca chaca*:

Live specimens of male and female *Chaca chaca* were collected every month for duration of twelve month from Tango Epong stream of Motum village under Mebo Block of East Siang District of Arunachal Pradesh, transported to the laboratory and kept in the aquariums according to the size of the fish. Kesteven (1960) proposed seven stages of maturity scale in the case of total spawners. However, in *Chaca chaca* four distinct stages of maturity scale could be identified by us. They were stage I (Early/ Premature), stage II (Immature), Stage III (Partially mature) and Stage IV (Mature). The length and weight of all the specimens were recorded. The specimens of both the sexes were dissected and gonads were fixed in the preservatives for further observations.

Relative fecundity:

Relative or comparative fecundity was calculated according to the following formula (Hardisty, 1964; Das, 1964).

$$\text{Relative fecundity} = \frac{\text{Egg number}}{\text{Body weight}}$$

D. To Study of Fishing Methods Applied by the Residents of Surrounding Villagers:

There is an intricate link between various fishing techniques and knowledge about the fish and their behavior among the villagers as well as the local fisherman. The fishing tools and techniques in Arunachal Pradesh are traditional, non-mechanized and mostly locally built. It is because the tribal's populations in the state is about 80%. Arunachal Pradesh is highest tribal's diversity in world. 25 major tribes and 125 sub-tribes with different life style and dialect. So, that the fishing is highly diverse in water areas adopts the operation of large and indigenously designed devices and nets in Arunachal Pradesh for capturing different varieties of fishes. Observed the Various tools and techniques applied for fishing in the areas where fish *Chaca chaca* is present.

E. To Create General Awareness among the People about an Endangered Fish Species

Our work has pledged itself in local communities of Arunachal Pradesh, India to conserve to the extent practicable, the fish species *Chaca chaca* facing endangered status and to prevent it from extinction in the near future. The purposes of our work is to provide a means whereby the ecosystems and various other factors upon which are endangered species in particular and threatened species in general depend may be conserved. This is to provide a programme for the conservation of such endangered and threatened species, and to take such steps as may be appropriate to achieve the purpose. The yearlong mass awareness programme for conservation of an endangered fish *Chaca chaca* has been organised in Arunachal Pradesh with the help of the members from all corners of the society.

F. Conservation Strategies:

It is expected that fish fauna in the state will deplete with accelerating rate due to spread of invasive species, habitat destruction, increasing anthropogenic pressure, destructive fishing methods of the non-traditional fishermen and discriminated management of the riverine resource including water etc.

Therefore, It now has entered into endangered category and is likely to become extinct in near future, if not conserved. Thus its conservation is important in respect of its aesthetic, ecological, educational, historical, recreational, and scientific values.

10. Results/Findings

a. Tango Epong stream is situated between the N28°04.318' to 28°04.831' longitude and E095°26.121' to 095°26.778' latitude and elevation varied from 423ft to 444ft. The whole area of the Epong is 70902 sq m i. e 7.092 ha. The main stream is situated in East-West direction, whereas the Nala (drain) of the Epong is in the North-south direction. The north side of the Epong covered by thin trees and human settlement whereas the south bank of the Epong is covered by the thick forests. The surface of the stream is formed from the young sedimentary rocks and its bottom is covered with the boulders and sand. Most of the water body is covered by the Eichhornia and other aquatic plants. The water depth in the Epong varied from few centimeters to 150 cms.

b. Among all the districts of Arunachal Pradesh, presence of *C. chaca* is recorded mainly from lower ridges of 10 districts viz East Kameng (Bhalukpong), West Kameng (Seijosa), Papumpare (Balijan & Kimin), Lower Subansiri (Dolelmukh), West Siang (Likabali), East Siang (Pasighat, Nari, Mebo &

- Bilat), Lower Dibang Valley (Dambuk, Kongkon, Shantipur), Tezu (Namsai), Changlang (Bardumsa), Tirap (Deomali).
- c. Among these districts East Siang district harbours these fishes in maximum areas like Pasighat, Nari, Mebo and Bilat. Since these areas lie at low altitude and it may be a possible reason for their availability. Other districts like Tawang, Kurung Kumey, Upper Subansiri, Upper Siang, Dibang Valley and Anjaw district did not show the presence of this fish species. *Chaca chaca* is found at the maximum elevation of 633 ft and above that elevation it was not found.
  - d. The major food items found in the gut of *Chaca chaca* is grouped into (i) Fish (ii) crustacea (iii) nematoda (iv) sand and silt particles and (v) miscellaneous items.
  - e. Fish: This group is the most dominant food items encountered in the gut content of *Chaca chaca* and formed 40% of the total food. The fishes found in the gut includes *Channa* species, *Chanda* sps., *Puntius* sps., *Rashora* sps., *Amblypharyngodon mola* etc.
  - f. Crustacea : The group is represented by Decapoda, Mycidacea and Malacostraca. This group forms 29% of the total food and ranked 2<sup>nd</sup> in the gut content.
  - g. Nematoda : It constituted 11% of the total gut content and ranked third in the gut content
  - h. Filamentous algae: Small quantity of filamentous algae are found. Their presence was found 3% only.
  - i. Sand and silt particles : Sand and silt are often ingested by the species, formed about 8% of the total gut content.
  - j. Miscellaneous : They are represented by fragmented animal matter and it contributed 9% of the total food matter.
  - k. In natural conditions the main factor that inhibits the population of *Chaca chaca* is less number of eggs. The fecundity rate of this fish species is very low as compared to other species of fishes. Beside this, other factor is predators in the fish habitat which fed on the helpless fingerlings and leave behind very few individuals to get developed into adults.
  - l. There is an intricate link between various fishing techniques and knowledge about the fish and their behaviour among the villagers as well as the local fisherman. The fishing tools and techniques in Arunachal Pradesh are traditional, non- mechanized and mostly locally built. It is because the tribal population in the state is about 80%. Arunachal Pradesh has the highest tribal diversity in world. 25 major tribes and 125 sub-tribes with different life style and dialect reside here. That's why the fishing is highly diverse in water areas which adopt the operation of large and indigenously designed devices and nets in Arunachal Pradesh for capturing different varieties of fishes.
  - m. The restricted distribution of this endangered fish species *Chaca chaca* seeks high and immediate attention towards its conservation. Focus on its conservation has been emphasized through mass awareness programmes carried out in many parts of Arunachal Pradesh. Keeping in mind the immediate attentions towards its conservation.
  - n. Addressing village Heads, ASM's and villagers, the active participation of the villager, Village Heads (Gaon Bura) and ASMs were briefly addressed about this fish, its importance and future prospects and their participation toward the novel steps of conservation.
  - o. Briefing sessions were made to the students who disseminated the knowledge about this endangered fish *Chaca chaca* to their society for its conservation. Short seminars at different levels were also organised.
  - p. Postering at different places like schools, colleges and other public places were done to motivate the people join their hands to conserve this fish. Notices were served with warning and prohibition on fish killing at fishing sites and motivation drive was organised towards its conservation.
  - q. Organized seminars and rallies at schools and Colleges for conservation were very informative to conserve this fish.
  - r. The mass awareness programmes were organized mostly in the area where its presence is seen in the state.
  - s. Thus the conservation of *Chaca chaca* is important in respect of its aesthetic, ecological, educational, historical, recreational, and scientific values.
13. Name of the Agencies by whom the results can be utilized: IUCN, ZSI, CSIR, DST, Biodiversity Board, DoBT, ICMR etc.
  14. The manner in which the finding will be utilized: Research and Development.
  15. Recommendations and their implementation: As described in report.

