CHAPTER - 6

SUMMARY

In the present work it was proposed to undertake the study of the STRUCTURE (Abiotic – climate; with more emphasis on Biotic – plant and orthopteran species composition and population dynamics); and FUNCTION (Standing crop biomass and energy, dry matter dynamics, secondary production and energy budget) of the two grasshopper populations. All these studies have been carried out in the forest floor strata of the protected forest; located in Guru Ghasidas University, Bilaspur campus. The detailed structural and functional studies have been performed on only two grasshoppers, namely, *Catantops pinguis innotabilis* Walk. and *Spathosternum prasiniferum prasiniferum* Walk. A summary of the results discussed in the preceeding chapters is dealt below.

6.1 Abiotic structure :

The climate of Bilaspur, according to Thornthwaite (1948) system of classification of climates, is of tropical and humid type. The year is divisible into wet, cool-dry and hot-dry seasons, each of nearly four months duration. Wet season in this region of the country falls between July to October (Table 1.i) and proves most favourable for grasshoppers' growth, and development. Due to physical dryness and cool low temperatures in winder season and high temperature in hot season (March to June), only limited species of grasshoppers were able to survive in the aboveground part of the ecosystem during these two seasons. The total rainfall between July to June was
1200mm, the major part of which (1070.5 mm) condensed in rainy
season (Table 1.iii).

6.2 Phytology and Phenology (Tables 3.i-ii and Fig. 3.1):

Vegetational structure and phenology of the study site revealed
that the site was although developed primarily as a protected forest,
but it also supported such forms of vegetation as grasses, sedges and
forbs which grew there in a natural sort of way. The vegetation, in its
vertical distribution was, therefore, found to be composed of grasses,
sedges, forbs, shrubs and trees.

There were in all 16 species of grasses, all belonging to the
single family Poaceae. The three species of sedges also belonged to
single family - Cyperaceae. Forbs comprised of ten species and they
belonged to six different families. The shrubs and trees were the
dominant group of the vegetation of the study site (Table 3.ii). On the
whole, there were seven types of shrubs and twenty four types of trees.
Among the trees, family Leguminosae formed the dominant group. The
study of these forms of vegetation also revealed that grasses, sedges
and forbs constituted the annual category of vegetation whereas
shrubs and trees formed the perennial group. Phenogram of the
annual category of vegetation (Fig. 3.1) revealed that all the plants of the
three group germinated, lived and died not at the same time but in
different periods of the year. One character found common in all these
plants was that germination, vegetative growth and flowering occurred in
rainy season. Thus the forest floor remained in the most luxurient state
in rainy season from the point of view of vegetational cover. Death of
the plants of herbal strata started from the month of October and the
process continued also in the months ahead to October to the extent that
most of the grasses and forbs and all the sedges had died by
April. There were only three grasses, namely, *Eragrostis minor*,
*Heteropogon contortus* and *Cynodon dactylon* that remained in green
form through out the year. In the forbs, plants of two species, viz. *Tridex*
procumbans, Achyranthes aspera were seen in the green form all along the year.

Among the tree vegetation Peltaforum ferriginium formed the southern belt of study campus, Eucalyptus globosa and Bombax malabaricum formed the eastern belt, while the remaining part of the campus forest was largely occupied by Butea frondosa, Gmelia arborea, Acacia catechu, Albizzia lebbeck and Diospyros melanoxylon. The rest of the trees and shrubs were found intermittently studded among the above types.

6.3 Orthopteran diversity:

The study site, being protected one, was inhabited by several species of invertebrate and vertebrate animals. But the present work was confined to the study of only the Orthopteran community. Grasshoppers, in general, form the dominant group of animals in the vegetation which are rich in grasses and herbs; particularly when the area is protected and undisturbed by cattles and man. The present study area was not only privileged with all these attributes but was additionally benefitted by shades of tree canopy of the forest. Thus it formed a favourable home for the grasshoppers. Their rich representation in such type of vegetation occurs in natural process (Dwivedi, 1977). The periodic surveys during the study year at regular fortnightly intervals showed that a total of 23 species of grasshoppers inhabited the study site (Chap. 3, Table 3.iii). These belonged to two sub-orders viz. the Caelifera and the Ensifera. Caelifera included short-horned grasshoppers. It was found that a total of 21 species of the grasshoppers belonged to the short-horn group. These were distributed in two superfamilies, namely, the Acridoidea and the Tettigoniioidea. Members of the superfamily Acridoidea were distributed in four families, viz. Pyrogomorphidae, Acrididae, Hemiacrididae and Catantopidae. Family Pyrogomorphidae was represented by two grasshopper species, family Hemiacrididae
was also represented by only two species and family Catantopidae was represented by eight species of short-horned grasshoppers. Family Acrididae formed the most diverse group in the community with its nine members distributed in three sub-families. Likewise, sub-family Oedipodinae was the richest sub-family of the short-horned grasshoppers being composed of five different species.

