A STUDY OF THE BUTTERFLY DIVERSITY IN THE ARABUKO-SOKOKE FOREST, KENYA

BY

WASHINGTON O. AYIEMBA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE IN THE UNIVERSITY OF NAIROBI

DECLARATION

This thesis is my original work and has not been presented for any other degree to the best of my knowledge

Washington O. Ayiemba

This thesis has been submitted for examination with our approval as University supervisors

Dr. Warui Karanja

Dr. Ian Gordon

Dedication

To my loving parents Elias and Margaret, in deepest appreciation for all that they have forgone to educate me.

Acknowledgements

I take this opportunity to thank all those who assisted me in one way or another in the making of this thesis. My first and special thanks go to my supervisors Dr. Warui Karanja and Dr. Ian Gordon. Their helpful suggestions and critical comments undoubtedly helped in the development of this study. I wish also to thank the University of Cambridge Research Group in Mammalian Ecology and Reproduction, courtesy of Dr. Fumi Mizutani, for sponsoring my tuition fees. Thanks also to the Department of Zoology for awarding me the necessary research funds which helped in undertaking the research work and final development of this thesis. Another vote of thanks goes to the the Forest Department, Kenya Wildlife Service and Kipepeo Project for their kindness and cooperation that I enjoyed over the research period. Also my student colleagues Ester Fondo and Jacqueline Uku were not only a constsant source of support during my research work but also communicated the challenge and excitement of doing the study. I owe special debt of gratitude to Dr. Eduard Van de Berghe, Lorna Depew and Kinaro Kibanya for allowing me the use of their personal computers in the analysis and writeup of my research. Lastly I owe immense debt of gratitude to friends and relatives who were a constant source of inspiration and encouragement.

Table of Contents

List of Figures

List of Tables

List of Plates

Abstract

In this study the diversity of butterfly fauna in the Arabuko-Sokoke Forest is examined by looking into their population abundance and seasonality. Investigation of these were by means of systematic collecting and trapping, and by use of weekly walking transects in which 60 butterfly species encountered were counted. From the general collection and trapping a total of 134 species of butterflies were caught. These were representative of 5 families, 14 subfamilies and 58 genera. Also recorded were the habitats in which the butterflies were caught and their periods of flight. Butterfly abundance fluctuated with change in weather conditions: the change in monthly abundance correlated positively with both change in temperature and rainfall. The different vegetation zones within the study area were observed to have significantly different diversities. These differences were present even amongst transects belonging to the same zone. The change in species richness and species diversity were, however, not significantly different amongst the transects within the different vegetation zones.

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Tropical forests stabilize global climate conditions, protect the diversity of biological species, support natural ecological systems and provide recreational benefits. Millions of people are locally dependent on the forest products, yet the age in which the demand for forest products was small in proportion to the forest is long gone (Rowe *et. al.*, 1992). Today the pressure on the forest due to their utilization will result in their loss as the rate of utilization renders their destruction irreversible. Hence communities face impoverishment in addition to the threat of climatic instability (BSP, 1992; Houghton *et. al.*, 1990). There is a need, therefore, for forest adjacent dwellers as well as non-forest adjacent dwellers to know how best the resources can be utilized.

The Arabuko-Sokoke forest is the largest of the five main forests on the East African Coast. It has an international importance in that it is a centre of endemism (Burgess and Muir, 1994; Collar and Stuart, 1988). The rate at which the local community that surrounding it is growing threatens its existence (Mogaka, 1991). The Forest Department and Kenya Wildlife Service manage the forest with the support of Birdlife International (BLI), Kenya Forestry Research Institute (KEFRI) and the Kipepeo Project through the Arabuko-Sokoke Forest Management Team (ASFMT). Present activities are steered to getting the locals to have a direct stake and interest in the conservation of the forest.

The Kipepeo Project is mainly involved in the sustainable utilization of the forest's butterflies by breeding them for the export market in Britain and the USA. The Kipepeo Project captures adult butterflies which are then kept in flight and breeding cages to lay eggs. Once the caterpillars emerge they are distributed to the farmers at the edge of the forest. The farmers then feed them until the pupal stage before selling them to the Kipepeo Project which inturn sells them to butterfly house dealers in Britain and the USA. Butterfly house dealers confine the adult butterflies after emergence for public viewing. At the heart of these activities is the development of the Arabuko-Sokoke forest into an ecotourism attraction coupled with the construction of basic infrastructure for the surrounding population. The education of the people that the living forest is more valuable than deforested land has also been emphasized. It is hoped that by involving the local community in forest conservation centered activities, their attitudes towards the conservation of the Arabuko-Sokoke forest will be positive.

It is important for the Kipepeo Project to ensure that the uptake of the butterflies from the forest is sustainable if the management of the butterfly breeding activities are to be proper. This required that the project collect baseline data on Arabuko-Sokoke forest butterfly populations. Previous surveys lasted only a few days (e.g. Bagine *et. al.*, 1992). My study would therefore provide a comprehensive inventory of the Arabuko-Sokoke forest butterflies and in addition objective information on the changes in their abundance. This information would be important not only for the conservation of the butterflies but would also contribute to an understanding of the ecology of the Arabuko-Sokoke forest butterflies.

The main objectives of this study are summarized as follows:

1. to determine the composition and relative abundance of the butterfly community in Arabuko-Sokoke Forest;
2. to develope an inventory and a reference collection of the butterflies of Arabuko-Sokoke;
3. to investigate the impact of seasonality in rainfall and temperature on the butterfly community; and
4. to construct a display of pinned butterflies for the Gede Station Visitor Centre.

1.2 Literature review

1.2.1 Butterfly diversity and conservation

It is estimated that the class Insecta contains more than 750,000 species of the 4 million living species of all animals described (Barnes, 1980; Parker, 1982 , Wilson 1992). Their tremendous number of species and individuals attests to their great adaptive radiation. Their ability to fly and hence easy access to food, more optimum environments and escape from predators has led to their success.

Worldwide there are 18,000 butterfly species of which 3,600 occur in Africa, thereby placing the African fauna second to the Neotropical fauna which is twice as rich (8,000). More than a third of these were discovered as recently as the past 30 years suggesting that more remain to be discovered and the estimation of the true total value may be 15 percent higher (Larsen,1993). The closest fauna to that of Africa is that of the Oriental Region. These two regions share all families, most subfamilies, many tribes and about 40 genera. Limited to Africa are two subfamilies, Pseudopontiinae and Lipteninae (Larsen,1993).

The Kenyan fauna constitutes 870 species (Larsen, 1991). This richness is attributed to Kenya's geographical position that endows it with different butterfly habitats. Many species are limited to the fringes of the country; the coastal forests, the Masai savannahs and the arid north. The highest species diversity is in the Kakamega. All the five families Papilionidae, Pieridae, Lycaenidae, Nymphalidae and Hesperidae, are found in Kenya. These are further classified into 20 subfamilies and 180 genera (Larsen, 1991). The Arabuko-Sokoke Forest is estimated to contain about 150 forest species (Larsen,1993) while a list compiled by Steve Collins (I.J. Gordon, pers. comm.)estimates the total number of species in the same forest at 262 (Appendix I). This is about 30% of the Kenyan total.

Butterflies are among the most popular groups of insects due to their pleasant colours. The positive attitude towards butterflies arises from their being relatively large, often very pretty and rarely harmful (New, 1991). Butterflies are important pollinators but their scientific importance is however much greater. This arises from their easy identification on wing, easy rearing in captivity and their large size, making them easier to study. Research has been carried out in butterfly aspects such as: mimicry; their co-evolution with plants; chemical communication; and, population dynamics (Vane-Wright and Ackery, 1984; Collins and Thomas, 1991).