  
 Principal Investigator  
 Principal Investigator  
 MoEF Research Project  
 Department of Zoology  
 J.N. College, Pasighat (Ar.P)

  
 Principal  
 Principal  
 J. N. College, Pasighat  
 Arunachal Pradesh

**EXECUTIVE SUMMARY OF THE PROJECT  
(2010 - 2013)**

- 1. Title of the project** : **ASSESSMENT OF BRYO-DIVERSITY IN UTTARAKHAND, WESTERN HIMALAYA**
- 2. Name of Principal Investigator** : **Dr Geeta Asthana** (Associate Professor)  
Department of Botany  
University of Lucknow  
Lucknow
- 3. Number & date of Sanction letter:** **(NO. 14/30/2008 – ERS/RE DATED 06.01.2010)**
- 4. Duration of the Project** : **Three Years (2010 - 2013)**
- 5. Date of Commencement** : **May 3<sup>rd</sup>, 2010 (Appointment of Fellow)**
- 6. Date of Completion** : **May 2<sup>nd</sup>, 2013**
- 7. Extension of Period** : **NA**
- 8. Total outlay of the Project** : **Rs. 10,17,324/- (For three Years)**  
**(Rupees Ten lakhs seventeen thousands three hundreds and twenty four)**
- 9. Total amount sanctioned during the entire tenure under different subheads** : **Rs. 9,16,600/- (Total Grant released till date)**
- 10. Total amount spent during the entire tenure under different** : **Rs. 8,92,009/-**
- 11. Brief Introduction** :

**Uttarakhand** is a large hilly state in west Himalayan territory with an area of 55845 km<sup>2</sup> and rich vegetation. It is located in the northern part of India (28<sup>o</sup> 43' N to 31<sup>o</sup> 27' N longitude & 77<sup>o</sup> 34' E to 81<sup>o</sup> 02' E latitude) in the southern slope of western Himalaya. It comprises of Kumaon and Garhwal Hills having 13 districts. The Kumaon region (the eastern part of the state) includes following districts: Almora, Bageshwar, Champawat, Nainital, Pithoragarh and Udham Singh Nagar. The Garhwal region (the western part of the state) includes following districts: Chamoli, Dehradun, Haridwar, Pauri, Rudraprayag, Tehri Garhwal and Uttarkashi.

In the present project, the area (Uttarakhand) has been surveyed to assess the Bryodiversity of Uttarakhand, western Himalaya.

## 12. Objectives:

1. Exploration, survey and collection of bryophytes from unexplored and under-explored areas in Uttarakhand, western Himalaya.
2. Preparation of a consolidated and illustrated floristic account of Bryophytes of Uttarakhand, western Himalaya.
3. Assessment of rare, threatened and endemic Bryophyte taxa of the region.
4. *In-vitro* propagation of selected bryophytes of the region.

## 13. Work done

- Different localities in Almora, Bageshwar, Champawat, Nainital & Pithoragarh districts of Kumaon Region and Chamoli, Dehradun, Haridwar, Pauri Garhwal, Rudraprayag & Tehri Garhwal districts of Garhwal Region in Uttarakhand have been explored and a number of bryophytes (1400 herbarium Packets) have been collected. They have been deposited in Lucknow University Bryophyte Herbarium (LWU). The collected specimens have been critically investigated, identified, illustrated and photographed in field as well as in Laboratory. Their distribution in Garhwal & Kumaon hills in Uttarakhand has also been observed.
- *In-vitro* studies on *Atrichum pallidum* Ren. et Card., *Brachymenium capitulatum* (Mitt.) Kindb. and *Funaria hygrometrica* Hedw., *Asterella wallichiana* (Lehm. & Lindenb.) Grolle, *Plagiochasma appendiculatum* Lehm. & Lindenb. & *Reboulia hemisphaerica* (L.) Raddi have been carried out.

## 14. Results / Findings:

- Following area (Districts) have been Surveyed: Almora, Bageshwar, Champawat, Chamoli, Dehradun, Haridwar, Nainital, Pauri Garhwal, Pithoragarh, Rudraprayag, Tehri Garhwal
- Total 176 taxa have been identified including 93 Liverworts, 7 Hornworts and 76 Mosses.
- Total ninety three liverwort taxa identified from Uttarakhand belong to forty eight genera, twenty six families and four orders.
- Total seven hornwort taxa identified from Uttarakhand belong to three genera, three families and two orders.
- Total seventy six moss taxa identified from Uttarakhand belong to forty one genera, twenty two families and two orders.
- Six species have been discovered as new to science: *Blepharostoma indica* sp. nov., *Frullania deobanensis* sp. nov., *Frullania garwalensis* sp. nov., *Lethocolea indica* sp. nov., *Plagiochila mukteshwarensis* sp. nov. & *Rectolejeunea udarii* sp. nov.
- Forty eight taxa have been observed as new records. Among these thirty seven are Liverworts & eleven are Mosses.

