INSECTS AS BIOINDICATORS OF CONSERVATION IN THE TROPICS

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INTRODUCTION

Insects are extremely important components of the world's biota. Insect conservation and biotope preservation are inextricably related and are integral part of biodiversity conservation. Increased insect variety is usually associated with increased plant variety (Samways, 1994). The impacts may range from river pollution, wetland and forest degradation, global warming, intensive and extensive agriculture and urbanisation. The biological entity or a toxon should be easy to recognise and sensitive to environmental changes. There are many variables and possibilities when choosing a taxon for environrnental monitoring.

Various groups of macro- and micro-invertebrates have been used in environmental monitoring (Erhardt and Thomas, 1991; Elliot, 1991). This possible factors affecting the use of invertebrates as bioindicators may vary in the tropical climate from the temperate climates and as a result the insect diversity in the tropics is much more than in the temperate regions. It appears that the evolutionary interaction between plant and insect and the rate of novel defensive and counter defensive characteristics seem to have contributed to the diversification of insects (Mitter, *et al.*, 1991).

This paper summarises selected published information on the use of insects as bioindicators of conservation in the semi-arid tropics and briefly indicates results of two case studies conducted in the evergreen tropical forests of Western ghats region in Karnataka.

INSECTS AS THE DOMINANT GROUP

The great variety of insects in the tropics may not only be attributable to suitable climatic conditions but also to the variety of native plant species existing. A number of intermediate level disturbances such as heavy downpour over millenia have granted high species richness (Braker, 1991). The foraging activity indicate clearly that insects are a dominant group, ecologically important and potentially valuable, genetically usefu as bioindicators particularly in the tropics.

INSECTS AS BIOINDICATORS

Insects in general are particularly suited for monitoring lanc scape changes because of their abundance, species richness, ubiquitous occurrence and importance in the functioning of natural ecosystems (Rosenberg, *et al.*, 1986 cited in Samways, 1994). The class insecta also has members even within different trophic levels therefore providing varied sensitive indication of changes.

Entomologists used all insect taxonomy groups to indicate changes. Samples have been obtained either by a single method or deliberately with capturing techniques to catch as many insect taxa as possible from all trophic levels.

Indicator species are worth identifying where they are associated with a particular biotope or landscape depending on the scale of measurement. But the paradox is that a single species which is sensitive to environmental perturbations may simply disappear not because of a disturbance but because of an intrinsic feature of its population dynamics. Betting and Hedging using landscape management practices may or may not save an insect species. There can be no guarantee of their continued existance particularly for stenotopic species on the edge of their range (Dempster, 1991). This means that species listing is important (Foster, 1991). But the species list ideally should be quantitative listing the number of species and their relative abundance (species richness). Sites can be compared with special reference to certain key species that are characteristic of a particular biotope. Sites with several rare indicator species are of particular value as these contain several endemic species of stenotopy.

Indicator species need not always be amongst the rarest of species. Abundant species may have value, being easier to locate. However, abundant species can also be generally more eurytopic than the rare species because stenotopic species are bound to be rare as their particular habitat is narrowly defined.

Certain species may also be subjected to biojogical factors limiting their indicator usefulness. They may be highly mobile even migratory or they may also be subjected to intraspecific and interspecific competition and be present or absent for reasons other than landscape modification.

Species lists have definite value and some of those species may be good indicators singly or as a group. Such short lists must take into account the life history styles of the species in

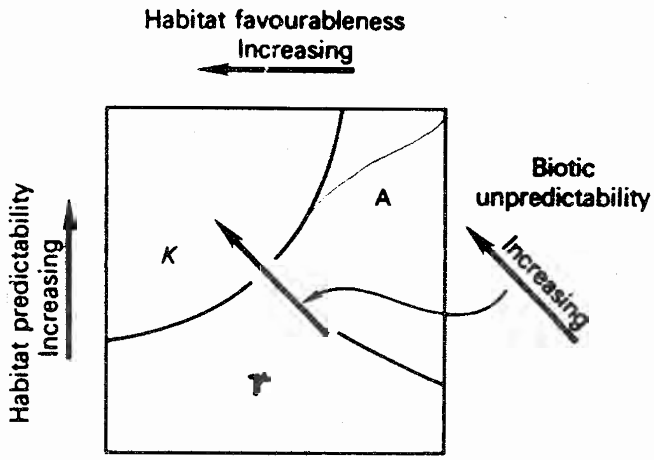

Fig. 1. The habitat (biotope) templet with special reference to insects. A = adversity selection, r = exploitation selection for productivity, K = interaction selection for persistence in crowded, competitive, species-rich environments. (From Greenslade, 1983)