Larsen (1993) decries the glaring gap that is seen in comparing the high-grade research coming out of Europe to Africa's very little. He goes on to suggest that the glory Africa once had early in the century as a result of fruitful activities by lepidopterists such as Carpenter (1920; 1925;1933), Eltringham (1890; n.d.), and Poulton (1884 -1903; 1904; 1913) can be regained once more. He further shows optimism that any project on African butterflies would be of high priority and therefore stood good chances of being funded. The priority need is butterfly inventories from the key forests all over Africa. Lack of this could lead to many of the species being wrongly classified as threatened due to their scarcity in collections or being assigned small ranges. In reality these species could be common at specific times of the year and hence not threatened.

Butterfly communities are known to be specific to the ecological zones with less than one percent being ubiquitous (Larsen, 1993). The lowland forest zone harbours most of the large important butterflies, but the less specialized Savannah species continue to invade agricultural lands and disturbed areas within the forest zone (Larsen,1993). Their ability to respond to mild disturbance of habitats at microsite and biotope level make them good candidates for use as ecological indicators (Pollard, 1982; Erhardt and Thomas, 1991). This ability arises from their short life spans, averaging four weeks, and also sensitivity to vegetation because of larval foodplants.

The larvae are an essentially feeding stage with most of the feeding being directed at the green foliage but precise preferences differ among species and habitats (Courtney, 1984; Singer, 1984). Plants evolve new and toxic deterrents to counter the larval herbivory but the butterfly larvae become adapted and even overwhelm these. Hence the larvae become specialized on one or a few plants (Dethier, 1970; Feeny. 1975). Owen (1971) thought that deterrents played a major role alongside attractants in determining the choice of a particular plant as food. The specific food plants tend to occur at different times of the year. By specializing on one type of food plant an animal could limit the competition it may face from other species (Matthes, 1976).

An effort to conserve insects was first initiated in 1835 when the Apollo butterfly (*Parnassius appolo*) was given protection under Bavarian state decree (Samways, 1994). Other countries such as Britain, Germany and the United States later established polices that protected endangered insect species (New, 1991; Pyle 1976). Today in many countries, legislation have been enacted that forbid the collection of specimens of named insects. However the value of this is doubtful as it is difficult to enforce (Heath, 1981; New, 1991). For example, in Kenya a law was enacted which prohibits the collection and killing of butterflies (Anon, 1981), but this is widely ignored and hardly enforced.

European naturalists noticed a considerable decline of insects during the 1960s (Heath, 1981). This decline was speculated to have resulted from the increased use of pesticides. Factors thought to lie at the heart of the decline in insects were habitat destruction, pollution, introduction of exotic species and commercial exploitation (Mellanby, 1967; Heath, 1981; Collins and Morris, 1985; New, 1991). At present there is no scientific evidence that can justify any total ban on collecting of most butterflies. Therefore, collectors need be careful especially in foreign countries in which the butterfly status is not known. The risk brought about by collection is on the decline as photography takes precedence over collecting (Heath, 1981; New, 1991).

Conservationists have come to think that the development of the economic potential of the species of concern and of their near relatives could be a means to overcome human-wildlife conflict (Collins, 1987; Posey, 1993). This they believe could give reasons to economists and developers, for managing the species for sustainable production and thus ensure their long term survival in protected areas. Locally, the conservation of butterflies could be enhanced by their sustainable use to generate income (Larsen, 1993). Commercial exploitation of butterflies occurs in four ways: the sale of specimens to collectors; the sale of decorative butterfly collections as souvenirs; the use of butterflies as decorative art; and the breeding of farming of selected butterfly species for sale to the butterfly exhibit industry.

In Papua New Guinea certain common butterfly species are reared by rural farmers who enrich their gardens to attract them (birdwings) from forest nearby. They lay their eggs on specially provided plants and the specimens thus obtained are sold on international markets via a government trading agency (Clark et al., 1983; Vietmeyer, 1979). In this way the village people participate in cash economy without conflicting with their traditional farming and village life (Vietmeyer, 1979). Collins (1987) cautioned that while the principle was sound theoretically, it was yet to be put in practice. Poverty, greed and corruption still remain the major factors that influence the rate of resource use despite increased education on their importance (Woodwell, 1993).

Research for the conservation of butterflies can be divided into three major contexts:

1. assessing the size and distribution of a given butterfly population, and whether its resource use can be satisfied in perpetuity.
2. assessing the numbers and relative abundance of the butterflies of a given area or habitat as an example of the complexity of the community present.
3. comparison of the butterfly faunas of different areas (New, 1991).

Basic research in the butterfly biology has demonstrated the potential to provide practical questions at much later stages when populations are threatened (Pollard and Yates,1993). The transect count method has been the most extensively used in surveying and monitoring butterfly populations and communities when accurate population estimates are not needed but only trends in abundance between occasions. The method although sacrificing information on absolute butterfly populations, provides an index which can be used to measure change in time. The index is based on the assumption that a count for a particular species is a more or less constant and only the proportion of butterflies seen is likely to be different (Pollard and Yates, 1993).

1.2.2 Status of forest Conservation

Tropical forests are classified into dry and moist forests. The moist forests are further divided into rain forests and deciduous forests. Deciduous forests generally lie on the edge of rain forests and are characterized by more defined dry and wet periods. Nearly half of the forests worldwide are tropical and two thirds of the moist forests are rain forests (Sharma *et. al.*, 1992). Therefore a major emphasis on forest conservation has been placed on addressing the loss of the tropical forests because like all natural systems, forests sustain life by acting:

1. as a source of raw materials vital for all human activity;
2. as a sink for waste and residue generated by human activity; and
3. as a means of maintaining essential life support functions (Munashinge, 1992).

At the local level forests provide the indigenous peoples with food, shelter and clothing. Nationally forests are important as a source of foreign exchange, energy and land for the expansion of human activities (Robinson and Redford, 1991; Plotkin and Falmolene, 1992). While globally the forests are considered as stabilizers of climate, protectors of biodiversity and beneficial for recreational purposes (BSP, 1992; Houghton *et. al.*, 1990).

In the international market forest related activities generate about US $ 100 billion worth of foreign exchange in the developing countries. This being an average of 2.7 % of the GDP in the developing countries (Sharma *et. al.*, 1992) while individual countries such as Malaysia, Liberia and Ivory Coast this constitutes 5% of the GDP. For Cameroon and Tanzania wood export generate about 4% of the GDP. The most valuable economic product is wood, round wood and fuel wood. Tropical hardwoods account for just over 10% of the total international trade of trade in timber (Sharma *et. al.*, 1992). About 13% of the total wood supply is consumed nationally as timber and the rest as fuel wood (Vanclay, 1993). Approximately 3 billion people rely on fuelwood as a source of energy which accounts for about 20% of the energy demand in the developing world (Vanclay, 1993).

Kenyan indigenous forests are classified into 4 categories:

1. closed broad leaved forests,
2. open broad leaved forests,
3. coniferous forests, and
4. mangrove (IUCN, 1995).

These are forest are distributed into four main regions based on climate. The regions are:

1. Coastal forest region (9.8 % of the total region),
2. Dry zone region (0.4 % of the total region),
3. Montane forest region (18 % of the total region),
4. Western rainforest region (1.9% of the total) (IUCN, 1995).

The closed forests are concentrated in the moist Central highlands. Open woodlands and scrub occupy large parts of the arid and semi arid regions. Each group of forests has a distinctive fauna and flora and experiences different human utilisation patterns. The most recent forest plant communities classification identifies 16 inland forest formations and at least seven at the coast (Beentje, 1990).

At present Kenya's gazetted forests occupy about 1.7 million ha., approximately 3% of Kenya's total area (KIFCON/ BLI, 1993). Another 1/2 million ha. lie outside the gazetted areas on trust lands under county councils, in the national parks and reserves and other government land. In 1981 interpretation of satellite imagery and aerial photography put the total forest area on both gazetted and non-gazetted land at 1.37 million ha (KIFCON/ BLI, 1993). The forests are used by the local communities for timber, poles for building, firewood, charcoal, grazing, medicinal plants, meat, water, fruit and honey. Many small forests are important social-cultural centres and have a high potential for development of forest based tourism (IUCN, 1995).