- ❑ Three liverwort taxa: *Geocalyx lancistipulus*, *Jamsoniella myriocarpa* & *Lejeunea kodamae* are new record for India.
- ❑ Twenty three taxa: *Anastrophyllum minutum*, *Aneura pelloides*, *Bazzania sikkimensis*, *Cephalozia darjeelingensis*, *Cephalozia hamatiloba*, *Cephalozia laxifolia*, *Cephaloziella willisiana*, *Cylindrocolea chevalieri*, *Frullania companulata*, *Frullania dilatata*, *Heteroschyphus parvus*, *Lejeunea wallichiana*, *Microlejeunea punctiformis*, *Radula kurzii*, *Rectolejeunea olivacea*, *Scapania griffithii*, *Scapania stephanii*, *Solenostoma comatum* & *Tritomeria exsecta* (among liverworts), *Campylopus ericoides*, *Entodon scariosus*, *Fissidens areolatus* & *Meteorium helminthocladum* (among mosses) are new to Western Himalaya.
- ❑ Four liverwort taxa: *Heteroschyphus orbiculatus*, *Liochlaena lanceolata*, *Metzgeria consanguinea* & *Porella platyphylla* are new to Uttarakhand.
- ❑ Ten taxa: *Chiloschyphus kashyapii*, *Cololejeunea latilobula*, *Lopholejeunea sikkimensis*, *Plagiochila chinensis*, *Plagiochila mundalensis*, *Plagiochila parvifolia*, *Riccardia levieri* (among liverworts), *Bryum bessonii*, *Lindbergia koelzii* & *Macromitrium moorcroftii* (among mosses) are new to Garhwal region.
- ❑ Eight taxa: *Cyathodium cavernarum*, *Haplomitrium hookeri*, *Lophocolea heterophylla*, *Plagiochila nepalensis* (among liverworts), *Grimmia fuculotea*, *Melendoa roylei*, *Pogonatum urnigerum* & *Rhodobryum giganteum* (among mosses) are new for Kumaon region.
- ❑ Five liverwort taxa: *Blepharostoma trichophyllum* (L.) Dumort., *Cephalozia darjeelingensis* Udar & Kumar, *Cephalozia hamatiloba* Steph., *Cephalozia laxifolia* Udar & Kumar & *Lejeunea bidentula* Herzog have been discovered after a long time.
- ❑ Following four liverwort taxa have been observed with their changed status: *Liochlaena lanceolata* Nees (= *Jungermannia leiantha* Grolle), *Solenostoma comatum* (Nees) C.Gao (= *Jungermannia comata* Nees), *Solenostoma tetragonum* (Lindenb.) R.M.Schust. ex Váňa et D.G.Long (= *Jungermannia tetragona* Lindenb.) & *Solenostoma truncatum* (Nees) R.M.Schust. ex Váňa et D.G.Long (= *Jungermannia truncata* Nees).
- ❑ Oil – bodies have been investigated in following twenty liverwort taxa: *Chiloschyphus himalayensis*, *Cololejeunea latilobula*, *Frullania companulata*, *Frullania dilatata*, *Frullania erecoides*, *Frullania muscicola*, *Heteroschyphus orbiculatus*, *Heteroschyphus pandei*, *Lethocolea indica*, *Lophocolea cuspidata*, *Lophocolea himalayensis*, *Lophocolea minor*, *Lopholejeunea sikkimensis*, *Microlejeunea punctiformis*, *Plagiochila nepalensis*, *Plagiochila parvifolia*, *Porella densifolia* subsp. *apendiculata*, *Radula companulata*, *Scapania griffithii* & *Solenostoma tetragonum*.

(DR GEETA ASTHANA)  
Principal Investigator

## Part - III

### 1. Recommendation including remedial measures relevant to the environmental problems studied under the Scheme.

India is a vast country and considerably rich in the bryoflora. Bryophytes are first land plant and are important component of the ecosystem. These liliputians of the plant kingdom grow on the variety of habitats like soil, rock surface, stone surface, tree bark surface, leaf surfaces and play an important role in ecological balance. A slight disturbance in the stabilized habitat may cause major loss of biodiversity in general and bryodiversity in particular which disturbs the environmental balance. If any type of construction is required for development & human welfare, the expert opinion of environmentalist & ecologist should be taken into consideration to minimize the loss of natural resources. The hilly areas of the country are the suitable niche of many rare and important Bryophyte taxa. Protection of forest cover at high altitudes of the study area is urgently required. Every possible precaution should be taken for the protection & conservation of biodiversity of this region as already a great loss of natural habitats of these plants has taken place due to natural disasters and unplanned anthropological activities. The conservation of plant diversity is very much needed for the survival of life on the earth and it can be achieved by proper designing of the developmental policies followed by certain rules and regulations and by joint collaboration of Government & Non Government Organizations involved in the Conservation of Biodiversity.

### 2. List of research papers published/accepted in journals/Patent the research work done under the Scheme.

(Two copies of each of the reprints/accepted Papers also to be enclosed).

#### Research Papers published / communicated

- (1) A new species of *Blepharostoma*, *B. indica* sp. nov. from western Himalayas, India with the observations on closely allied species *B. trichophyllum*(L.) Dumort. *Journal of Bryology* 2013. (Geeta Asthana, Murti Saxena, Mridula Maurya) Proof Corrected
- (2) *Lethocolea indica* sp. nov. - a new liverwort from India. National Academy Science Letters 2013. (Geeta Asthana and Mridula Maurya) Communicated.
- (3) *Solenostoma comatum* (Nees) C.Gao (Jungermanniaceae) – An Addition to West Himalayan Bryoflora (India). *Geophytology* 2013. (Geeta Asthana and Mridula Maurya) Communicated.
- (4) *Haplomitrium hookeri* (Smith) Nees: A Rare Species New To Kumaon Hills (Uttarakhand), Western Himalaya. National Academy Science Letters 2013. (Geeta Asthana and Murti Saxena) Communicated.

#### Abstracts Published:

- (1) *Microlejeunea punctiformis* (Taylor) Spruce new to Western Himalaya. “XXXIII Conference of Indian Botanical Society & International Symposium on the new Horizons of Botany” held on November 10-12, 2010, at Department of Botany,

- Shivaji University, Kolhapur, Maharashtra. pp. 37. (Geeta Asthana, Murti and Mridula Maurya)
- (2) *Lethocolea indica* sp. nov. an interesting gemmiparous liverwort from India. In “XXXIV All India Botanical Conference” held on October 10-12, 2011, at Department of Botany, University of Lucknow, Lucknow. pp. 135. (Mridula Maurya)
  - (3) *Entodon laetus* (Griff.) Jaeg. (Entodontaceae): an addition to Western Himalaya. In “XXXV All India Botanical Conference” held on October 10-12, 2012 at Botany Department, The Maharaja Sayajirao University of Baroda, Vadodra. p. 96. (Mridula Maurya)
  - (4) *Cephalozia darjeelingensis* Udar & Kumar new to western Himalaya. In “XXXVI All India Conference of the Botanical Society” held on October 18-20, 2013 at Department of Botany, Deen Dayal Upadhyay Gorakhpur University, Gorakhpur. p. 80. (Murti Saxena and Geeta Asthana).
  - (5) *Scapania stephanii* Mull (Scapaniaceae): an addition to western Himalaya. In “XXXVI All India Conference of the Botanical Society” held on October 18-20, 2013 at Department of Botany, Deen Dayal Upadhyay Gorakhpur University, Gorakhpur. p. 92. (Murti Saxena and Mridula Maurya)

**FORMAT FOR EXECUTIVE SUMMARY OF RESEARCH PROJECTS FUNDED BY THE MINISTRY OF ENVIRONMENT & FORESTS (Not more than 3 Pages)**

**1. Title of the Project**

Taxonomy and Ecology of the Himalayan Genus *Oxytropis* DC. (Leguminosae) in India

**2. Name of Members of Research Team and their designation**

1. **Dr. L. B. Chaudhary**, Principal Scientist & PI
2. **Mr. Soumit Kumar Behera**, Scientist & Co-PI
3. **Mr. Omesh Bajpai**, Research Scholar
4. **Mr. Nayan Sahu**, Research Scholar

