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Complementarity and taxonomic difference estimates and priority analysis for assessing the tettigoniid diversity in Chennai, Tamil Nadu (India)

(Orthoptera: Tettigoniidae)

With 4 figures and 4 tables

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Summary

We explored the diversity of tettigoniids in four habitats in Chennai, India, namely forest lands, wastelands, grasslands, and arable lands. The number of species and the number of individuals observed during a sampling period of 24 months were recorded. Seventeen species of tettigoniids belonging to 5 subfamilies of Tettigoniidae were encountered, with 9 species belonging to the subfamily Phaneropterinae. Root weights were provided to assess differences between the species and priority analysis was carried out to assess site selection for conservation augmentation. Results indicate that theforest lands were the most diverse habitat, with the wastelands serving as a complementary site. Fisher's α-diversity and Shannon's index also gave high values of theforest lands. Several species richness estimators were calculated to assess the number of additional species that one could expect had sampling been more intense. The Michaelis-Menten model and the Coleman curve indicated an early asymptote for the grasslands, wastelands, and arable lands in contrast to the coverage based estimators ACE and ICE for these habitats. However, all the species richness estimators fitted well for theforest lands. Estimates of β-diversity showed that the forest lands, grasslands, and wasteland were similar in species composition, but different in species abundance and that the wastelands complemented the forest lands in the species richness attribute.

Zusammenfassung

Die Diversität der Tettigoniidae von vier Biotoptypen in Chennai, Indien, wurde untersucht: Waldbiotope, Brachen, Grasgesellschaften und landwirtschaftlich genutzte Flächen. Arten- und Individuenzahlen wurden in einem Untersuchungszeitraum von 24 Monaten aufgezeichnet. 17 Arten aus 5 Unterfamilien, davon 9 aus der Unterfamilie Phaneropterinae, wurden nachgewiesen. Die Ermittlung von Wurzelgewichten sollte Hinweise auf artspezifische Unterschiede ergeben, und anhand von Prioritätsanalysen wurden Untersuchungen zur Habitatwahl durchgeführt. Die Wälder, gefolgt von den Brachen, waren die artenreichsten Biotope. Auch Berechnungen der α-Diversität und des Shannon-Index ergaben die höchsten Werte für die Wälder. Auf der Grundlage verschiedener Reichhaltigkeits-Schätzmethoden wurde die Zahl zusätzlicher Arten ermittelt, die bei höherer Untersuchungsintensität zu erwarten gewesen wären. Im Gegensatz zu den ACE- und ICE-Schätzungen ergaben das Michaelis-Menten-Modell sowie die Coleman-Kurve frühe Asymptoten für die Grasbiotope, Brachen und Äcker. Übereinstimmend waren dagegen die Ergebnisse der verschiedenen Schätzmethoden für die Waldbiotope. Berechnungen der β-Diversität ergaben einerseits, dass sich die Wald- und Grasbiotope sowie die Brachen in Artenzusammensetzung ähnelten, sich aber in den Abundanzen der Arten unterschieden, und andererseits, dass die Brachen die Waldbiotope in der Artenreichhaltigkeit ergänzten.

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Key words

Complementarity, Priority analysis, Tettigoniidae, Biodiversity, Species conservation.

Introduction

Biodiversity is the sheer variety of life forms: the different plants, animals and microorganism, the genes they contain and the ecosystem they form. Estimates of total species richness is a straight-forward measure of species diversity (SOUTHWOOD & HENDERSON, 2000). It is estimated that nearly 2 million species have been named or recognized (MAY, 1991) and nearly half of them are insects. Faced with such huge numbers, and the rapid ecological changes affecting all areas throughout the world, entomologists are convinced that a period of massive extinction is imminent (MYERS, 1989; VANE-WRIGHT, 1992). We have begun to realize the loss of several species that make up the web of life of our planet. Future survival of majority of the species will depend on better management of all ecosystems. Adequate protection of the biodiversity will require a global strategy involving a worldwide network of reserves that provide refuge to the species. There is a need to recognize and set priorities for the selection of reserves so that the maximum possible diversity can be protected (MARGULES et al.,1988). Measuring biodiversity in a way which will allow us to compare areas on both absolute and relative scales appear important from the point of view of selecting conservation sites to provide refuge to a wide variety of species. This can be achieved by measuring three properties of fauna, namely species richness, complementarity and taxonomic difference (VANE-WRIGHT et al., 1991; WILLIAMS et al., 1991). This paper attempts to study these aspects with respect to the long-horned grasshoppers, the tettigoniids, of Chennai, India.