It has been predicted through the use of satellite imagery techniques that deforestation would lead to the destruction or serious degradation of 20% of the world's remaining tropical forests by the end of the century (Table 1). Myers (1989) and FAO (1988) after conducting reviews and syntheses of ground surveys together with estimates of population size estimated annual deforestation for the early 1980s at $7,340 \times 10^3$ ha and of $7,253 \times 10^3$ ha respectively. The annual rate of increase in deforestation ranged from 50-90 percent for both. Africa now loses about 5 million ha. per year and tropical America loses 8.3 million ha. per year. At this rate Africa stands to lose all her existing forests in about 60 years (UN-FAO, 1992). Close to 60% of all deforestation is due to the expansion of agricultural settlements and the remainder is by logging, ranching and mining (World Bank, 1992).

In Kenya most of the major areas, about 830,000 ha., with forest had already been declared forest areas and were controlled by the government. The area had increased to 1, 930, 000 ha. by 1990 but some of the areas have been converted to commercial forest plantations (IUCN, 1995). Excisions, although, continue to be the major means through which forest is lost. A total of 290,000 ha. have been degazetted with another 35,000 currently proposed for excision (IUCN, 1995). Some of these have been transferred to the national parks and reserves with only 210,000 ha being transferred to non-protected status. The indigenous forests are

Table 1 Estimated rates of tropical deforestation(10^3 ha/yr)

	Closed forests			Closed and open forests	
	Myer's	FAO/UNEP	Myer's	FAO/UNEP	FAO
Years of deforestation	1979	1976-80	1989	1976-80	1981-90
Tropical America	3,710	4,119	7,680	5,611	8,400
Tropical Africa	1,310	1,319	1,580	3,676	5,100
Tropical Asia	2,320	1,815	4,600	2,016	3,500
Total	7,340	7,253	13,860	11,303	17,000

Adapted from Houghton, 1993.

known to be declining in quality and quantity, but data on the extent to which this is happening is inadequate (Wass, 1994). The coastal forests are constantly under threat of excision as the government tries to settle squatter populations in the region. These forests need to be conserved because in them are found about 50% the plants, 60% of the birds and 65% of the mammals that are forest dependent and nationally threatened (IUCN, 1995).

CHAPTER 2

STUDY AREA, MATERIALS AND METHODS

2.1 Study Area

2.1.1 Location and history of the study area

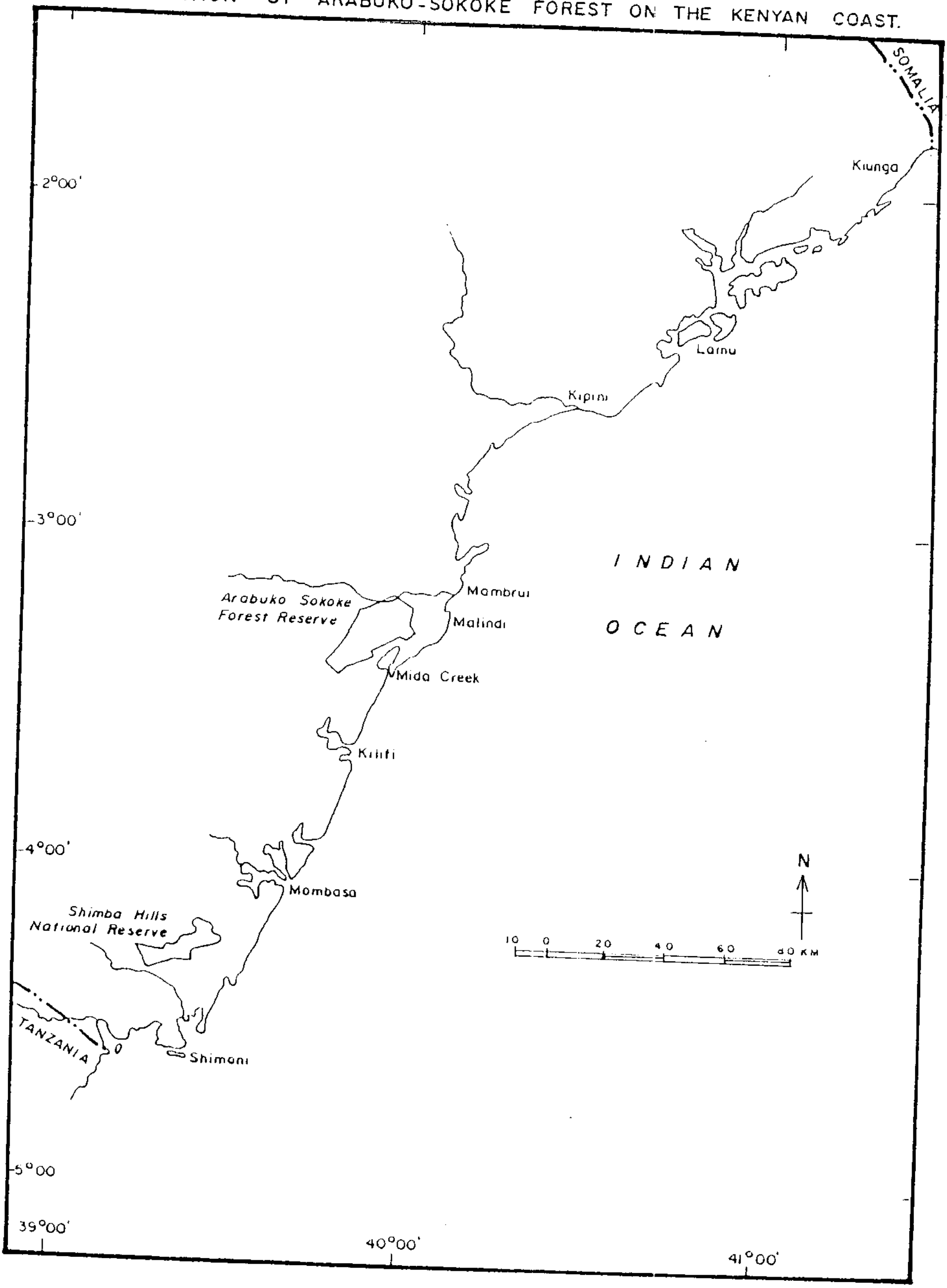
The study was carried out in the Arabuko-Sokoke Forest, situated in Kilifi District on the Kenyan coast. It's exact location is between Gede (south of the Galana River) and to the North of Kilifi Creek, between 03°11'' and 03°29'' S and 39°48'' and 40°00'' E (Fig. 1). This is the largest block of lowland forest on the East African Coast (Kelsey and Langton, 1984). Others include the lower Tana River, Shimba Hills (Kenya), Pugu Hills (Tanzania) and Sofala Coastal forest (Mozambique) (Larsen, 1993).

Before 1920, the Sanya hunted as the main traditional use of the forest (Mogaka, 1991). During this time the Swedish and the European timber merchants also came in to remove commercially viable timber. This created employment opportunities and thus an influx of people. Timber was also supplied to Arab traders for the construction of boats and for use as building material (Mogaka, 1991).

Saw-mills were set up at Sokoke, Dida, Kararacha and Arabuko. These processed hard wood (*Sterculia appendiculata, Manilkara sansibarensis, Afzelia quanzensis* and *Brachylaena huillensis)*. The souvenir carving industry was also established and utilized smaller hardwood left by saw millers (Mogaka, 1991). At the present Hafswa Sawmills (Ltd.) and Kwale Sawmills are the only licensed industries that extract sawn wood especially *Brachystegia speciformis* , from the forest reserve at limited rates.

Arabuko-Sokoke was proclaimed as crown forest in 1932 and was gazetted in 1943, covering an area of 420 square kilometers (Blackett, 1994). This was in an effort to control the

FIG. 1 : LOCATION OF ARABUKO-SOKOKE FOREST ON THE KENYAN COAST.



unchecked exploitation of its resources. Later 27 square kilometers was gazetted as a Nature Reserve by the Forest Department. This was increased to 43 square kilometers as a result of a policy aimed at creating 10 percent of the forest as nature reserves countrywide (Waruingi *et. al.*, 1993). Within this area all forestry and related activities were terminated in an effort to conserve biodiversity. Also, the primary function of the Nature Reserve was to provide data on tree regeneration to the Forest Department. For the easy management of the forest two stations were set up at Jilore and Gede in 1959 and the late sixties, respectively (Mogaka, 1991).