**3. Number and date of Sanction letter:** 14/38/2009-ERS/RE dt. 25. 11. 2011

**4. Duration of the Project:** 3 years and 6 months

**5. Total outlay of the Project:** Rs. 18,65000/-

**6. Date of start of Project:** 15/02/2012

**7. Date of completion of Project:** 31 August 2015

**8. Brief introduction:**

*Oxytropis*, a member of Fabaceae under subtribe *Astragalinae* of tribe *Galegeae*, consists of ca. 300 – 400 species throughout the world. The closest relative of the genus is *Astragalus*, which grows together in similar kind of habitats. The two genera are very similar in their gross morphology and differ chiefly in the shape of keel petals. The study of literature, herbarium specimens and our own field survey reveal that in India the genus has about 21 species, occurring at high reaches throughout the Himalaya. This included one new species and five new records for India. The majority of the species shows affinity either with European or Sino Himalayan elements. *Oxytropis* is widely distributed in the temperate to alpine zones of the Himalaya up to 6000 m altitude. Since *Oxytropis* grows in very cold climate in dry and hard soil, it develops perennial thick woody root-stock and herbaceous and profusely caespitose habit to counter the environmental stress. As the habitats of *Oxytropis* are covered by heavy snow during the most part of the year, the life cycle (flowering & fruiting) of the species is completed within short span of time during July to August (-September). The species grow on mountain slopes,

along riverbeds and agriculture lands in open among grasses and boulders. *Oxytropis* is a very complex genus and shows great morphological plasticity that causes much difficulty in identification and natural grouping of the species.

### **9. Objectives:**

1. To assess the diversity in the genus *Oxytropis* - both at species and infra-specific levels.
2. To study the community association and population dynamics in different altitudinal gradients and its bearing on Systematics.
3. To study the impact of microclimate on species distribution and phenology.
4. To bring out a systematic revision on the genus including morphological and ecological parameters.

### **10. Work done:**

Large number of areas of Leh & Ladakh, Lahul-Spiti and N. Sikkim were surveyed for the collection of *Oxytropis* and record the field data. In addition to the field studies, the specimens collected earlier and housed at many herbaria like BSD, BSHC, CAL, CDRI, DD, K, LWG, have also been examined to know the correct number of species and record the variations within them. Based on field studies, literature survey and examination of previous collections, 21 species of *Oxytropis* have been recorded from India. The detailed taxonomic account of all species with correct nomenclature, description, phenology, distribution, habitat/ecology, etc. has been provided. All species have been critically examined and new descriptions have been prepared including all variations of the taxon. A new species *O. sanjappa* Chaudhary has been described and published in international journal. Five new additions (*O. guntensis*, *O. hypoglottoides*, *O. kansuanensis*, *O. malloryana* and *O. melanocalyx*) have been made for the first time for India. *O. kansuanensis* has also been recorded here from Bhutan. *Oxytropis shivai*, *O. rauti* and *O. thomsonii* have been treated as synonyms of *O. cachemiriana*, *O. lapponica*, and *O. mollis* respectively while *O. microphylla* and *O. chiliophylla* have been treated separately contrary to the earlier work. The line drawing illustrations, photographs of type specimens and colour photographs have also been provided for all species. A dichotomous key has been made for all species for quick identification.

The plant phytosociology at three altitudinal gradients was studied by laying total 70 random quadrates of 1m X 1m area. Quantitative analysis of frequency, density, dominance and

importance value index were done. Relative frequency, density, dominance and importance value index (IVI) for individual species were calculated at three altitudinal gradients. Shannon-Wiener index (H') and Simpson's dominance index (C) were computed. Diurnal data on five microclimate variables such as photosynthetically active radiation (PAR), air temperature, soil temperature, atmospheric ambient CO<sub>2</sub> concentration, air absolute humidity were collected. Maximum plant diversity was observed at lower altitudes (i. e. 3000-3600 m). The higher altitudes ranging from 4000-4400 m experienced maximum variability in microclimatic parameters, which indirectly exerts stress at higher altitudes for plant establishment that leads to lesser diverse community in higher altitudes. *Oxytropis sanjappae* exhibited heighest population dynamics having 35.74 % of annual population increament among five species examined. This needs to be further investigated interms of considering grazing effects and habitat destruction on population dynamics and further stabalization of the species.

## **11. Results / finding:**

The large number of specimens have been collected from Himachal Pradesh, Jammu & Kashmir and Sikkim and deposited at LWG for future record. All previous collection deposited at LWG, CAL, BSD, DD, CDRI, BSHC, K have been examined to record the variations within the species and correctly annotated. Detailed taxonomic account of 21 species of *Oxytropis* occuring in India has been provided and a taxonomic key has been prepared for identification. A new species *O. sanjappae* Chaudhary has been described and published. Five new additions (*O. guntensis*, *O. hypoglottoides*, *O. kansuanesis*, *O. malloryana* and *O. melanocalyx*) have been made for the first time for India. *O. kansuanesis* has also been recorded here from Bhutan. *Oxytropis shivai*, *O. rauti* and *O. thomsonii* have been treated as synonyms of *O. cachemiriana*, *O. lapponica*, and *O. mollis* respectively while *O. microphylla* and *O. chiliophylla* have been treated separately contrary to the earlier work. Habitats and ecology have been studied at different altitudinal levels which will help to understand the reason for morphological plasticity within the species. The plant phytosociological study reveals more than 60 associates of *Oxytropis*. Microclimate at three altitudinal gradients were recorded which shows maximum variability at higher altitudinal gradient. *O. sanjappae* shows highest population dynamics.



## **Studies on Dynamics of Floral and Faunal Components of three selected Pond Ecosystems of Sivaganga District, Tamil Nadu**

**(F.No.14/43/2009-ERS/RE)**

### **Recommendations**

Based on results of the project work, the following recommendations could be made:

- Vettangudi pond ecosystem is a suitable habitat for avian species, especially local and overseas migratory birds. Some endangered avian viz., Asian open bill stork, Oriental White Ibis are also recorded in Vettangudi Birds Sanctuary. Since, the migratory birds visit is entirely depend on the water and other environmental resources of Vettangudi Pond Sanctuary for their brooding, nesting and breeding purpose, the pond environment has to be maintained properly.
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- The presence of birds, certainly influences on the water quality, sediments and soil quality, the influencing parameters to be identified through continuous monitoring and evaluation of water, soil and biotic species from the pond
- The communities, living adjacent to the Vettangudi Birds Sanctuary Ponds utilize the water collected from the bore wells for their domestic needs. Since, the pond water quality will have the greater influence over the ground water quality, the water samples, collected through bore wells and open wells, adjoining to the pond area are to be analyzed for making the assurance of public health.
- Removal of the top soil surface of the dry ponds, during the summer months is essential to control the addition of excess chemical substances, due to the addition through the bird droppings and from the sedimentation process. The top soil removed from this can be used as the soil mix for the production of quality forest seedlings; thereby the excess addition as well as infiltration of chemical substances into ground water can be prevented.
- The sub-surface soil removed from these ponds can be used to strengthening of bunds area. These management practices can be done by utilizing the Village Community, as Joint Management Programme by the State Forest Department and the local community.
- Cattle grazing inside the dry pond area is found to be the important reason for the spread of thorny bushes of *Acacia* species and hence, cattle grazing inside the pond area has to be prevented. Alternately, provision of livestock and cattle feed through an effective supply to the herders would be benefiting in the maintenance of ponds.
- In addition to the above points, other management system can be adopted for the management of pond resources of Vettangudi Birds Sanctuary, for obtaining the multiple benefits viz., pond resources conservation, wildlife management and improved ecotourism can be achieved; thereby a sustainable ecosystem conservation can be done.