Globally the family Tettigoniidae includes over 6200 species within over 1000 genera (NASKRECKI and OTTE, 1999) and most of them occur in the tropical and subtropical regions of the world. In the Indian subcontinent about 250 species have so far been recorded and little is known about the fauna of Tamil Nadu. In this paper we explicitly explore the diversity of the Tettigoniids within habitats using the α-diversity index and compare habitats using similarity index as a measure of β-diversity, restricting however, our studies to habitats in and around Chennai district of Tamil Nadu, India.

Materials and methods

Study site

Chennai, located 13°N Latitude and 80°E Longitude, is the largest city in southern India. Four habitats were chosen which represents forest lands, grasslands, arable lands and wastelands for the study. The first study site is the Guindy Reserve Forest (GRF) which just abuts our research Institute and has an area of 270 Hectares. It is a natural forest comprising mostly of shrubs and herbs besides tall trees of *Lannea coromandelica,* (HOUT.) Merr., *Tephrosia purpurea,* PERS. and *Borassus flabellifer*, L. The arable land selected for this study lies about 12 kilometer southwest from the GRF and is a private land measuring

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about 100 hectares at Kanchipuram with *Oryza sativa* as the principle crop cultivated. A further 15 kilometer North of this arable land is our third study site representing the grassland sprawling to an area of about 5 hectares. The fourth habitat lies about 10 kilometer south of the GRF at Chenglepet. It represents a vast area of open lands, which we here describe as wastelands containing a few herbs and shrubs growing irregularly and completely free of anthropogenic interference.

Field methods

In order to make an inventory of the tettigoniid species, the habitat selected was divided into as many quadrats of 10 x 10 m^2 area and 10 quadrats selected at random. Sampling was carried out by using sweep net, search method and hand picking of all specimens of tettigoniids encountered. Our earlier studies (SANJAYAN et al., 1994) have shown that among the various techniques, this method provides the best sampling for Orthopteroid insects. Sampling was done each month between 6-8 AM and between 6-8 PM so as to includes also the nocturnal species of tettigoniids. Overall 24 samples were taken. All tettigoniids collected were identified to species level using RENTZ (1979), PITKIN (1980), RENTZ & GURNEY (1985), INGRISCH (1990a, 1990b & 1990c), KEVAN & JIN (1993), INGRISCH & SHISHODIA (1998) and NASKRECKI & OTTE (1999). Records were maintained for the number of individuals of each species collected during every survey trip.

Data analysis

As a measure of α-diversity (diversity within a habitat) the most popular and widely used Fisher's α- and Shannon's diversity indices were calculated because it is well accepted that all species at a site, within and across systematic groups contribute equally to its biodiversity (GANESHAIAH et al., 1997). Fisher's α-diversity assumes that the distribution of the relative abundance of the species in the sample follow the log series distribution while Shannon's index does not require such assumption. Morisita-Horn similarity index and Sorenson Incidence and Abundance indices were calculated as measure of β-diversity (between habitat). WOLDA (1981,1983) found that the only index not strongly influenced by sample size and species richness was the Morista–Horn index. SMITH (1986) also concluded that, for quantitative data, the Morista–Horn index was one of the most satisfactory. This index takes little account of rare species (SOUTHWOOD & HENDERSON, 2000). Several estimators were calculated using COLWELL (1997). Michaelis-Menten model was fitted to the sampling data after randomizing them for 50 times. Chao 1 and Chao 2 which are estimators that emphasize „rare species" in the sample were also included in the analysis in addition to coverage based estimators (abundance based: ACE, and incidence-based : ICE).

Results and Discussion

Absolute species richness

Tab. 1 provides a list of 17 species collected from the four habitats in Tamil Nadu. Nine species belonged to the subfamily Phaneropterinae, while only 3 species belonged

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Tab. 1: List of tettigoniid species collected from forest lands, grasslands, arable lands and wastelands in Chennai, Tamil Nadu.