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Table 1. Classification of some Tasmanian taxa according to level of endemism at species level associated biotope and predominant selection type (Greenslade and New, 1991).

Selection type	Usual biotope	Taxon	Endemism %
A*	Cold torrents	Psephenidae	100
	Cold, fast streams	Plecoptera	89
	Caves	Trechini	93
	Burrows	Parastacidae	88
	Cold, alpine lakes and streams	Anaspididae	80
	Deep soil	Oligochaeta (terrestrial)	92
	Logs (late decay)	Lucanidae	83
KA+	Cold, slow streams, lakes	Tipulidae	75
		Turbellaria (Terrestrial)	69
		Trichoptera	70
		Oligochaeta (aquatic)	60
K	Eucalyptus forest	Coccinellidae	30
r	Pasture	Collembola	2-4

* Overall percentage endemism for A taxa = 91 (150/ 165 species excluding Trechini)

+Overall percentage endemism for KA taxa = 69 (167/ 241species).

question. Pertinent to this is the life history style (Southwood, 1988). Greenslade and New (1991) summarise various Tasmanian insect taxa (Table 1) the highest levels of endemism tend to occur in the most severe landscapes, that is those which are predictably unfavourable and in which adversity (A) selection operates (Greenslade,1983). A selection implies long life histories, low reproductive rates, few offspring, low dispersal ability and conservative genetic systems, all making the species susceptible to disturbance. Endemism was lowest in temporary and disturbed biotopes such as agricultural land where exploitation (r) selection for productivity was dominant and the fauna showed high population variability and high dispersal ability. Diversity was greatest in relatively stable, favourable biotopes, where interaction (K) selection for persistance in crowded, competitive environments was dominant. In conservation terms, this means that a shift from that the top left corner towards the bottom in figure 1 implies a loss of sensitive species, and indicates a detrimental impact upon the landscape and insect community.

Choice of a particular indicator species as with other aspects of insect and landscape conservation depends on the precise goal, the scale of the assessment and availability of material and human resources. The goal should be to determine the selection of a species with an array of characteristics suitable for attaining that goal. Much characteristics may include life history style, local or widespread abundance and distribution, availability and seasonality, sensitivity to disturbance and possible genetic uniqueness where an historical biogeographical perspective is required.

PROBLEMS AND PROSPECTS IN THE TROPICS

Recent work suggest that the richness of the tropical insect fauna is beyond all earlier expectations (Erwin and Scott 1980; Erwin, 1983 and Stork, 1988). It is equally undisputed, however, that most tropical organisms are poorly studied and the little that we do know about any group of organisms comes largely from studies of temperate species (Robinson, 1978). The poor state of our understanding of tropical biology may be partly attributed to the relative economic backwardness of tropical countries, the lack of facilities for research and sometimes the lack of tradition of modern scientific work (Gadagkar *et al.*, 1990). However this is due to the lack of appropriate research methodology suitable for tropical conditions. Studies on insect species diversity and the long-term monitoring of insect species and populations in different habitats are good examples. Almost all the major long term insect monitoring programmes are based on light trap catches, a method that requires uninterrupted supply of electricity, often in the middle of a forest (Halloway 1983, 1987, Taylor, 1928, Taylor *et al.,* 1976; Walda 1983 a, b; Wolda and Boubic, 1986). Sometimes the light traps are operated for years together without interruption. The establishment and longterm maintanance of electrically operated devices is probibitively expensive for most ecologists working in tropical countries. This has prevented many tropical ecologists from understanding studies on insect species diversity (Walda, 1981 a).