2.1.2 Vegetation, soils and climate

Britton and Zimmerman (1979) described the forest vegetation as constituting of four zones:

1. Cynometra-Manilkara forest
2. Brachystegia forest and
3. Afzelia forest
4. Lowland rainforest

They observed these to have the following characteristics:

Cynometra-Manilkara forest

This occupies about 220 kilometers and lies above the 50 m contour. The canopy is closed and understory tangled with saplings and lianas, extending from near the ground to the canopy. Cycads are plentiful in high rainfall areas. The forest in the south is rich over 15 m high while it is impoverished in the north and is about 4 m high or lower. Soils are the infertile dark loams in this area. *Cynometra webberi* and *Manilkara sansibarensis* are the dominant tree species.

Brachystegia forest

This occupies about 70 square kilometers. It is floristically and structurally defined but merges with the above zone. Canopy coverage rarely exceeds 50 percent. Shrub layer is diverse due to adequate sunlight. Numerous thickets, cycads and knee high grasses are also present *Brachystegia speciformis* is the dominant tree species. Soils are deep, loose light grey to buff and are medium to coarse sands (Moomaw, 1959). Demarcation between the light soils and the red is very abrupt typically in the form of a drainage line with seasonal pools. The woodland is open and includes *Adansonia digitata* tree species.

Afzelia forest

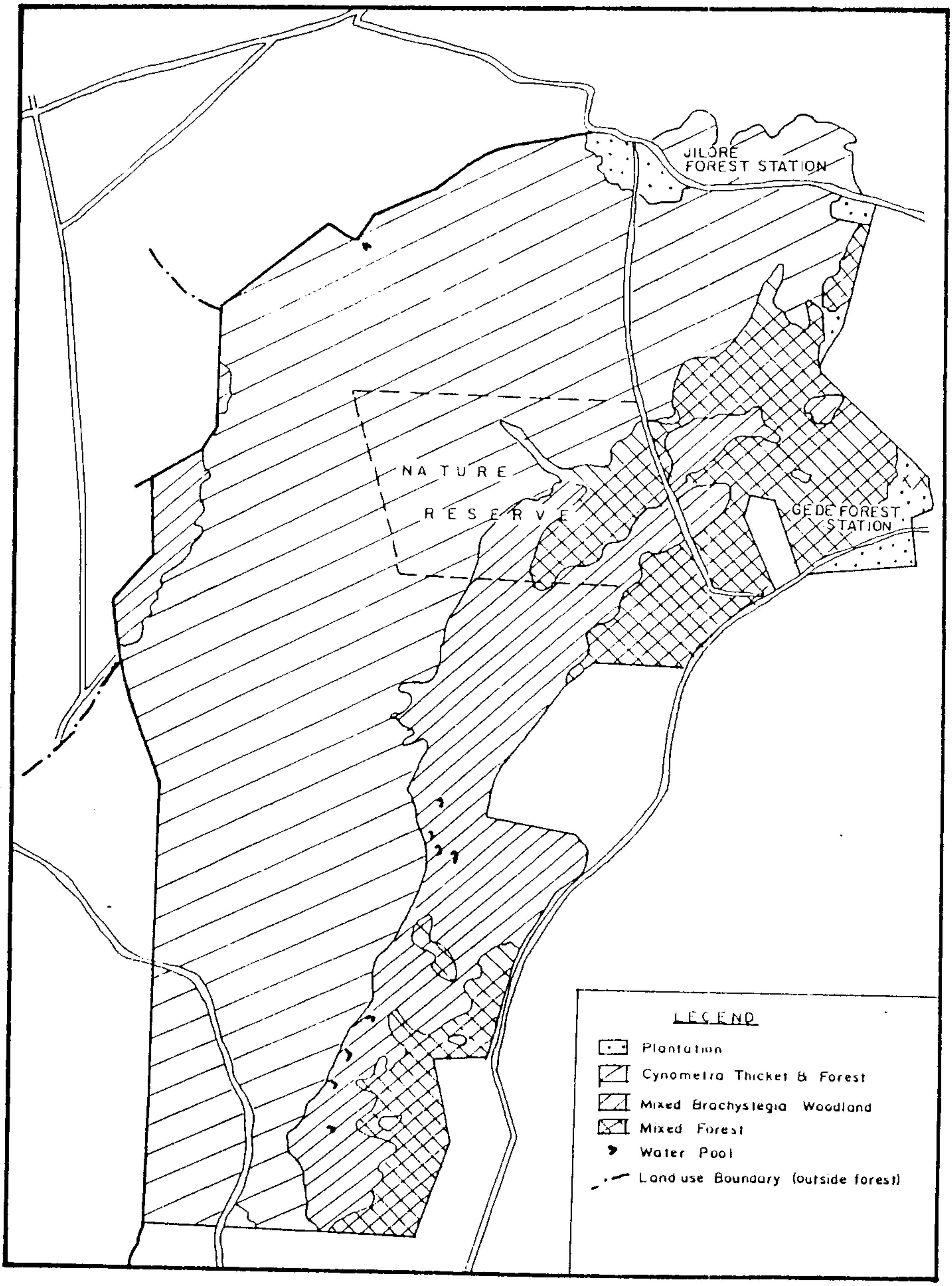
This occupies about 50 square kilometers. It is constituted by a dense evergreen forest with a nearly continuous canopy as low as 10-12 meters. The understory is tangled with shrubs and small trees and moderate leaf litter. Structurally it is similar to part of the *Cynometra-Manilkara forest.* The Soils are more buff grey sands. *Afzelia quanzensis* was the dominant tree species but is not now.

Lowland rainforest

This occupies less than 20 square kilometers. It replaces the Afzelia forest and is restricted close to the Gede Forest Station. The canopy is higher and understorey less tangled. Structurally it is similar to the Afzelia forest.

Later studies on the forest's vegetation by Wairungu *et. al.*, (1993) and Kelsey and Langton (1984) further subdivided the forest into seven and six habitat types respectively. KIFCON (1992) and Robertson and Luke (1993) classify the vegetation into three main zones with the non- indigenous Kenya Forestry Research Institute(KEFRI) plantations forming the fourth (Fig. 2). These main zones are:

FIG. 2 : GENERAL VEGETATION TYPES IN THE ARABUKO - SOKOKE FOREST



Habitat type	% of Total Area
1) Cynometra/Brachylaena forest and thicket	64
2) Brachystegia woodland	18
3) Mixed forest	16
4) Non-indigenous plantations	2

The Mixed forest zone comprises of the zones formerly classified by Britton and Zimmerman (1979) as the Lowland rainforest and Afzelia forest. The above classification was used for this study.

Rainfall is the most important climatic factor, and together with soil type they determine the type of vegetation in each zone (Moomaw, 1959). Annually the forest receives between 900mm and 1100 mm of rainfall, and high humidity of about 60 % (Blackett, 1994). The rainfall is bimodal in pattern with the long rain beginning in April with the advent of the monsoon and ending in June. There is also a short dry season from December to February (Gwyne and Pratt, 1977).

2.1.3 Human settlement and activities

The remnant population of the Sanya is now found in Mijomboni in the northern parts of the forest to which they were pushed by the invasion of the Mijikenda (Mogaka, 1991). Also to the northern and western parts of the forest are found the Giriama. Towards the eastern and southern parts, the settlement schemes attracted an assortment of people both from within and outside Kilifi. Thus other ethnic groups such as the Swahili, Kikuyu and Taita occupy these areas (Mogaka, 1991).