- **Studies on Dynamics of Floral and Faunal Components of three selected Pond Ecosystems of Sivaganga District, Tamil Nadu**

-  
- (F.No.14/43/2009-ERS/RE)

**Executive Summary**

Ponds are one among the freshwater resources which are categorized into natural or man-made; permanent or temporary; small or large, depending upon the period of water availability and the quantity of water present in the ponds. Whichever type of the ponds, they serve for the goods and services to the man and environment. The temporary or ephemeral ponds remain flooded in a sufficiently few or long period and totally depend on the rainfall or water discharge from river canals or other resources and during the summer, such ponds get dried up due to the hot and dry weather conditions. Hence an alternate wet and dry conditions exist in the temporary pond ecosystems, thereby holding an unique nature of flora and fauna communities, including different types of aquatic, semi-aquatic and terrestrial vegetation; fauna groups like birds, amphibians, fish and terrestrial insects, etc., thereby these type of ponds also show greater biotic and environmental amplitudes than rivers and lakes, which are more or less perennial system..

**Problem Description**

Land-use pattern changes with the utility nature of pond resources make these fragile habitats into having a drastic ecological change, through altering the environment and their yield potential. Hence, it is of paramount important to study the ecological components of ponds in terms of water, sediment and biotic organisms' diversity and their interaction upon the ecological functioning. Further, varying utilization of these temporary ponds leads to have a dynamic ecological change, as it was emphasized by Ramsar Convention. These aspects of Pond monitoring and ecological analysis form a strong basis to relate the factors over the ecological functioning of the ponds, which would be developed the best management practices to protect the ponds.

No much detailed information is available on the biotic diversity and their interactions with the ephemeral pond environment of Vettangudi Birds Sanctuary Ponds with varying nature of biotic disturbances. Hence the research question may be arising "How would be the different kind of biotic disturbances impact on the flora aggregation in those ponds of Vettangudi Birds Sanctuary, Sivaganga District, Tamil Nadu, with varying utilization?"

## Objectives

The project work was completed with the objective of analyzing the flora and fauna diversity and their seasonal dynamics and further attempted to relate with the water quality and soil characteristics viz., physical nature and chemical quality of the ponds, due to the biotic interactions were analyzed.

## Description of the study area

The present work was undertaken in the 3 ponds in Vettangudi Birds Sanctuary with a total area of 38.4 ha.. The sanctuary is encompassing three drainage ponds such as Periya Kollukudi patty pond, Chinna Kollukudi patty pond and Vettangudipatty pond. Those ponds are located in Vettangudipatty and Kollukudipatty Villages of Thiruppathur taluk, Sivagangai District of Tamil Nadu. State. Those ponds were declared by the Government of Tamil Nadu as bird sanctuary in June 1977 (G.O.Ms.No.574, Forest Department, Tamil Nadu).

Perriya Kollukudi patty pond (PKPTY) spreads to an area of 13.66 ha. (10° 06.57'N and longitude 78° 30.81'E latitude. This pond was the major pond of the Vettangudi birds Sanctuary. The pond attracts several bird species, mainly migratory birds from various parts of India and also from abroad for their breeding. The pond water is used for irrigation and a open well and a bore well are also available in the pond area. This pond is well protected as it forms as the Bird Sanctuary.

Chinna Kollukudi Patty pond (CKPTY) spreads to an area of 6.32 ha (latitude 10° 06.57'N and longitude 78° 30.41'E).. This pond was mostly covered with the *Prosopis juliflora*, since the pond area is not well protected and cattle grazing are commonly seen in that pond.

Vettangudi Patty pond (VKPTY) is the biggest pond among the select ponds, spreading to an area of 18.42 ha. (latitude 10° 06.10'N and longitude 78° 01.23'E). *Prosopis juliflora*, *Acacia nilotica* and other bushes are largely found in the pond surface and the pond resources are utilized for the irrigation, domestic purpose including drinking and cattle grazing by the adjoining Vettangudipatty village.

All the three ponds are ephemeral, as water recharges in the ponds during monsoon rains, generally by North-East Monsoon. Thus, generally water availability in the ponds are lasting only between November and February and during the early summer, the ponds get dried up and the desiccate nature causes the ponds to dry for 8-9 months in a year. The nature of the ephemeral ponds becomes unique, with the associated intermediate conditions of dry and wet conditions, causing a distinctive feature of vegetation diversity.

## **Water and soil Sampling and analysis**

Water samples were collected from the experimental ponds in regular monthly intervals, from February 2013 to September 2014, whenever water was available in the ponds. Depending upon the availability, water samples were collected from 0-1 ft. and also at a depth of 1-2 ft. in clean plastic bottles at 06:00 hrs, during every sampling period and brought to the laboratory for further analyses. Sampling and analytical procedures were done using available standard method (APHA, 2005). pH was determined with the help of pH meter (Elico, India). Water temperature was measured as soon as sampling was done. TDS, conductivity, salinity, alkalinity and DO were analyzed using Water Analyzer kit (Systronics Make; Model No. 371). The presence of microalgae were analyzed in the water samples.

Soil analysis was done by sampling soil cores from the ponds surfaces at three different depths; viz., 0-10cm, 10-20 cm and 20-30 cm. at regular monthly intervals for one year. June, 2013 to May, 2014. Soil physical parameters viz., pH, TDS, conductivity, salinity, alkalinity and chemical substances viz., total nitrogen, chloride contents were analyzed from the soil samples collected from the experimental ponds. Surface CO<sub>2</sub> emission was quantified, using alkali absorption method, to find out the extent of carbon stock and carbon sequestering mechanism of ponds due to their varying ecological conditions and biotic interventions.