There have been attempts to standardize a package of methods for quantitative sampling of insects suitable for tropical ecologists with modest research budgets. This methodology includes the use of a small light trap as well as sweepnets, pitfall traps and scented traps. The methods have been used to sample insect species diversity in three replicate one hectare plots each in twelve selected sites in the Uttara Kannada district of Karnataka. This methodology is adequate for sampling insects and differentiating habitats on the basis of the distribution of insect species (Gagadkar *et al.*, 1990)

Objective choice of insect indicator groups depends on various factors. Termites would be of no value in northern Europe, but may along with ants (Anderson, 1990), be good indicators of negative and possitive factors of epigaeic environmental conditions in warm arid areas. Disney (1986) has suggested that Diptera and Hymenoptera parasites are useful as indicators of conservation value, as they interact with a broad spectrum of ecological niches and microhabitats. This may be more feasible in temperate areas, but in the tropics better known groups with generally large sized species may be of greater and more expedient use in making conservation decision. Butterflies and dragon flies are prime candidates in the tropics (Sutton and Collins, 1991). Butterflies have been targetted for temperate regions as well as the tropics (Gilbert, 1980; K.S. Brown, 1982; Pollard 1982; Murphy and Wilcox, 1986; Erhardt and Thomas, 1991). They are generally fairly readily identifiable, there is a relatively good taxonomic knowledge of the group and they are also sensitive to environmenal changes in microsite and biotope characteristics. They are often highly plant specific for their growth and development (Ehrlich and Raven, 1964) and sometimes have close plant-pollinator relationships.

Pearson and Cassola (1992) have proposed the use of tiger beetles (Cicindelidae) as good indicator group for identifying areas for biodiversity conservation. Tiger beetles are well known groups occuring over a broad range of biotope types and geographical areas. Clark and Samways (cited in Samways, 1994) also found that Cicindelids are particularly useful as past indicators of biotope quality relative to disturbance. Pearson and Cassola (1992) took only 50 hours of observation to find 93% of the tiger beetle fauna, while the butterfly list of over 1200 species is still rising and to find 90 % of the butterfly species entailed nearly 1000 hours of field work.

Wood and Samways (1991) found butterflies (Papilionidae) to be good indicators of biotope type and landscape pattern at a mesoscale (e.g. 50 m x 50 m), but cicindelids were much more sensitive indicators at a microscale (e.g. 1 m x 1 m) (Clark and Samways, 1992). Further, different developmental stages give different indications, often the larva being more sensitive at the smaller scale because of its relative immobility compared with the adult. Some larvae such as odonata and Ephemeroptera may even be viewed as different organisms from the adults for monitoring purposes. The larvae are aquatic rather than arial as the adults, and represent quite different media and conditions must be suitable for both adult and larva. Providing the call/ song has been related to the species, orthoptera can also be excellent biotope indicators, as they can be recognised in the canopy at night without having to resort to any trapping or landscape disturbance (Samways, 1989 f). From these view points, there are many variables and possibilities when choosing a taxon for environmental monitoring. It is important to define clearly conservation of the most appropriate insect group which may not be the one most familiar to the researcher. Elliott (1991) examined the possibility of using aquatic insects as subject organisms being affected by projected climate change in Britain. Aquatic insects generally have stenothermic requirements and vary considerably between species and also life stages of the same species. River and stream inhabiting species will also be affected by possible changes in the temporal distribution of rainfall because this may influence the frequency of spates and droughts.

Elliot (1991) identified criteria that should be used in selecting freshwater species for a study of the effects of projected climate change :

1. Long term data sets should be available on the population dynamics of the selected species and an associated climatic variables.
2. Ecophysiological information should be available on effects of climatic variables on the selected species (e.g. temperature).
3. Ecological information should be available on the functional role and the selected species within their ecosystem.

Under European condition specially in Britain, no species of aquatic insects could be found to meet all these three criteria, but the stone flies (Plecoptera) as a group and their eggs satisfied 2 and 3. Bearing in mind the relative extent of knowledge of the British fauna, it means that comparative work in other parts of the world, especially the tropics, requires much more basic research as insect fauna is more diverse and a great variety of habitats exist.