The inhabitants use forest products mainly for fuel wood, medicinal purposes and building material. Table 2 gives estimates of the use of the forest for the various products. Maundu (1993) obtained data that were comparable to those that are reported above from his survey of the community bordering the eastern side of the forest. From his sample population 60.9%

Table 2 Use of forest products by the neighbouring community

Product/Use	% Population
(a) Medicine	61.3
(b) Food	60.0
(c) Utility items	18.7
(d) Fuelwood	62.7
(e) Polewood	58.7
(f) Honey	34.7
(g) Animals (hunting)	53.3
(h) Business	8.0
(i) Employment	12.0
(j) Rain (attractant belief)	60.0

Adapted from Mogaka, 1991

obtain fuelwood, 16.7% obtain honey, 12.3% obtain medicine, 13.0% obtain water and 6.5% hunt from the Forest.

Subsistence agriculture is also practiced in which maize, sorghum, cassava and banana constitute the main food crops. Main cash crops are coconuts, cashewnuts and mangoes. Livestock keeping is a minor occupation. Trade in the named cash crops are the main source of income. Makuti, woven dry coconut leaves, used for roofing by the hotels is now rated as a high income product (Mogaka, 1991). Afew people are employed as casual or permanent employees and they contribute an average income of Ksh.23,784 per annum as compared to Ksh.32,991 per annum from all the activities combined in each household (Maundu, 1993).

2.1.4 Negative impact of the forest

The Arabuko-Sokoke forest supports a wide diversity of animals (Bagine *et. al.*, 1992; Benun and Waiyaki, 1991; Britton and Zimmerman, 1979; Chira, 1993; KIFCON, 1992; Munir, 1993). Some of these animals destroy crops like cassava, bananas, pineapples, peas and debark cashewnuts. The main problem animals are baboons, monkeys, elephants and wildpigs. KIFCON (1992) estimated elephant damage at the rate of Kshs 3,425 per annum per household. This compares well with Maundu's (1993) Kshs 4,000 per annum. On the eastern border, 41% of the farmers complained of daily attack from baboons (Maundu, 1993). A further 26.8% complained of consistent attack during the rainy season and the rest of the year, 20.4% during the rainy season only, and only 11.3% had no baboon problem at all. Many man hours are therefore lost in guarding crops against the animals.

Other animals that feed on chicken such as mongoose are also problematic. Livestock keeping is deterred by the presence of tse-tse fly, as this would involve the use of expensive preventive measures especially for cattle. Less than 30% keep cattle with most of these occupying the Western side of the forest. The increase in human population around the forest also enhanced the feeling, in more than half of the inhabitants, that the forest be cleared for agriculture (Maundu, 1993; Mogaka, 1991).

2.1 Conservation status

The Arabuko-Sokoke Forest is known to have a rich biodiversity but of more importance is the exceptionally high degree of endemism. This gives it high conservation value. International Council for Bird Preservation(ICBP) places it as the second most important bird centre in Africa (Collar and Stuart, 1988). Six species of the ICBP/IUCN Bird Red Data Book (Collar and Stuart, 1985) occur here; including the Sokoke-scops-owl *(Otus irenae)*, now also known from the Usambara, and the Clarke's weaver *(Ploceous golandi)* which are endemic. Others include the Sokoke Pipit *(Anthus sokokensis)*, Amani sunbird *(Anthrepta palidigaster)* and the East Coast Akalat *(Sheppardia gunningi)* (Collar and Stuart, 1985) A further 17 species /subspecies restricted to the coast are found in the forest (Collar and Stuart, 1988) Six species/subspecies of butterflies endemic to the coast are also found in the forest. These are: *Acraea matuapa, Baliochila latimarginata, B. minima, B. stygia, Charaxes blandae kenyae, C. lasti.lasti* (Larsen, 1991). The Forest is also home to three endemic and endangered mammals: Golden-rumped Elephant-shrew (*Rhynchocyon chrysopygus*), Ader's duiker (*Cephalophus aderai*) and the Bushy-tailed mongoose *(Bdeogale crassicauda amnivora)* (KIFCON, 1992).

2.2 Materials and Methods

2.2.1 Determination of butterfly composition

A list of butterflies of Arabuko-Sokoke Forest was assembled from Bagine *et al.* (1992) and a list compiled by Steve Collins for KIFCON. Illustrations from Larsen (1991) were used for the initial familiarization with the butterflies in the first two weeks of the study. During this period the characteristics of each genus/species of butterflies as described in Larsen (1991) were observed. This included appearance in flight and at rest.

A sweep net and traps constructed from mosquito netting were used to capture the butterflies. The butterflies were approached carefully, either in flight or when settled, and secured by a rapid sweep of the net. The traps were cylindrical in shape with a 30 cm diameter and with a 1 inch left at the bottom, for entry of the butterfly, worked on the principle that butterflies fly upward after feeding. Traps were baited using very ripe fruits such as bananas, oranges and papaws. A little palm wine was occasionally added to the bait since alcohol is a good attractant to some butterfly species. The traps were suspended in the shade of trees at about 1.5 meters above the ground. Netting and trapping were spread to as much of the forest as was possible for at least two days a week during the study period. When a butterfly was netted or trapped the thorax was pressed to immobilize or kill it. Those that were immobilized were killed in a bottle containing cotton wool saturated with ethyl acetate. Captured butterflies were transferred into medical envelopes. On the envelop was re recorded the locality of capture, date of capture and name of the collector.

Specimen were removed from envelops using entomological forceps. They were then placed into a plastic container holding wet sand covered with bloating paper (Williams 1969), until such a time that they were relaxed enough to be set. Afew drops of phenol were added to quicken the process. The relaxed specimen were set with the aid of a setting needle on setting boards. They were then left to dry for about 4-7 days after which they were transferred into storage boxes. Naphthalene balls were put in the storage boxes which were tightly closed, to preserve the specimen. At the end of the survey the pinned collection was verified with the collection at the National Museum of Kenya, Nairobi.

Two glass show cases, each 1.5m x 2.0m, were made for the Gede Visitor Centre and the Kipepeo Project. In these were mounted butterfly specimen of species commonly seen in the forest, from the families Papilionidae, Pieridae and Nymphalidae.

2.2.2 Determination of butterfly abundance

The line transect method as described by Pollard (1977, 1982) was used with modifications. Nine transects, three in each of the three vegetation zones, were walked during the study period (Fig. 3). Each transect was approximately 10m wide and 1.5 Km long. The road network within the Nature Reserve served as the center of the transects. Censusing along the transects was carried out between 08:00 to 12:00 hours with each transect being run for an hour. All individuals encountered from 60 chosen butterfly species, were counted. Each transect was walked at least once every week of the study period except on rainy and/or overcast mornings, and for three weeks in August when I was away from the study area. Temperatures were considered above the threshold necessary for butterfly activity. Rainfall data was obtained from the rain gauge kept at the Gede Forest Station and temperature data from the Msabaha Meteorological Station.