S.No.	SPECIES	SUBFAMILY
1.	*Sathrophilia fuliginosa*	Pseudophyllinae
2.	*Trigononympha unicolor*	Phaneropterinae
3.	*Holochlora* sp.	Phaneropterinae
4.	*Acanthoprion suspectum*	Pseudophyllinae
5.	*Paramorcimus oleifolius*	Pseduophyllinae
6.	*Elimaeo securigera*	Phaneropterinae
7.	*Mirrollia* sp	Phaneropterinae
8.	*Mecopoda elongata*	Mecopodinae
9.	*Himertula* sp.	Phaneropterinae
10.	*Conocephalus maculatus*	Conocephalinae
11.	*Hexacentrus major*	Listroscelidinae
12.	*Holochlara indica*	Phaneropterinae
13.	*Phaneroptera* sp.	Phaneropterinae
14.	*Latana infurcata*	Phaneropterinae
15.	*M.cercinata*	Phaneropterinae
16.	*Neoconocephalus* sp.	Conocephalinae
17.	*Euconocephalus incertus*	Conocephalinae

to Conocephalinae and Pseudophyllinae. The subfamilies Mecopodinae and Listroscelidinae were represented by only one species each.

Tab. 2 provides the species richness, which counts the number of species in the defined area, for the four ecosystems studied. It is evident that the forest ecosystem was the richest with 14 species followed by the wastelands with only 6 species. Some of the species present in the wastelands, grasslands and arable lands were also present in the forest land. Therefore in terms of site selection, complementary sites have to be indicated. The number of species in all the areas combined represent the Tettigoniid complement of Chennai, a total of 17 in this case. Fourteen species of tettigoniids were present in the forest making the residual complement to be 3 species. The residual complement represents the three species of Tettigoniids not present in the forest. The forest ecosystem therefore represents 82.35 % of the Tettigoniid fauna. The grassland and arable land offers a 5.88 % increment while the wasteland offers a 17.64 % increment. Therefore given the requirement for the selection of sites so as to conserve the maximum tettigoniid species, our first choice would be invariably the forest followed by the wastelands. To assist the choice among the arable land and grassland, complementarity analysis using taxonomic differences become a useful tool.

Taxonomic differences facilitate ranking of sites. This requires measurement of diversities in terms of absolute values, and also in terms of their relative contribution to residual complements. Species richness treats all species as equally valuable and hence not always appropriate. „Megadiversity“, as measured simply by species richness, is by no means always the best. Taxonomic distinctness or difference is based on an appreciation of the taxonomic hierarchy. This allots differential weighting to the species, the weights being fixed or relative.

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Tab. 2: Species richness and Priority analysis through root weighting of tettigoniid species for site selection

S.NO	SPECIES	WEIGHTS (W)	FOREST LANDS	GRASS-LANDS	ARABLE LANDS	WASTE-LANDS
1.	*S. fuliginosa*	9	*	-	-	-
2.	*T. unicolor*	7	*	-	-	-
3.	*Holochlora* sp.	7	*	-	*	*
4.	*A. suspectum*	9	*	-	-	-
5.	*P. oleifolius*	9	*	-	-	-
6.	*E. securigera*	7	*	*	*	*
7.	*Mirrolia* sp.	7	*	-	-	-
8.	*M. elongata*	10	-	-	-	*
9.	*Himertula* sp.	7	-	-	*	*
10.	*C. maculatus*	8	*	*	*	*
11.	*H. major*	10	-	*	-	*
12.	*H. indica*	7	*	-	-	-
13.	*Phaneroptera* sp.	7	*	-	-	-
14.	*Latana infurcata*	7	*	-	-	-
15.	*M. cercinata*	7	*	*	-	-
16.	*Neoconocephalus* sp.	8	*	-	-	-
17.	*E. incertus*	8	*	*	-	-
T = Total Diversity		134	**107**	30	29	49
P1 = Percentages of the complement			**80**	22	22	37
P2 = Diversity increments after selecting the Forest ecosystem			-	8	5	**20**
P3 = Diversity increments after selecting the Forest and wasteland ecosystems				**0**	0	-

Root weighting is a fixed weight index where species are valued for difference according to their position in the taxonomic hierarchy (VAN-WRIGHT et al., 1991).

To arrive at taxonomic differences among the tettigoniids, the following weights were assigned: each species = 1 unit weight; each genera = 2 unit weights. The Tettigoniids collected belonged to five subfamilies namely Phaenoroptinae, Conocephalinae, Pseudophyllinae, Listroscelidinae and Mecopodinae. Based on the gradation of the dispersion measures, the following weights were assigned as per the order of families written above - 4, 5, 6, 7 & 7. The last two subfamilies had relatively higher weights because of their poorer representation in this region. This method, although very subjective, was used as no weights derived from taxonomic hierarchy or even based on strict phylogenetic methods could be assigned due to paucity of studies and information on these lines for the Tettigoniids.