Unquestionably, insects are excellent indicators of environmental change, however that they are often readily subject to local extinction when environmental changes affect their biotope, mobility can vary enormously even within small taxon (Samways, 1989 f).

CASE STUDY 1

The survey was conducted to study the invertebrate fauna in Mercera, Western Ghats, Karnataka with an altitude of 3300 ft MSL (75° 21' E 11° 15' N). The study site was situated very close to state highway between Medikeri and Kushalanagar and an area of 103 ha. preserved as biodiversity National park vvhere precipitation ranged from 100 to 150" from June to October with prevailing temperature of 12 to 30°C. Red loams is the predominent soil type with evergreen and semi-evergreen vegetation and the under growth is largely covered with *Lantana* and *Chromolaena* weeds.

Four habitats were selected viz., wet tropical forest, Devarakadu (God's forest), Newly planted area and *Eucalyptus* planted area.

In wet tropical forest the ground is moist covered with thick layer of leaf litter, decaying organic matter. Devarakadu stretches about 10 ha. with four deep valleys. The moist nature of valleys support the rich and closed vegetation. Interiors of valleys are well covered with bushes of various species. The newly planted area was about 10 ha. Nearly 7000 trees of various species have been planted at the site. *Eucalyptus grandiflora* is the predominent tree of the site in *Eucalyptus* planted habitat with 15,680 trees. The fauna was monitored for three days each in February and September,1994.

Over 80 species of insects, 50 species of birds and 3 species of mammals were recorded during the survey. Over 50 species of birds belonging to 35 familes were studied in all the habitats of the park. None of the birds were recorded resting at the site and strongly influenced by the surrounding vegetation with shade trees of coffee estates. Many birds exhibited considerable local movements. 40% of the species were migratory and none of the species of birds was consistantly observed associated with any pairticular kind or group of vegetation and utilised the sites for activities like nesting, roosting, feeding, foraging etc. So birds as a group presented problems as bioindicators of changes at the site.

Insects were found to be the most dominant group at the site. The number of insects on common herbs and shrubs in cleared and planted habitats were recorded. The number of insects varied from 7 to 57 on *Lantana camera* with a mean of 25 insects per plant. The number of species of insects per plant varied from 2 to 8 with a mean of 4 per plant. The number of insects on *Solanum* species plant varied from 1 to 12 with a mean of 58 and the number of species from 1 to 5 (n=5) with a mean of 2.6. Seventy eight percent of insects sighted were phytophagous. Bees like *Apis dorsata*, *Apis cerana*, *Melipona* spp., *Apis florea* and other hymenopterous and dipterous insects were pollinators which constituted about 9%. About 5% of the insects were common predators such as coccinellid beetles, wasps, reduviid bugs, odonatans, etc. and the rest were saphrophytic or scavengers.

The dominance of phytophagons species in insect community in dewed and planted habitat was evident from the damage to the herbs, shrubs and medium sized trees. Some plants showed more than 80 percent foliage damage. Insects were also found feeding on roots (root grubs), stem (stem borers), leaves (defoliators), buds, flowers, fruits (fruit borers) and seeds (seed eaters).

The dominent weed plants like *Lantana,* wild *Solanum* etc. were heavily defoliated by insect herbivores when compared to other plants and so insects contributed to the natural suppression of weeds to some extent. This is more desirable than management of the weeds chemically in a conservation area like National parks.

Under normal conditions, the grazing of insect herbivores increases the flow of energy and nutrients through an ecosystem. Grazing increases light penetration through the foliage canopy reducing competition between plants, alters the plant species comparision of communities, increases the rate of nutrient leaching from the foliage and increases the rate of litterfall and its accumulation.

Moderate defoliation and damage was observed in the evergreen forest patch when moderate (20 to 30%) defoliation occurs, there may be a substantial rise in nitrogen, phosphorus and potassium content of litter as a result of increased production of material containing insect excrement and cadavers.