2.2.3 Analysis of data

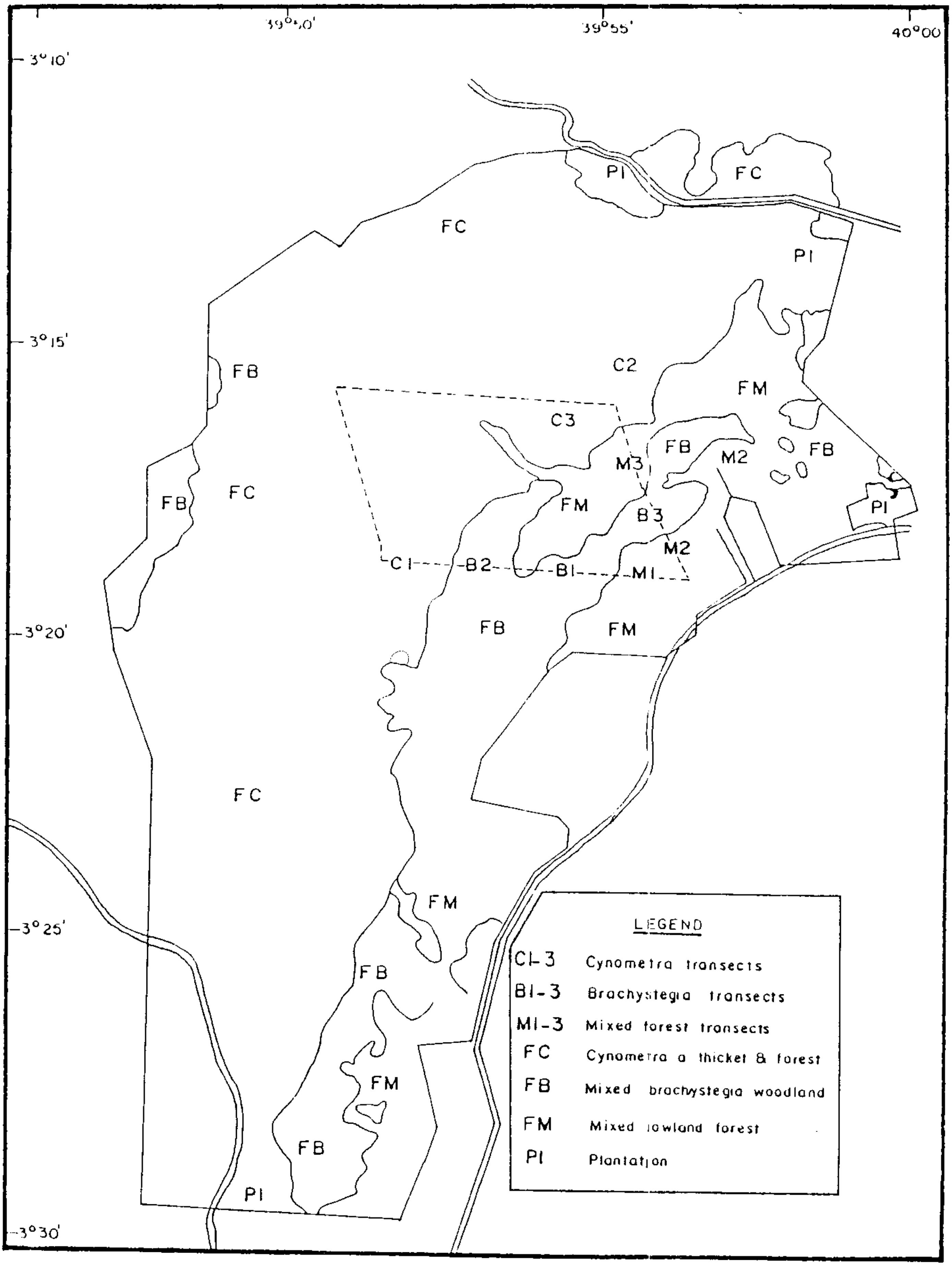
The majority of the data analysis was conducted with Lotus 1-2-3 Release 2.01. Mean monthly abundance was calculated from the weekly census data. Data are always presented as means plus or minus (+/-) standard error (se).

The criteria used by Torben *et al.*(1980) was employed to assign the censused species a status depending on their average frequency of encounter. Those encountered once were considered rare, 2 to 4 encountered uncommon, 5 to 9 encountered common and 10 and above encountered as abundant.

The Margalef index and the Shannon diversity index (H') were calculated to obtain species richness and species diversity respectively (Magurran, 1988). These were calculated as follows:

$$\text{Margalef index } (D_{mg}) = (s-1)/\text{Log } N$$

FIG. 3 : LOCATION OF CENSUS TRANSECTS IN THE ARABUKO-SOKOKE NATURE RESERVE



where

s = number of species

N = sample size

Shannon index (H') = 1/n (n log n - fi log fi)

where

f = number of observations in category i

n = sample size

The null hypothesis that the Shannon diversities of populations from the nine transects were equal was tested using the Hutcheson t test (Magurran, 1988; Zar, 1984).

$$t = H'_1 - H'_2 / S_{H'1-H'2}$$

where

$$S_{H'1-H'2} = (S^2_{H'1} + S^2_{H'2})^{1/2}$$

The degrees of freedom associated with the preceding t are approximated by:

$$v = (S^2_{H'1} + S^2_{H'2})^2 / \; ((S^2_{H'1})^2 / n_1 + (S^2_{H'2})^2 / n_2)$$

CHAPTER 3

RESULTS

3.1 Butterfly composition

3.1.1 Families of butterflies

All the five butterfly families (Papilionidae, Pieridae, Nymphalidae, Lycaenidae and Hesperidae) were recorded in the Arabuko-Sokoke Forest during the study period. These phylogenetically break down into 14 subfamilies, 58 genera and 136 species (Table 3). Table 4 gives an inventory of the butterflies captured during the study period: 105 species were captured from the Mixed Forest, 114 in the Brachystegia and 48 from the Cynometra.

Papilionidae

A total of 11 species were captured and identified (Table 4). These constitute 8.2% of the species recorded during the study period. Only three species out of the 14 known to be present along the Kenyan coast (Appendix I) were not captured. *Graphium angolanus* was captured from Gede Forest, 2 Km North of the Arabuko-Sokoke Forest.

Pieridae.

A total of 34 species were recorded constituting 25.4% of the total species recorded during the study period (Table 4). Two species *Eronia leda* and *Colotis auxo* were recorded but do not appear on earlier records for coastal species (Appendix I). *Eronia leda* was captured in the plantations around the Gede Station while *C. auxo* was frequently seen in the Brachystegia zone.

Table 3 Taxonomic profile of Arabuko-Sokoke butterflies

Family	Subfamilies	Genera	Species	% composition
Papilionidae	1	2	11	8.2
Pieridae	2	11	34	25.4
Nymphalidae	5	26	58	43.3
Lycaenidae	3	11	17	12.7
Hesperidae	3	8	14	10.5
TOTALS	14	58	134	

Table 4 Butterfly record butterfly record of the Arabuko-Sokoke forest, Jan-Dec 1993

Family	Species	Habitat
Papilionidae	*Papilio dardanus*	M B
	P constantinus.	M B C
	P. nireus	M B C
	P. demodocus	M B C
	Graphium philonoe	M B C
	G. leonidas	M B C
	G. kirbyi	M B C
	G. colonna	M B C
	G antheus	M B C
	G. porthaon	M B C
Pieridae	*Catopsila florella*	M B C
	Eurema regularis	B
	E. brigitta	B
	E. hecabe	M B C
	Pinacopteryx eviphia	B C
	Nephronia argia	M B
	N. thalassina	M B
	N. buqueti	M B
	Eronia cleodora	M B C
	E. leda	Plantation
	Colotis antivippe	B
	C. amatus	B
	C. vesta	B
	C. ione	M B C
	C. hetaera	B
	C. dane	B
	C. eucharist	B
	C. daira	B
	C. evagore	B
	C. eris	M B C
	C. evenina	B
	C. auxo	M B
	C. regina	B
	C. euippe	M B
	Belenois aurota	B
	B. creona	M B
	B. gidica	M B C
	B. thysa	M B C
	Dixeia charina	M B C
	Appias sabina	M B
	A. lasti	M B C
	A. epaphia	M B C
	Leptosia alcesta	M B C
	Mylothris agathina	M B C
Nymphalidae	*Danaus chrysippus*	M B C
	Tirumula petriverana	M B

Table 4. cont.

Nymphalidae	*Amauris niavus*	MBC
	A. ochlea	M B
	Melanitis leda	M B C
	Bicyclus safitza	M B C
	Ypthima asterope	M B C
	Physcaeneura leda	B
	Charaxes varanes	M B C
	C. candiope	M B C
	C. protoclea	M B
	C. lasti	M B
	C. castor	M B
	C. brutus	M B
	C. violetta	M B
	C. cithaeron	M B
	C. jahlusa	M B
	C. blandae	B
	C. ethalion	M B C
	C. contrarius	M B C
	C. gudariena	B
	C. zoolina	M B C
	Euxanthe wakefieldi	M B
	Euryphura achlys	M B C
	Bebearia chriemhilda	M B C
	Euphaedra noephron	M B C
	Hamanumida daedalus	M
	Harma theobene	M
	Pseudacraea lucretia	M B
	P. biosduvali	M B
	Neptis saclava	M
	N. laeta	M
	N. serena	M B
	N. trigonophora	M
	N. carcassoni	M
	N. melicerata	M B
	N. goochi	M
	Byblia illithya	M B
	Neptidopsis fulgurata	M
	Eurytela dryope	M B
	Hypolimnas misippus	M B C
	H. deception	M B C
	H. anthedon	M B C
	H. usambara	M
	Salamis anacardii	M B C
	Junonia oenone	M B C
	J. hierta	M B C
	J. natalica	M B C
	J. terea	M
	Vanessa cardui	B
	Phalanta phalantha	M B C

Table 4. cont.