## **Floristic Composition Study**

Vegetation analysis in terms of aquatic and semi-aquatic species was done in the pond area. Terrestrial vegetation was enumerated using all-out search method, done in the dry pond surfaces and their bunds. Plants species were identified using standard flora and monographs and the herbarium on the plant specimens, after processing are stored in Thiagarajar College Herbarium, Madurai. Terrestrial plants occurred on the dry surfaces and bunds were noted in 4 months of the year 2013-2014, for the three temporary ponds and the Sorenson's similarity index was calculated between the pairs of the ponds.

## **Vegetation Diversity Analysis**

Quadrat analysis was done at 12 randomly select points of the dry surfaces and the bunds of the experimental ponds, at regular monthly intervals, for 12 months, between the period of December 2013 and November, 2014. From the quadrat analysis data on the herbaceous vegetation, Importance Value Index or IVI of the species (Curtis, 1959) was calculated using the formula:  $IVI = \text{Relative Frequency} + \text{Relative Density} + \text{Relative Basal Area}$

*Shannon's Index*: (Shannon and Weiner, 1963) was calculated using the formula:  $H = -\sum p_i \log p_i$ ; where,  $p_i$  is the decimal ratio of individuals of a species to the total number of over all individuals. Similarly, Simpson's Diversity Index was also calculated and Species Richness was calculated, using the following formula,

$$\text{Species Richness} = \frac{\text{Total number of species occurred}}{\text{Log (Sum of total number of Individuals)}}$$

Raunkaier's frequency class distribution was analyzed from the data on the relative frequency of vegetation, calculated from the quadrat analysis. Sorenson's similarity index values by comparing the occurrence and non-occurrence of the herbaceous vegetation in the three different sampling sites were analyzed through Sorenson's similarity index, using the following formula:

$$\text{Jaccard's Similarity Index} = \frac{2a}{2a * (b+c)}$$

; where, a = no. of species, occurred commonly in both the sites,  
 b = No. of species occurred only in site A and not in B and  
 c = No. of species occurred only in site B and not in A

### **Fauna Diversity Analysis**

Birds diversity analysis was done for 2 years period (2013-2015) using Point count protocol, using Nikon Action 16\*50 4.1 zooming binocular and photographic documentation was made, using Nikon Camera (DS-3100 Model). Bird species were identified by their Zoological and vernacular names, using standard Monographs on birds.. Similarly, butterflies and ants diversity were listed from the experimental pond areas.

### **Statistical analysis:**

Descriptive statistics, ANOVA, correlation matrix, Principal Component Analysis (PCA) were computed, using SPSS programme.

### **Results**

#### **Water Analysis**

Relatively a high alkaline range of pH was observed from the water samples, collected from the PKPTY pond, where the birds sanctuary is located, supports tens of thousands of birds species, visiting to this pond. Dissolved oxygen was found varying between the sampling periods and also from the different ponds' water samples. VKPTY pond showed higher amount of DO, followed by PKPTY pond and the water sample from CKPTY pond had the least amount of DO, among all the experimental ponds. Total dissolved solids,, hardness, salinity, calcium, magnesium concentration of the water samples, collected from the PKPTY ponds were found markedly higher than from the water samples of rest of the two experimental pond water samples. Correlation co-efficient was found differently between the analyzed variables of water quality parameters for the water samples, collected from the different experimental ponds, which

could be mainly attributed to the different biological interactions and also due to the different nature of pond utilization. The bird droppings in the PKPTY pond water would have caused the enhanced nature of TDS, salinity, alkalinity, nitrogenous substances and in which condition, the ultimate cause for high value for hardness from the water samples, collected from the ponds. PCA analysis revealed that the different parameters in the different pond water samples were found to be aggregated as components, which were found responsible for the total water quality. It was also observed that the variable grouping is found notably different for the different ponds, clearly indicating that the experimental ponds with varying nature of biological interactions ultimately causing the difference in the weightage loading of the analyzed parameters.

### **Microalgae species**

Water samples collected from PKPTY pond in March, 2014 showed the presence of *Chalmydomonas macrosphera* is generally considered as a pollution indicator species. During the same sampling period in this pond, *Anabaena torulosa*, a Cyanophycean member was present which produces intercalary heterocysts and these structures are used in the nitrogen fixation. Another organism, *Spirogyra webri* was found occurred in the water samples which prefer to dwell on the lentic environment and forms thick mat on the surface of the pond. This feature causes oxygen depletion, eventually creates the anaerobic and ahotic conditions to the water body on which it spreads. These algal mats form as the ideal hiding location for many insects and zooplanktons.

### **Soil analysis**

Due to the nesting birds of the PKPTY pond, wherein, bird droppings to the ponds occur at high level, which would be a reason for higher level of nitrogenous elements in the soil, where from higher amount of CO<sub>2</sub> emission rate was found. The occurrence of the vegetation on dry ponds' surface has the ability to fix the CO<sub>2</sub>, which forms a sequestering mechanism; thereby controlling the emission of CO<sub>2</sub>, from the sediment zone of the ponds, used in the study. The work has the future prospects in these areas, through which the relationship between the soil ecological conditions and the vegetation composition in the ability of reducing the emission of CO<sub>2</sub>.

### **Vegetation diversity analysis**

#### ***Aquatic and semi-aquatic species***

Aquatic plants such as *Lemna minor* L., *Wolffia globosa* (Roxb.) Hartog & Plas, *Aponogeton natans* (L.) Engl. & K.Krause., *Cyanotis axillaris* (L.) D.Don ex Sweet., *Ipomoea aquatica* Forsskal., *Hydrolea zeylanica* (L.) Vahl., *Nymphaea nouchali* var. *pubescens* (Willd.)

Hook. f. & Thomson. and *Typha angustifolia* L. were recorded among the total of 47 Species of aquatic and semi-aquatic plants, comprised in 25 families.

### ***Floristic composition on the dry surfaces and over the bunds***

The study revealed that the species the occurrence of 174 species of 134 genera belonging to 52 families found in the dry surfaces of three experimental ponds. Among these, 61% (106) were herbs, 14% (24) climbers, 11% (20) tree seedlings, 11% (19) shrubs and 3% (5) lianas were recorded. The dominant number of species were from the families such as Poaceae (26 species), followed by the co-dominant family are Euphorbiaceae (15) and Fabaceae (13) species and 23 families are mono-specific. Similarity index showed the dry pond surface has shown relatively a higher variability among the species similarity among the three experimental ponds, than their diversity in the bund regions. Raunkaier's frequency class analysis revealed the distribution of species, according to the frequency class was closely similar in CKPTY and VKPTY ponds, whereas PKPTY pond showed only with three categories of frequency class and this condition could be related with the occurrence of single dominant species, which could be influenced by the enhanced soil chemical substances, especially nitrogenous substances, added as birds droppings. From the correlation matrix found, the number of species and species richness showed the positive relationship as well as the diversity indices and the IVI showed positive relationships, indicating the vegetation rich condition, rather than the number of individuals, determine the vegetation diversity.