Tab. 2 provides the species, area, complementarity and taxonomic difference for priority analysis. Taxonomic difference calculated by root weight method gives a set of additive weights (column W) reflecting the position of each species in the taxonomic hierarchy. Total diversity for the 17 complementary species and each area is given in row T. Scores as percentage of complement are given in row P1. Row P2 gives the diversity

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increments for the grasslands, arable land and wasteland based on residual complement, after selecting the forest land. Row P3 gives the diversity increment for grassland and arable lands after selecting the other two habitats. The data indicate that the forest ecosystem represent the maximum diversity of Tettigoniids followed by the wastelands. The arable land and grassland does not significantly add to the diversity of the tettigoniid fauna, after selection of the forest lands and wastelands.

Species richness estimators

COLWELL and CODDINGTON (1994) have, in recent years, been much concerned with the development of methods to estimate „total species numbers“ from samples, which are notoriously incomplete. This is a key problem in particular with tropical insect communities, which are usually so rich in species that a complete species inventory will almost never be achieved, at least on the scale of a local community. For example, literature data may be available to give a relatively precise number of butterfly species (an unusually well known group) for India, or for any state within India (since faunal lists have been compiled many times). But when it comes to the number of species present in one particular area (which of course can only harbour a subsample of the regional species pool), problems become huge. The simple reason is that „rare“ species will be missed with great likelihood in any sampling scheme on a small regional and temporal scale.

In this situation, of course, application of „complementarity“ and related concepts will be grossly misleading. The very reason is that two sites, represented by some incomplete samples, will - for statistical reasons – look more dissimilar to each other than they really are. If one selects, then, the most dissimilar sites to cover, for example, a maximum number of species, this procedure can be flawed by sampling error which yields overestimates of beta diversity (WOLDA, 1981; LANDE, 1996). One way of dealing with this problem is to estimate how many more species one should expect at a site if sampling would be possible to „completely“ cover a fauna or flora. For this we have used the computer programme of COLWELL (1997).

During the entire sampling period of 24 months, we recorded 14 species with 231 individuals from the forest lands; 5 species with 849 individuals from the grasslands; 4 species with 551 individuals from the arable lands and 6 species with 676 individuals from the wastelands. A pooled total of 2307 individuals belonging to 17 species were encountered. 7 species were singletons, 3 species doubletons and 11 uniques (Number of species that occur in only one habitat among the four habitats surveyed) in this study.

Generally, it is invalid to simply compare absolute species numbers between samples since with increasing sample size the number of recorded species also increases due to stochastic effects. Although in our study the sample size for the four habitats were equivalent, we still calculated Fisher's alpha, and Shannon's diversity indices as a measure of diversity within a habitat. Fisher's α-index indicates that forest was rich in the tettigoniid species followed by the wastelands, the grasslands, and lastly the arable lands (Tab. 3). Distribution of tettigoniid species confirmed the log series distribution pattern (Fig. 1) thereby giving creditability to the Fisher's α values. On the other hand Shannon's index which has gained great popularity as it does not assume theoretical distribution, also gave the top ranking for the forest lands. If the relative abundance of species is plotted against the rank, the plot will often approximate to straight line. The more horizontal the line, the more equitable the distribution

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Tab. 3: Diversity statistics for Tettigonids from the four habitats

Habitat	α-diversity	Shannon	Michaelis Menton Mean		Chao 1	Chao 2	ACE		ICE	
			Total Sp No.	% observed of estimated total			Total sp No	% observed	Total Sp No	% observed
Forestland	3.27±0.45	1.27	17	82.35	15.62±3.4	15.05±2.1	19.73	70.95	18.16	77.09
Grassland	0.70±0.11	1.03	5	100	5.0±0.0	5.5±0.0	5.0	100	5.91	84.60
Arableland	0.58±0.10	0.29	4	100	6.0±0.0	6.0±0.0	6.0	66.67	6.0	66.67
Wasteland	0.90±0.14	0.89	6	100	6.05±0.72	10.5±0.0	6.75	88.89	10.5	57.14

Actual recorded number of species : wasteland=6; arable land = 4; forest land = 14; grassland = 5

as seen for example in the forest ecosystem. A rare faction approach by plotting the cumulative number of species collected against the measure of sampling effort, in this case 24 sampling events, also yielded the similar rankings of the habitat (Fig. 2). As the sampling effort increased, the forest lands showed a steady increase in the species accumulation. The species accumulation curve for the other three habitats showed accumulation with effort (months in our case) that was possibly dependent on environmental factors.