	Acraea eponina	M B C
	A. equitorialis	M
	A. natalica	M
	A. rabbai	M B
	A. satis	M B
	A. anemosa	M
	A. noebule	M B
	Pardopsis punctatissima	B
Lycaenidae	*Pentila tropicalis*	B
	Baliochila hildergarda	M B
	B. minima	M B
	Teriomina subpunctata	B
	T. micra	M B
	Axioxerses tjaone	B
	A. punicea	B
	A. amanga	B
	Iolaus diametra	B
	I. silanus	B
	I. pallene	B
	I. bowkeri	B
	Hypolycaena phillipus	B
	Leptotes pirithous	B
	Zizula hylax	B
	Anthene lanulata	M B
	Freyeria trochylus	M
Hesperidae	*Coeliades anchises*	M B C
	C. forestans	M B C
	C. pisistratus	M B C
	C. sejunta	M B C
	C. keithloa	M
	Tagiades flesus	M
	Sarangesa motozi	M
	Spiala confusa	M
	Acada biseriatus	M B
	Borbo fatellus	M B
	B. detecta	M B
	B. gamella	M
	Geneges niso	M
	Coprana pillaana	B

Legend
M = Mixed forest zone
B = Brachystegia zone
C = Cynometra zone

Nymphalidae

A total of 58 species were recorded constituting 43.3% of the total species recorded during the study period (Table 4). These species represent 26 genera out of the expected 33 (Appendix I) on the Kenyan coast.

Lycaenidae.

A total of 17 species were captured constituting 12.7% of the total species recorded during the study period (Table 4). These species only total to 20% of those expected to occur along the Kenyan coast (Appendix I). Only one of the six species listed by Larsen (1991) as endemic to coastal forests in Kenya was recorded: *Baliochila minima*.

Hesperidae

A total of 14 species were recorded constituting 10.5 % of the total species recorded during the study period (Table 4). These species only total to 35.9% of those expected to occur along the Kenyan coast (Appendix I).

3.1.2 New species recorded

Two new species for the Araboko-Sokoke forest were recorded: *Colotis auxo* and *Eronia leda*. *Colotis auxo* was present throughout the study period and mostly restricted to the Brachystegia zone. *Eronia leda* was captured in the last week of January in the Plantation forest near Gede Forest Station. After this period it was not captured again.

3.1.3 Coastal endemic species recorded

One species (*Baliochila minima*) and two subspecies (*Charaxes lasti lasti* and *C. blandae kenyae*) endemic to the East African coast were captured (Table 5). These constitute 50% and 2.2% of the butterfly species listed as endemic to the East African coast (Larsen, 1991) and the 134 species recorded during the study period (Table 4), respectively.

3.1.4 Mimetic species recorded

11 species recorded during the study exhibited Batesian mimicry (Table 6). These constitute 7.6% of the total species recorded. *Papilio dardanus, Hypolimnus misippus, H. anthedon* and *H. deceptor* are nearly perfect mimics of their models (Table 6). *Belonois thysa* and *Graphium leonidus* are good mimics while the rest generally look like their models. The mimicry rings were mainly centred around three colour forms; black-white based on the *Amauris sp.*; orange based on the *Danaus chrysippus* and *Acraea sp.*; and black-blue based on *Tirumula petriverana.*

3.1.5 Visitor Centre displays

Plate 1 shows one of the standing glass case displays that were constructed for the Gede Forest Station and Kipepeo Project visitor centres. The cases contain pinned butterfly specimen, each having a label with the scientific name, common English name and the larval foodplant found in the Arabuko-Sokoke Forest.

Table 5. Coastal endemic species recorded in Arabuko-Sokoke forest, Jan-Nov 1993

Species	Family	Vegetation zones
Baliochila minima	Lycaenidae	M B
Charaxes blandae kenyae	Nymphalidae	B
Charaxes lasti lasti	Nymphalidae	M B

Table 6 Mimicry in Arabuko-Sokoke forest

Mimic Species	Model Species
Belenois thysa thysa	*Mylothris agathina*
Papilio dardanus tibullus	*Amauris niavus dominicanus*
Hypolimnas deceptor	*A. ochlea ochlea*
H. misippus alcipoides	*Danaus chrysippus alcipus*
H. misippus inaria	*D. chrrysippus dorripus*
H. misippus albinus	*D. chrysippus dorripoides*
H. anthedon	*Amauris niavus dominicanus*
H. usambara	*Amauris niavus dominicanus*
Graphium leonidus	*Tirumula petriverana*
G. philonoe	*Amauris sp.* (generalized)
Pseudacraea lucretius expansa	*Amauris ochlea ochlea*
P. boisduvali	*Acraea zetes acara*
Euxanthe wakefieldi	*Amauris ochlea ochlea*

Plate 1. Display case at the Gede Forest Station Visitor Centre

3.2 Butterfly Adundance

3.2.1 Butterfly abundance in Arabuko-Sokoke

Table 7 lists the 60 species counted along the walking transects, in each of the different vegetation zones, during the study period. A total of 16,593 individual butterflies were counted in a total of 250 hours (Table 8). The family Pieridae had the highest number of individuals comprising 60.9% of the total (Table 8). It was followed by Nymphalidae with just over 25% of the total number of individuals, and the remaining 13.5% belonged to the family Papilionidae. The average number of individuals sighted per hour within the forest was 66.4 + 18.86 for the entire study period.

3.2.2 Butterfly abundance in the different vegetation zones

The Brachystegia zone had the highest count of 7709 individuals followed by the Mixed Forest zone with 7466 individuals (Table 8). In the Cynometra zone only 1379 individuals were counted (Table 8). A total of 94 sample hours were carried out in the Mixed Forest zone, 95 in the Brachystegia zone and 61 in the Cynometra zone. Therefore the number of individuals counted per hour was highest in the Brachystegia zone, 81.1 +/- 27.05 (Table 8). The Mixed forest zone came second with a count of 79.7 +/- 20.19 individuals per hour and last came the Cynometra zone with 22.6 +/- 10.32 individuals per hour. Pierids constituted the highest percentage of individuals in both the Mixed Forest and the Brachystegia zones, 56.96 % and 71.29 % respectively (Fig. 4). While in the Cynometra zone the Nymphalids were the most common comprising slightly over half the total number of individuals counted (Fig. 4). Notably no zone contained all the 60 species that were on the census list. 57 species were counted within the Mixed Forest zone, 58 within the Brachystegia zone and 48 within the Cynometra zone (Table 7).