## **Fauna Diversity**

### ***Bird species***

A total of 78 species belonging to 38 families were recorded during the study period (November 2012 to October 2014). Among the birds species enumerated during the study period, 67% resident migrant and 33% overseas migrant. From the list of birds species, different red list categories such as one threatened species, four nearly threatened and 68 least concerned species and were recorded.

### ***Butterflies***

Fourteen species of butterflies, belong to 9 genera and three families were found occurred in the ponds area, during the study was conducted. *Danaus* is the dominant genus with four species, followed by *Graphium* and *Pachliopta*, which contains 2 Species and other genera are monospecific. Nymphalidae family was found with higher number of species (7), followed by the Pieridae family, which include 4 genera; whereas Papilionidae family represented with 3 species.

### ***Ants Diversity***

Thirty ant species of ants under 15 genera and all composed in a single family was observed. In this *Camponotus* is the dominant genus, which had 9 species, followed by *Crematogaster* genera, which contains 5 Species; 3 Genera containing 2 Species each and 10 monospecific genera were recorded. .

### **Interactions among the analyzed variables**

Several beneficial features were observed on the utilization of diverse plant communities by the birds, visiting to the bird sanctuary pond, as they utilize the vegetation for nest building, and the tender straggler plant stem materials are used by the birds to weave the nests. *Acacia nilotica* (L.) Willd. ex Delile, *Prosopis juliflora* (Sw.) Dc., *Parkinsonia aculeata* L. trees are used by several birds species, including Open-bill stork (*Anastomus oscitans*), and Asian Oriental white ibis (*Threskiornis melanocephalus*) for their nesting and breeding. The edge plant *Phyllanthus reticulatus* Poir, occurred in PKPTY pond is found used by ducks as their sheltering nests and also breeding their chicks. The edge reefs like *Typha angustifolia* form shelter for the aquatic insects, further being the feed for the perching birds, visiting to the ephemeral pond habitat.

### **Conclusion**

Nutrients enrichment condition occurred in the PKPTY pond could lead to the higher level of addition of chemical substances on the dry pond surface, due to sedimentation. This could lead to the existence of single species, spreading to a larger area, over the dry surface of ponds, during the dried-up condition, which is well evident from the results of the study. Soil carbon stock present in the experimental pond through sedimentation process during drying up of ponds and the sequestering nature of ponds, through the addition of nitrogenous and other substances and their interaction are the factors in controlling or enhancing of emission of CO<sub>2</sub> from the dried-up pond surface. The study results clearly indicate that the biological interaction has significantly affect the water quality and thereby affecting the dry surface of the ephemeral ponds. Alternate wetting and drying conditions of such ephemeral ponds would lead to have the dynamic change over the ecological quality in terms of the physical nature and chemical substances, present in the water and further over the sediment or soil of the pond during dry conditions. This effect is further causing to have the aggregation of specific herbaceous vegetation. Therefore the ecological components such as water, sediment, soil, biotic organisms and the interaction among these factors are important to analyze, since the effective management principles and practice could be evolved. The scope of the study includes the development of data base on the ecological components of the ephemeral ponds of different eco-climatic zones with varying nature of biological interactions and with varying utilization, which will enable on the development of management guidelines, on the sustainable management of the dynamic nature of ephemeral ponds and their diversity, from which the ecological benefits could be obtained.

**FINAL TECHNICAL REPORT**

17-02-2012 TO 16-02-2015

**EXECUTIVE SUMMARY**

**Studies on Abundance, Diversity and Ecology of Parasitic Hymenoptera of Rice fields in Kerala**

**PRINCIPAL INVESTIGATOR: DR. NASSER, M.**

**CO-PRINCIPAL INVESTIGATOR: DR. NARENDRAN, T.C. FASc (LATE)**

**PROJECT TEAM: RANJITH, A. P., RAJESH, K. M., REMYA & SOUMYA**

**Order N. F.No.14/3/2011ERS/RE**

**Submitted to**

**Ministry of Environment, Forest and Climate Change**

**New Delhi, India**

**FORMAT FOR EXECUTIVE SUMMARY OF THE RESEARCH PROJECTS  
FUNDED BY THE MINISTRY OF ENVIRONMENT & FORESTS**

(Not more than 02 to 03 pages)

**1. Title of the Project:**

Studies on Abundance, Diversity and Eco-biology of Parasitic Hymenoptera of Rice fields in Kerala

**2. Name of Members of Research Team and their designation:**

Principal Investigator : Dr. Nasser, M., Associate Professor,  
Department of Zoology, University of  
Calicut

Co-Principal Investigator : Dr. Narendran, T.C. (Late)  
Retd. Professor, Department of  
Zoology, University of Calicut

Junior Research Fellows : Ranjith, A. P. & Rajesh, K. M.

Field Assistant (s) : Remya & Soumya

**3. Number and date of Sanction letter** : F.No.14/3/2011ERS/RE  
dated 01-02-2012

**4. Duration** : Three years

**5. Total outlay** : 27, 32, 890.00

**6. Date of start** : 17-02-2012

**7. Date of completion** : 16-02-2015

**8. Objectives:**

1. To study the taxonomy of some major genera of Chalcidoidea and Ichneumonoidea Super family associated with rice fields of Kerala.
2. Study the species diversity and species abundance of selected taxa of Chalcidoidea and Ichneumonoidea Super family at selected localities of rice fields in Kerala.
3. Study on the biology, behavior, host-parasitoid relationship and seasonal abundance of two selected species of parasitic Hymenoptera.

**9. Methodology:**

The hymenopteran specimens and pests of rice were collected using the passive methods of collection such as Pan trap (Moericke Trapping) and active methods such as sweep netting, hand picking and rearing

- a) Moericke Trapping

This is a pan coloured yellow, measured 6–7 cms deep and 30 cms square. Water is kept in the pan for trapping the wasps and little soap is added to break the tension on the water surface. A small hand net was used to empty the tray before transferring the specimens to 70% alcohol

b) Sweep netting, handpicking and rearing

Sweeping with the specially made sweep net was found to be the most rewarding way of collecting these parasitic wasps since a relatively short time. A good day's collecting with sweep net will provide as much material as an average Malaise trap in four month. The sweep net used in this investigation is the model designed by the Chalcidologists of the British Museum of Natural History, London. Aspirator is used for collecting smaller insects from the net by sucking through one tube and collecting insects through the other.

Eggs, larvae and pupae collected from the fields are kept in emergence cages for possible parasitoid emergence. Handpicking of the various stages of the pests will provide host data and also help in getting data on the rate of parasitization.

### Measurement of Diversity

The diversity index was calculated by using the Shannon–Wiener diversity index (1949)

$$\text{Diversity index} = H = - \sum P_i \ln P_i$$

where  $P_i = S / N$

S = number of individuals of one species

N = total number of all individuals in the sample

$\ln$  = logarithm to base e

### Measurement of species richness

Margalef's index was used as a simple measure of species richness (Margalef 1958)

$$\text{Margalef's index} = (S-1) / \ln N$$

S = total number of species

N = total number of individuals in the sample

$\ln$  = natural logarithm.