While diversity indices provide rather abstract figures, one may use extrapolation methods to estimate the total number of species from empirical samples that make up the community under study, since complete inventories are practically impossible. Mathematical models underlying extrapolation procedures are usually asymptotic i.e., converge to a 'true value' of total species richness, if sampling effort increases

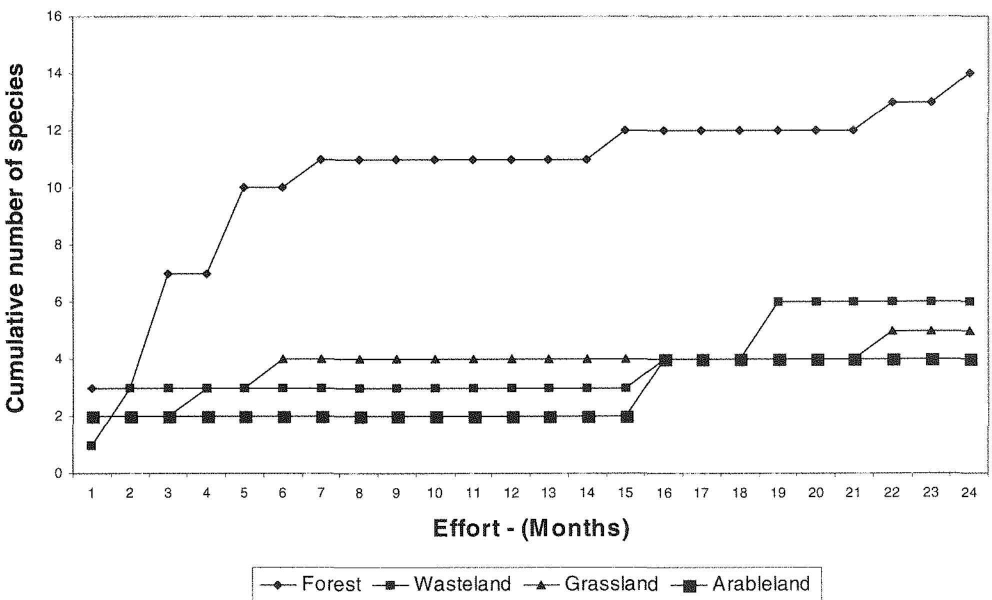

Fig. 1: Cumulative species number of tettigoniids recorded from monthly samples collected between June 1999 to May 2001.

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(SUESSENBACH and FIEDLER, 1999). We chose the following estimators: A Michaelis-Menten model and Coleman curve were fitted to the sampling data after randomizing them 50 times using the procedure of COLWELL (1997). Two coverage based estimators namely abundance-based ACE and incidence based ICE were also calculated.

Michaelis-Menten type models describe well the accumulation of species records as sampling increases, with steady increasing likelihood of adding new species (LAMAS et al., 1991). Fig. 3 depicts the species accumulation curve using MMMeans and Coleman curves as estimators of species richness. The curve for the wasteland, grassland and arable lands had reached the asymptote at 3 months of effort. However, the forest land depicted the curve with an increasing trend indicating greater chances of encountering more species with further increase in effort. This is also reflected in the values of the ACE and ICE estimated which for the forest lands (Tab. 3) in the present study is 70.95 % and 77.09 % respectively. The coverage based estimators for the arable lands wastelands were between 66 and 89 % indicating that there is still scope for encountering more species in these habitats as against what the MMMean species accumulation curve depicted. Coverage-based estimators for both abundance data and incidence data are characteristic of data types in which some species are very common and others very rare. All the useful information about undiscovered species lies in the rarer discovered classes. Coverage is the sum of the probabilities of encounter for the species observed, taking into account species present but not observed. The Abundance-based Coverage Estimator (ACE) is based on those species with 10 or fewer individuals in the sample (CHAO et al., 1993). The corresponding Incidence-based Coverage Estimator (ICE), likewise, is based on species found in 10 or fewer sampling units (LEE and CHAO, 1994). Taking into consideration the species richness reported by NASKRECKI & OTTE (1999) for the Indian subcontinent, the Coverage based Estimators appears to be more acceptable and as their indicate more further chances encountering tettigoniid species from these localities. Fig. 3 also depicts the Coleman curve. The more the species accumulation curve lies below the Coleman (or