The Encifera sub-order, characterised by long-horned grasshoppers, was represented by two species from two separate families. Both the families belonged to the same superfamily (Table 3.iii).

Observations into the species adaptation in the habitat suggested that the 23 species of the grasshoppers could conveniently be categorised as the (i) Purely rainy season species, (ii) Rainy and winter species (iii) Summer and rainy season species and Annual species. One species, namely, Hetracris sp. was a rare one for the fact that it was captured at only one or two occasions in the area in numbers of one or two as only adult. The grasshoppers of the study site also showed **Voltanism** in their reproductive behaviour. Thus there were univoltine species with their life cycle restricted to only one season; and some with their life-cycle extended to two seasons. Then there were bivoltine species that completed two generations within the same year. The third category was of those grasshoppers in whom voltanism was found extended to annual cycle (Table 3.vii).

The Topic behaviour of the grasshoppers revealed that they could be classified into three categories. The first category was of Stenotope types, whose members had a short post-embryonic cycle and a long diapause period. The second category consisted of semi-uritope type. Grasshoppers of this category had the epigean and hypogean periods nearly equal. The third category was of uritope type. The species belonging to this category had a long epigean and a short hypogean existence.
6.4 Population structure:

Population and other ecological investigations, such as the dry matter production and energy structure, were carried out on only two grasshopper species of the habitat, namely, *Catantops pinguis innotabilis* and *Spathosternum prasiniferum prasiniferum*. Population structure was investigated taking into account the average density, percentage frequency, relative frequency and relative density of the two grasshoppers (Table 4.ii to v). The study revealed that highest values of all the above parameters were obtained for *C. pinguis innotabilis* and lowest values were obtained for *S. prasiniferum prasiniferum*, both in the rainy season as well as in the summer season generations. The maximum total species density of 7.1 ind/m$^2$ was obtained in rainy season in the first half of August. The population of this time comprised of only post-embryonic stages of both the experimental species. The lowest value of average density (1.6 ind/m$^2$) for the two grasshoppers was recorded in November. The population density of summer generation of the same two species was obtained highest (3.4 ind/m$^2$) in the first half of April; and lowest (0.9 ind/m$^2$) at the end of June. The population with lowest values of average density, consisted of only adult individuals in both the generations (App. Table 1 & 2).

Interspecies Association (Table 4.vi) among the individuals were also observed with the help of "Index of affinity" and "Index of association". The former index was drawn to know the degree of togetherness between the members of population; while the latter was drawn to know the proportion of individuals of the constituent populations living together. Computation of the data revealed that highest degree of joint occurrences was 61.3% in the rainy season population. The degree of joint occurrences in summer season population was found to be 54.5%. Association index, when tested for its significance (Davis, 1963) revealed that almost each
population lived in significant association with other population in the habitat, in both the generations and at maximum occasions.

6.5 Climate and population:

Impact of seasonal changes in diel temperature, relative humidity and total rainfall was also observed on the population dynamics of the test insects. It suggested that moderately high temperature, highest relative humidity and wet soil surface of the rainy season favoured the emergence, development and growth of both the populations to their inherent maximum in this period.

The cold and dry climate, hard soil surface and withering vegetation of winter season brought elimination of the two populations from the aboveground part in this period. In the hot and dry climate of summer season with hot and hard soil surface and only a few short green patches, caused the population of summer season to emerge, complete its development, perform its biological responsibility and then disappear from the aboveground part, all in a brief period of time.

Statistics of correlation \( r \) drawn between the average density and different abiotic parameters (atmospheric temperature and relative humidity) revealed that both the populations showed a moderate positive correlation with temperature (Table 4.x) in rainy season and poor and negative correlation in summer season. Thus, grasshoppers, having poor and negative correlations with the abiotic conditions of summer season, could face the unfavourable conditions and completed their ontogenic cycle of summer season. The variations as obtained in average density and longevity of the two grasshoppers, may also be due to the fact that each species has its own biotic potential and an ontogenic duration, which is governed by its genetic constitution (Whittaker, 1962 and Golley, 1968).

Regarding the decline of population of grasshoppers the present author differs with the views expressed earlier by Birch (1957);
Watt (1960) and Whittaker (1962), who have stated that the population of phytophagous insects declines because of scarcity of green food, due to phenological changes in vegetation of the ecosystem. However, it has been reported by Bansal (1975) for a local grassland vegetation of the district that the energy value (cal/gm) of green grasses decreases as the season progresses from rainy towards winter and summer seasons. The present author is, hence, of the view that decline in the population of grasshoppers is more due to lowering of the nutrient value of their food source, and less due to the scarcity of food source in the ecosystem.