Many of the insect species observed in forest and valley habitats were unique and restricted to these habitats only. Notable among such species were the meloid, longicorn, scarabaid and chrysomelid beetles. This group also included saturnid, hesperid butterflies, bees and other hymenopterous and dipterous flies. This group of insects are indicators of the richness and uniqueness of the habitat.

A wide variety of invertebrates inhabited the soil of the forest patch and valley. These comprised microorganisms, nematodes, earthworms, microorthropods, millipedes, termites, ants, dungbeetles, crickets, grasshoppers, cockroaches, maggots, grubs etc. Organic matter formed an essential component of the soil where these organisms contribute to its decomposition and nutrient cycling resulting in soil fertility.

The forest and the valley habitats contained a number of spiders, forming large webs occupied entire space between canopy of two adjacent trees or bushes. A number of predators like carabids, tiger beetles, dragonfly, centipedes and coccinellid were found in the habitats which indicated the complexity of the insect community.

These preliminary observations and inferences indicated that various groups of insects could be utilized to indicate different aspects of the habitat. A soil insect could be used to indicate the fertility of the soil. The phytophagous insect could be associated with the kind and richness of the vegetation and a particular species of a parasite and predator could be used to indicate the presence or absence of phytophagous insects. Similarly blood suckers are quite common with the presence of worm blooded animals including human beings.

Table 2. The potential insect taxon that could be used as bioindicators in different habitats of National park at Mercara

Habitat	Insects inhabited	No. of insect sp.
Wet tropical forest	Butterflies, Meloid & longicorn beetles	28
Devarakadu	Butterflies, Meloid & longicorn beetles	22
Cleared & planted area	Coccinellid beetles Bees and Wasps	72
Eucalyptus planted area	Chrysomelid beetles and butterflies	19

CASE STUDY 2

Thungabhadra river basin covers about 2/3 of Karnataka state. The river originates amidst evergreen tropical forests in Gangamoola and then flows downstream covering a number of towns before it joins the Arabian sea. Coffee estates and factories are situated along the river and they discharge effluents into the receiving bodies of water. In order to reduce the risk, to the health of the animal population and serve as a habitat for endemic wild flora and fauna, it is important not only to put an end to discharge of any effluent, but also monitor the condition of water at regular intervals so that dangerous problem can be identified at the right time. Such monitoring methods take a lot of time and are quite expensive. One good way to answer these types of questions is to determine the quality of water by means of indicator organisms. Invertebrates especially insects are closely associated with specific sites and vegetation and consequently they are the preferred group of biota. The natural fluctuations in the distribution of indicator species should be taken into account while using indicator species.

The study was undertaken during June -July 1995 when more than 300 km. stretch of Thungabhadra river was monitored for butterflies. The species lists were prepared for a cross section of 10 km. For instance the longitude, altitude, land use, water quality, anthropogenic factor and vegetation was similar along the entire cross section of the 10 km. stretch.

The results revealed that butterflies could be used as indicators only at selected sections of the river. Butterflies did not provide any indication of the water quality, degree of pollution and the vegetation associated with each 10 km. stretch. However, using butterflies, practically oriented method could be developed for field use to indicate differences in the extreme conditions of the river over a long period; for indicating short-term changes butterflies may be unsuitable. For instance, wherever the river was highly polluted with industrial effluents and urban wastes like in Bhadravati town only pierid butterflies (*Pieris* sp.) were present. These butterflies were observed to interact with weed population present in that patch. In contrast to this habitat in and around Gangamoola, where the water was relatively clear with climax vegetation around, the different butterflies belonging to papilionidae, lycaenidae, pieridae, hesperidae, danidae, nymphalidae and satyridae were recorded. From this observation it was concluded that butterflies were of little significance as suitable organisms for indicating the degree of water pollution and the type of vegetation along Thungabhadra river basin. Macrophytes and aquatic insects may also be considered for indicating changes in the water quality and land use patterns along the river.

CONCLUSION

Insects are important as bioindicators and they have special role to play particularly in the tropics. Insect taxonomic groups are useful in identification of particular landscape and communities for conservation of biota. Insects are generally interacting with biotic and abiotic factors at different trophic levels in an ecosystem. Temporal and special variabil.ty, numerical and functional response and short- and long-term disturbances are of particular significance in the tropics.