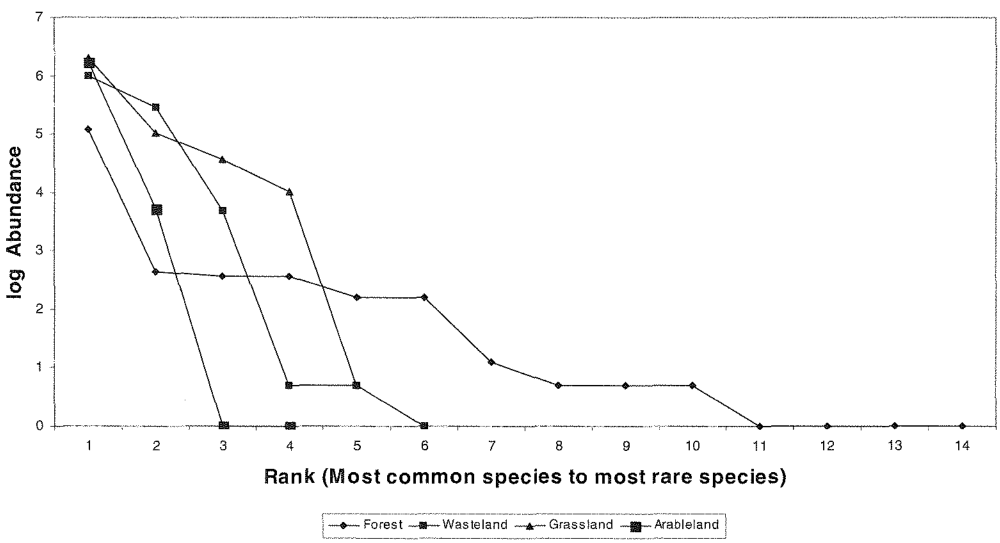

Fig. 2: Rank order abundance plots for tettigoniid species in Chenai

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rarefaction) curve, the more heterogeneous the samples. Our studies indicate the forest sample alone to be homogeneous as the species accumulation curve lies above the Coleman curve.

Tab. 4 provides the shared species statistics between pairs of the four habitats. The number of species observed in each habitat and the number of species seen in both of the habitats under comparison are provided. For the comparison of diversity between habitats we calculated two binary similarity indices namely, Sorenson Incidence based and Sorenson Abundance based indices in addition to Morisita-Horn index. The Morisita-Horn index indicated a 95-96 % similarity between the forest lands, grasslands and arable lands; a 91 % similarity between grasslands and arable lands and exceptionally no similarity of the wastelands with the other habitats. The incidence based Sorenson index showed a 80 % similarity between the wastelands and grasslands, while the abundance based Sorenson index indicated a 78 % similarity between the grasslands and arable lands. A rescaled reversed absolute squared Euclidean similarity coefficient Matrix was developed and the dendrogram clustering the habitats was drawn (Fig. 4). The grasslands and arable lands formed a single cluster group while the forest and wastelands formed two independent groups.