6.6 Biomass structure:

Biomass structure of the grasshoppers analysed at the population level (Table 5.i) revealed that there were two peaks of the standing crop biomass; one in the rainy season and the other in the summer season (Fig. 5.1). The first peak of standing crop biomass of the two populations of grasshoppers was 1118.0 mg/m² in rainy season and the second peak was 569.3 mg/m² in summer season. The standing crop biomass was nil in the aboveground part for some period in winter season.

The biomass of both the grasshoppers showed a fluctuation in its standing crop values. In the rainy season the lowest value was obtained in the start of the season at the time of the emergence of the population in the ecosystem, while the highest value was obtained during the later part of the same season. The values of the highest and lowest standing crop biomass remained always higher in rainy season population but lower in summer season population. The last record of the standing crop biomass was as low as 261.8 mg/m² in rainy reason and 208.5 mg/m² in summer season.

The Karl Pearson's correlation derived between population density and the population biomass, showed a very poor positive correlation. It thus suggested that the growth in biomass is only poorly dependent on the population number of the grasshoppers.
6.7 Energy structure:

Energy structure of the individual species cal/gm.dry wt (Table 5.iii) showed different values during hopper and adult stages. The energy value ranged between 4113.2 to 4975.6 cal/gm.dry wt. in *Catantops pinguis innotabilis* and 4856.1 to 5439.4 cal/gm.dry wt. in *Spathosternum prasiniferum prasiniferum*. The lowest value of 4113.2 cal/gm dry wt. was obtained for 1st instar hoppers of *C. pinguis innotabilis* and highest value of 5439.4 cal/gm dry wt. was obtained for 2nd instar hoppers of *S. prasiniferum prasiniferum*. The energy values (cal/gm dry wt.) of the experimental grasshoppers lie around the energy values of other grasshoppers reported by earlier workers (Smalley, 1960; Golley, 1961; Dwivedi and Chattoraj, 1985 and Dwivedi, 1990, 1991).

The standing crop calorie, computed on dry weight basis (Table 5.iv) was found to be highest (5400.5 cal/m²) for rainy season population of *C. pinguis innotabilis*. The highest for *S. prasiniferum prasiniferum* population for rainy season was only 197.4 cal/m² in the same generation. The highest value of summer season generation remained much lower, compared to rainy season generation in both the grasshopper populations. In general, individuals differed significantly with respect to their energy values, both on the calories/gm. dry wt. basis as well as on cal/m² basis.

The increase in the energy value in the successive higher stages of the hoppers is an indication of general tissue growth and accumulation of dry matter of developing hoppers. On the other hand, the growth in the energy value of adult insects can be attributed to the development and maturation of their gonads.

6.8 The metabolic rate:

The respiration was measured for each instar of hoppers as well as adults of both the test insects. It was found that O₂ requirement (ml O₂/gm live wt) was higher in the hoppers of early instars but lower
in the instars of successive higher stages. The metabolic rate of adult insects showed an increase over its previous stage (Vth instar hopper). This increase in O₂ requirement was perhaps due to the growth and maturation of their gonads in this stage.

6.9 Secondary productivity:

Annual net dry matter production for the two grasshopper population was 1675.95 mg/m²/year (Table 5.vii). Its major part (1116.8 mg) was produced during rainy season and only 559.15 mg was produced during summer season. Dry matter production of individual population revealed that C. pinguis innotabilis contributed maximum (1613.7 mg/m²) to the total annual production while S. prasiniferum prasiniferum contributed only 62.25 mg. Thus the percentage contribution of the individual species to the total dry matter production was 96.3% by C. pinguis innotabilis while only 3.7% by S. prasiniferum prasiniferum.

The annual energy budget (Table 5.x) showed that the annual total of assimilated energy of the grasshopper populations amounted to 31453.8 cal/m²/year in the aboveground part. However, a greater part (30378.4 cal) to this total was added by C. pinguis innotabilis. From the total annual energy accumulation of the populations of the two grasshoppers, the major part was used in metabolism by the individuals of the constituent populations (Table 5.x) while only a small fraction of the total assimilated energy accumulated in the form of tissue growth. Energy contained in these two components of the populations, when tested for the efficiency, showed that the tissue growth efficiency of C. pinguis innotabilis was 26.7 per cent while that of S. prasiniferum prasiniferum was 30.9 per cent. These values lie well within the limits of tissue growth efficiency that ranged between 9.2 to 29.9 reported for four other grasshoppers by Dwivedi (1977).
At the end, it may be concluded that the study site supported a total of 23 species of the grasshoppers. The detailed investigations in the present work, leading to population structure, dry matter production, energy production and energy budget have been performed on two grasshoppers. Investigations on all the 23 species was much beyond the limits of the present thesis. However, the author, thus, leaves much scope to the future researchers, interested in the ecology of Orthoptera, to take up the study on the other uninvestigated species, inhabiting the present study site (forest floor).