It is now timely and vital that attention should be diverted to give more importance to the conservation of the insect species in the tropics, so that more research can be initiated on insect conservation. This is urgently required in developing countries like India where the socioeconomic conditions and landscapes are rapidly and drastically changing from time to time.

REFERENCES

Andersen, A.N. 1990. The use of ant conmunities to evaluate change in Australian terrestrial ecosystems: a review and recipe. *Proceeding of the ecological society of Australia*, 16: 347-357.

Braker, E. 1991. Natural history of neotropical gap inhabiting grasshopper. *Biotopica*, 23 : 41-50.

Brown, K.S. 1982. Paleoecology and regional parterns of evolution in neotropical lorest butterflies. In : *Biological Diversification in the tropics* (Ed. G.T. Prance), Columbia University Press, New York, pp. 255 - 308.

Chakravarthy, A.K. 1995. *Observations on Invertebrate and vertebrate fauna at the biodiversity park Mercara, Coorg district, Karnataka.* Report submitted to special Secretary Department of Ecolcgy and Envircnment, Bangalore-1, pp- 22.

Dempster, J.P. 1991. Fragmentation, isolation and mobility of insect populations, In : *The conservation of insects and their Habitats* (eds. N.M.Collins and J.A.Thomas), 15th Symposium of the Royal Entomological Society of London, pp. 143-153.

Disney, R.H. 1986. *Assessments using invertebrates: posing the problem, in wildlife conservation evaluation* (ed. M.B. Usher), Chapman & Hall, London, pp. 271- 293.

Ehrlich, P.R. and Raven, P.H. 1964. Butterflies and plants: a study in co-evolution. *Evolution*, 18: 586-608.

Elliott, J.M. 1991. Aquatic insects as target organimms for the study of effects of projected climate change in the British Isles. *Fresh water Forum*, 1 : 195-203.

Erhardt, A. and Thomas, J.S. 1991. Lepidoptera as indicators of change in the semi-natural grasslands of lowland and upland Europe, In : *The conservation of insects and their Habitats* (eds. N.N.Collins and J.A.Thomas), 15th Symposium of the Royal Entomological Society of london, Academic Press, London, pp. 213-236.

Erwin, T.L. 1983. Tropical forest canopies: The last biotic frontier. *Bull. Ent. Soc. Am.*, 30: 14-19.

Erwin,T.L. and Sott, J.C. 1980. Seasonal and size patterns, tropic structure and richness of coleoptera in the tropical arboreal ecosystem. In : *The fauna of the tree Luchea seemannii Triana and Planch in the canal zone of Panama.* The Caleopterist's Bulletin, 34 : 305-322.

Foster 1991. Conserving insects of aquatic and wetland habitats, with special reference to Beetles. In: *The conservation of insects and their habitats* (eds. N.M.Collins and J.A.Thomas), 15th Symposium of the Royal Entomological society of London, Academic Press, London, pp. 237-262.

Gadagkar, R., Chandrashekara, K. and Nair, P. 1990. Insect species diversity in the tropics: Sampling methods and a case study. *J. Bombay nat. Hist. Soc.*, 87: 337-353.

Gilbert, L.F. 1980. Food web organisation and the conservation of neotropical diversity, In: *Conservation Biology. An evolutionary -ecological perspective* (eds. M. E. Soule and B.A. Wilcox), Sinauer Associates, Massachusetts, pp. 11-34.

Greenslade, P. and New, T.R. 1991. Australia: Conservation of a continental insect fauna, In: *The conservation of insects and their Habitats* (eds. N.M.Collins and J.A.Thomas), 15th Symposiun of the Royal Entomological Society of london, Academic Press, London, pp. 33-70.

Holloway, J.D. 1983. Insect surveys - An approach to environmental monitoring. *Aui XII Congr. Nat. Ital Etomol.* Roma, 1980, 239-261.