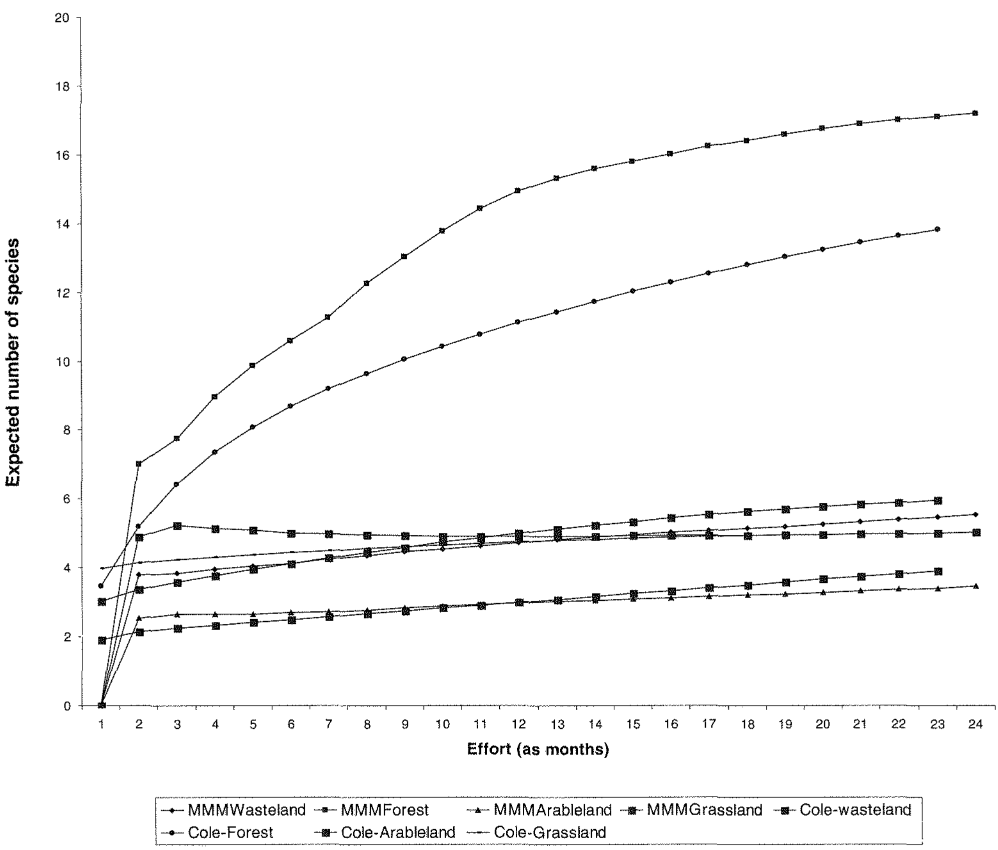

Fig. 3: Rarefaction curves for the comparison of habitats using performance of Michaelis-Menten richness estimator (MM Mean) and Coleman curve as a function of Randomized sample accumulation.

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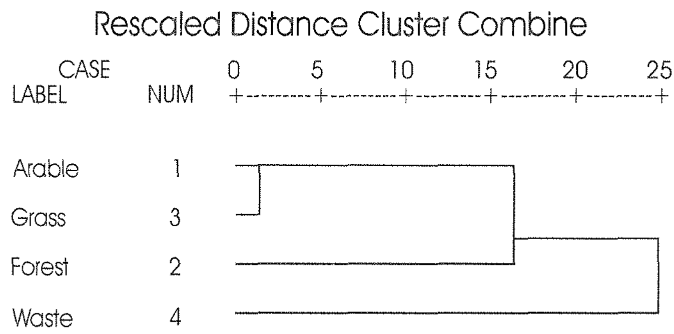

Fig. 4: Dendrogram measured by rescaled reversed absolute squared Eucliden similarity coefficient matrix for the four habitats.

In sum, although we found differences in the number of species and number of individuals in the four habitats that was also reflected in the differences in the α-diversity values. The Morisita–Horn similarity index clearly indicated that tettigoniid species of the wastelands effectively complemented that of the forest lands, a result that was also shown by the root weighting priority analysis.

In conclusion, site selection in terms of species richness as a measure of megadiversity gives the first selection choice for the forest, followed by the wastelands, grasslands and finally the arable lands. Similar ranking was obtained in the complementarity analysis including analysis that takes into account the taxonomic distinctness of the species. A more recent analysis of the biodiversity of an area, is the species richness estimates which provide an insight into the likelihood of encountering further species, had inventory been more complete. Extrapolation analysis have shown that over 80 % in forest lands and almost cent percent in other habitats, of the possible species complement of the area were encountered during our studies. The various species estimators also facilitated comparison of the sites and the results have conclusively shown the forest lands to support most of the tettigoniid fauna.

Tab. 4: Shared species statistics between pairs of the four habitats

FIRST SAMPLE	SECOND SAMPLE	SOBS I	SOBS II	SHARED OBS	MORISTA HORN	SORENSON INC	SORENSON ABD
Forest land	Arable land	14	4	3	0.95	0.33	0.45
Forest land	Wasteland	14	6	3	0.51	0.3	0.38
Forest land	Grassland	14	5	4	096	0.42	0.35
Arable land	Wasteland	4	6	4	0.49	0.8	0.45
Arable land	Grassland	4	5	2	0.91	0.44	0.78
Wasteland	Grassland	6	5	3	0.49	0.55	0.36

SOBS = species observed; INC.= incidence; ABD. = abundance OBS= observed

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