### 10. Output:

- A new caterpillar pest of rice viz: *Psalis pennatula* Fabricius (Erebidae: Lepidoptera) from Kerala is reported.
- Species diversity and abundance of chalcidoid and ichneumonoid parasitoids in the districts surveyed.

- Two potential egg parasitoids viz., *Tetrastichus* sp. and *Telenomus* sp. against yellow stem borer, *Scirpophaga incertulas* is reported, and these parasitoids may be adopted in the biological control programme to manage yellow stem borer of rice.
- New reports of seven braconid wasps parasitizing three major pests of rice in Kerala.
- Sixty one ichneumonoid and chalcidoid genera are reported from rice fields of Kerala.
- One egg, three larval and two pupal parasitoids of *Psalis pennatula* are also reported.
- An interesting host manipulating behaviour of a parasitoid, *Microplitis pennatulae* Ranjith & Rajesh was observed.
- Studies on the biology and field level efficacy of one larval and seven egg parasitoids carried out.
- One new eulophid genus was collected during the study.
- Seven unidentified Braconid parasitoids were collected during the project period.
- Two *Microplitis* species, namely *Microplitis narendrani* Ranjith & Nasser and *M. pennatulae* Ranjith & Rajesh as the larval endoparasitoids of *Psalis pennatula* (Fab.) was reported (Ranjith et al. 2015).
- A pimpline species, *Clistopyga sziladyi* Kiss, which is recorded from India for the first time (Varga & Reshchikov 2015).
- New distribution record for two microgastrine species, *Microplitis similis* Lyle and *M. spodopterae* Rao & Kurian from Kerala. *Microplitis similis* is recorded for the first time from south India (Ranjith et al. 2015).
- A braconine genus, *Furcadesha* Quicke recorded from paddy fields and which is known from Kerala for the first time.
- An orgiline genus, *Orgilonia* van Achterberg is recorded from India for the first time with its host. This will record a new host family for Orgilinae (Hymenoptera: Braconidae).
- One tetrastichine genus *Kiggaella* Narendran recorded from Kerala for the first time.
- Three *Tropobracon* Cameron species namely *T. persimilis* Szépligeti, an Afrotropical species which is recorded from Oriental region for the first time in addition with *T. hayati* Haider and *T. shafeei* Haider which are recorded from south India for the first time.
- The host record of *Aspidobracon* sp. as pupal parasitoid of *P. mathias* is reported from India for the first time.
- Another braconine species *Scutibracon* near *hispa* reported from Kerala for the first time.
- The following braconid genera, *Aleiodes*, *Aspidobracon*, *Cardiochiles*, *Euagathis*, *Exoryza*, *Gnamptodon*, *Iconella*, *Macrocentrus*, *Parapanteles*, *Spathius* and *Utetes* are recorded from Kerala for the first time.
- Host records of 32 parasitoids could be established, out of these five host records are reported

for the first time and 13 host records are reported for the first time from peninsular India.

- Two possible new species of Ichneumonids and species belonging to Mymaridae, Eurytomidae, Eulophidae, and Trichogrammatidae could be collected.
- *Telenomus oryzae* Rajmohana & Nisha has emerged from the eggs of *Pygomenida varipennis* Westwood (Pentatomidae: Hemiptera), and it is found to be the first host report from Kerala.
- Ten hyperparasitoids reported from rice fields of Kerala.
- Efficacy of parasitoids in the field was determined.

#### 11. Outcome:

The rice fields of Kerala are facing many threats from various insect pests. We can achieve the long term control of the pests only by the introduction of the parasitoids which are reported from the pests. Many of the parasitoids are specific in nature and exhibit generalist behaviour to a lesser degree. Our three year study reported 32 host records from the rice fields of Kerala. Out of these five host records are reported are new to science and 13 host records are reported for the first time from peninsular India. The generic diversity and abundance of parasitoids in the rice fields in all districts of Kerala was determined. The study also gave distribution records of pests of rice in the different districts of Kerala.

The control of rice pest is problematic to some extent, because of the domination of the chemical insecticides over the classical biological control programs. Pest control by the application of insecticides often disrupts the natural enemy complexes present in the rice ecosystem. Here comes the importance of the classical biological control programs, as we introduce the specific parasitoids to the ecosystem. The data presented here will help workers in the field of pest control to add more parasitoids to their repertoire of natural enemies that can attack and help in management of the insect pests of rice.

The studies on the distribution of the rice pests of Kerala reflect the real picture about the pest problem and its abundance. Our study indicates that *P. pennatula* which is considered as a minor pest of rice may become a major pest of rice. Sampling in rice fields across Kerala has indicated the major presence of *P. pennatula* in all districts surveyed. Periodic sampling of the diversity and abundance of the rice pests is very important to predict the pest attack in the future. We all know that the classical biocontrol programs does not create any harmful effects on the non target organisms so, the conservation of those potential natural enemies is much important to establish a natural enemy complex in the rice ecosystem.

The present study has noted that the egg parasitoid, *Tetrastichs* sp. has high field parasitization rate on *Scirpophaga incertulas* Walker in all stem borer infested fields in Kerala. It is proposed that *Tetrastichus* sp. can acts as an efficient biocontrol agent against yellow stem borer.

## 12. Deliverables:

- New ichneumonoid and chalcidoid species identified.
- Host records of 32 parasitoid species confirmed of which five are new to science and 13 are new reports from India.
- Development biology of *Psalis pennatula* on rice confirmed.
- Generic diversity and abundance of parasitoids in the different districts of Kerala determined.
- The distribution of different pests of rice across Kerala documented.
- Efficacy of different parasitoids determined in the field.

## 13. Name of the Agencies by whom the results can be utilized:

- Agriculture Universities and agricultural extension workers like State Parasitic breeding centers.

## 14. The manner in which the finding will be utilized:

The host records of the different parasitoid species and the efficacy studies on the parasitoids have revealed data that will be helpful in designing better biological control methods for managing insect pests of rice.

The handbook on the chalcidoid and ichneumonoid parasitoids of insect pests of rice which is brought out as a part of the project will help workers in the field of insect pest control to easily identify the parasitoids present in rice fields, which again will help in adopting better biocontrol strategies.

## 15. Recommendations and their implementation:

Further studies need to be carried out to unravel more host-parasitoid relationships in the rice fields of Kerala. Our studies indicate that discoveries of many more new species of parasitoids can be made if more rice fields are surveyed. Conservation of these parasitoids in the rice fields can help us in managing the insect pest attack in a more ecofriendly way. The parasitoids with high efficacy observed as a part of the study can be made use of when designing Biocontrol programmes.



Signature of the Principal Investigator