Holloway, J.D. 1987. Macrolepidoptera diversity in the doaustralian tropics. Geographic, biotopic and taxonomic variations. *Biol. J. Linnean Soc.* 30 : 325-341.

Lawton, J.H. and Strong, D.R. Jr. 1981. Community patterns and comptition in falivorous insects. *The American Naturalist* 118: 317-338.

Mitter, C., Farrell, B. and Futuyama, L.J. 1991. Phylogenetic studies of insect-plant interactions : insights into the genesis of diversity. *Trends in Ecology and Evolution*,6: 290-293.

Murphy, D.D and Wilcox, B.A. 1986. Butterfly diversity in natural habitat fragments; a test of the validity of vertibrate-based managemnent, In : *Wildlife 2000, Modelling Habitat Relationships of Terrestrial Vertebrates* (eds. J. Verner, M.L. Morrison and C.J. Ralph), University of Wilconsin Press, Madison, pp. 287- 292.

Owen, D.F. and Owen, J. 1990 Assessing insect richness at a single site. *Environmental conservation*, 17 :362-364.

Pearson, D.I. and Cassola, F. 1992. World-wide species richness patterns of tiger beetles (Coleoptera : Cicindelidae) indicator toxon for biodiversity and conservation studies. *Conservation Biology* 6:376-391.

Pollard, E. 1932. Monitoring butterfly abundance in relation to the mangement of a nature reserve. *Biological Conservation*, 24 : 317-328.

Robinson, M.H. 1978. Is tropical biology real? *Trop. Eco.* 19: 30-50.

Samways, M.J. 1989f. Farm dams as nature reserves for dragonflies (Odonata) at various altitudes in the natal Drakensberg Mountains South Africa. *Biological Conservation* 48 : 181-137.

Samways, M.J. 1994. *Insect conservation Biology.* Chapman and Hall, London. Glassgow. NewYork, Tokyo, Melbourne, Madras, pp. 356.

Southwood, T.R.E. 1988. Tactics, Strategies and templets. *Oikos*, 52 : 3-18.

Stork, N.E. 1988. Insect diversity: Facts, fiction and speculation. *Biological J. Linn. Soc.*, 35 : 321-337.

Stork, N.E. 1991. The comparision of the arthropod fauna of Bornean lowland rainforest trees. *Journal of Tropical Ecology*, 7 : 161 - 180.

Sutton, S.L. and Collins, N.M. 1991. Insects and tropical forest conservation, In: *Conservation of insects and their Habitats* (eds.N.M.Collins and J.A.Thomas), 15th Symposium of the Royal Entomological Society of London, Academic Press, London, pp. 405 - 424.

Taylor, L.R. 1978. Bates, Williams, Hutdhinson - a variety and diversities. In : *Diversity of insect faunas* Mound L.A.,Walloff, N. Symp. Ray Entomol. Soc. London IX Blockwell, Oxford, london, Edinburgh, Melbourne, pp. 1-18.

Taylor, L.R., Kempton, R.A. and Woiwod, I.P. 1976. Diversity statistics and the log series model. *J.Anim. Ecol.*, 45 : 255-272.

Thomas, J.A. 1984. The conservation of butterflies in temperate countries : past efforts and lessons for the future. In : *The Biology of Butterflies* (eds. R.J. Vanewright and P.R.Ackery), Academic press, London, pp. 333-353.

Usher's, M.B. 1986. *Wildlife conservation evaluation: attributes, criteria and values, in Wildlife conservation Evaluation* (ed. M.B.Usher), Chapman and Hall, London, pp. 3-44.

Wolda, H. 1983 a. Diversity, diversity indices and tropical cockroachs, *Oecologia* (Berlin) 58 : 290-298.

Wolda, H. 1983 b. Spatial and temporal variation in abundence in tropical animals. In : *Tropical rain forest : Ecology and management* Whitmore, T.C., Chadwick, A.C. (eds) Blackwell Scientific publications, Oxford, pp. 93 - 105.

Wolda, H. and Roubic, D.W. 1986. Nocturnal bee abundance and seasonal bee activity in a panamanian forest. *Ecology*, 67 : 426-'433.