Table 7. Monthly abundance of Arabuko-Sokoke Forest butterflies in the different vegetation zones.

a) Mixed forest zone

	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL
Papilio dardanus	1.8	0.9	0.0	0.3	1.1	1.4	0.2	0.0	0.1	5.8
P. constatinus	10.3	5.3	6.7	4.8	7.8	4.3	0.2	0.0	0.6	39.9
P. nireus	0.6	2.4	3.0	7.5	8.6	4.0	0.2	0.0	0.8	27.1
P. demodocus	0.0	0.5	0.3	0.8	1.7	0.6	0.3	0.0	0.0	4.2
Graphium philonoe	0.3	0.5	3.8	1.7	1.1	0.7	0.0	0.0	0.3	8.4
G. leonidus	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3
G. kirbyi	0.0	0.3	2.5	0.8	0.7	0.2	0.0	0.0	0.1	4.5
G. colonna	0.0	0.0	0.0	3.2	1.4	0.3	0.0	0.0	2.2	7.1
G. antheus	0.6	0.7	4.8	1.4	1.6	0.8	0.0	0.0	0.7	10.6
G. porthaon	0.0	0.0	0.7	1.6	1.1	0.0	0.0	0.0	0.9	4.3
Dixea charina	0.0	2.7	2.0	0.6	0.1	1.4	1.7	0.3	0.4	9.1
Catopsilia florella	0.0	13.7	28.8	1.3	1.4	1.3	0.7	0.0	0.1	47.4
Eurema sp.	2.6	0.4	1.8	0.7	2.6	2.2	0.0	0.4	0.0	10.6
Pinacopteryx	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nephronia	2.9	1.1	0.5	1.2	0.9	1.1	0.3	0.6	0.3	9.4
Eronia cleodora	9.7	7.9	6.0	7.9	10.1	7.5	3.5	1.5	1.1	55.2
Colotis regina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C. ione	6.3	9.3	8.2	7.1	4.4	1.8	1.3	2.3	2.7	43.4
C. euippe	6.5	4.3	7.5	6.3	9.6	4.5	2.5	4.0	11.5	56.7
C. eris	0.0	0.2	0.2	0.2	0.3	0.2	0.2	0.0	5.2	6.5
C. auxo	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.4
C. evagore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Belenois creona	0.2	0.0	0.2	0.0	0.2	0.3	0.0	0.0	0.0	1.0
B. gidica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
B. thysa	7.9	3.9	1.3	0.7	2.0	3.2	6.3	3.4	2.4	31.2
Appias epaphia	0.0	0.0	0.0	0.0	0.4	0.8	0.3	0.0	0.0	1.6
Leptosia alcesta	40.2	2.9	0.2	0.2	2.0	7.2	39.7	32.8	17.1	142.1
Mylothris agathina	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.6
Danaus chrysippus	1.2	1.9	0.7	0.0	0.2	0.3	0.0	0.0	0.0	4.2
Amauris niavus	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.4
A. ochlea	0.0	0.0	0.0	0.0	0.6	0.0	0.3	0.0	0.1	1.0
Melanitis leda	0.0	0.0	0.0	0.0	0.2	0.4	0.2	0.3	0.0	1.2
Bicyclus safitza	0.3	1.3	2.0	1.7	1.6	1.3	0.8	0.3	0.4	9.6
Yptima asterope	0.0	0.0	0.0	0.7	0.1	0.8	0.0	0.3	0.2	2.1
Euryphura achlys	0.8	1.4	4.0	1.3	0.0	0.0	0.0	0.0	0.0	7.6
Bebearia	0.0	0.0	0.2	0.3	0.1	0.7	0.3	0.3	0.2	2.1
Euphaedra	2.9	3.8	7.3	4.3	2.4	1.4	1.3	0.7	0.3	24.5
Neptis sp.	3.3	4.1	1.7	2.2	0.1	1.6	0.3	0.2	0.4	13.9
Byblia illithya	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.1	1.0
Eurytela dryope	0.0	0.2	0.0	0.0	0.6	0.7	0.0	0.0	0.0	1.4

Table 7. cont.

Hypolimnas	9.4	10.3	2.5	0.5	1.9	4.3	[illegible].8	0.4	0.1	31.3
H. deceptor	0.0	0.3	0.8	1.5	0.9	2.0	2.0	0.2	0.1	7.8
H. anthedon	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.1	0.6
Salamis anacardii	0.0	0.0	0.2	0.0	0.7	0.0	0.0	0.0	0.1	1.0
Junonia oenone	0.4	0.7	1.8	0.0	0.0	0.0	0.0	0.0	0.1	3.3
J. hierta	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.6
J. natalica	3.8	3.3	1.3	0.5	0.1	0.0	0.0	0.0	0.0	9.1
J. terea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phalanta phalantha	3.6	1.4	0.0	12.0	12.0	22.8	3.8	0.3	0.1	56.0
Acraea sp.	0.0	0.3	0.0	0.3	0.2	1.2	0.2	0.4	0.2	2.8
Pardopsis	0.0	0.0	0.0	0.0	0.0	0.3	0.8	0.3	0.0	1.4
Phsycaeneura leda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Charaxes varanes	0.0	0.3	0.2	0.2	0.3	0.0	0.2	0.3	0.1	1.5
C. candiope	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.6
C. cithaeron	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.4	0.3	1.3
C. protoclea	0.0	0.2	0.2	0.0	0.0	0.2	0.0	0.3	0.2	1.0
Euxanthe wakefieldi	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2
Tirumula	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.3
Pseudacraea	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3
Harma theobene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	115.	86.7	101.	73.8	82.1	83.7	70.7	51.1	50.0	715.5

Table 7. cont.

b) Brachystegia zone

	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL
Papilio dardanus	0.8	0.7	0.2	0.9	1.7	0.9	0.7	0.8	0.0	6.8
P. constatinus	3.0	1.5	2.5	3.8	4.3	3.1	0.5	0.3	1.4	20.4
P. nireus	2.2	1.6	5.2	3.0	3.6	1.8	0.2	0.0	1.0	18.6
P. demodocus	0.0	0.0	0.2	0.8	2.0	0.6	0.0	0.0	0.0	3.7
Graphium philonoe	0.0	0.7	2.0	0.4	1.1	0.2	0.0	0.0	0.4	4.8
G. leonidus	0.0	0.1	0.0	0.3	0.4	0.0	0.0	0.0	0.2	1.0
G. kirbyi	0.0	0.7	1.7	0.4	0.6	0.2	0.0	0.0	0.0	3.5
G. colonna	0.0	0.0	0.0	1.2	3.2	0.6	0.0	0.0	0.8	5.8
G. antheus	0.3	0.5	2.0	2.2	1.4	0.7	0.0	0.0	0.0	7.1
G. porthaon	0.0	0.0	1.2	0.9	0.4	0.0	0.0	0.0	0.0	2.5
Dixea charina	0.0	0.0	0.0	0.0	0.4	2.1	1.3	1.8	0.5	6.1
Catopsilia florella	0.0	9.3	13.0	1.5	0.6	1.3	1.5	1.2	1.8	30.1
Eurema sp.	12.8	15.1	25.0	49.5	34.4	12.0	1.5	1.3	0.8	152.5
Pinacopteryx	0.0	0.5	0.8	0.3	0.3	0.0	0.0	0.0	0.0	2.1
Nephronia	2.4	1.4	1.2	1.0	1.2	1.9	0.2	1.2	1.0	11.5
Eronia cleodora	8.5	8.1	8.7	7.8	10.3	12.7	7.5	6.9	6.2	76.6
Colotis regina	0.0	0.0	0.7	10.9	14.0	6.4	2.3	5.7	6.8	46.8
C. ione	2.2	4.2	7.7	3.9	1.3	1.4	1.2	2.0	1.5	25.4
C. euippe	2.2	1.5	3.3	4.8	6.4	3.8	3.8	3.4	3.5	32.8
C. eris	0.0	1.1	4.8	1.4	6.7	2.8	1.2	0.6	1.5	20.1
C. auxo	0.3	0.9	1.2	0.5	1.6	1.8	1.5	1.3	1.8	10.9
C. evagore	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.5	1.1	2.6
Belenois creona	7.5	7.2	0.7	0.0	0.7	2.1	5.2	2.3	1.3	26.9
B. gidica	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.4
B. thysa	5.3	3.3	0.8	0.5	2.3	4.2	3.7	3.9	2.6	26.6
Appias epaphia	0.0	0.0	0.0	0.0	0.3	1.3	1.0	0.6	0.0	3.3
Leptosia alcesta	6.9	2.5	2.8	0.3	1.7	5.2	[illegible]	9.5	3.8	45.1
Mylothris agathina	0.0	0.0	0.0	0.0	0.0	2.1	1.7	2.6	0.3	6.6
Danaus chrysippus	0.0	1.9	2.0	0.0	0.1	0.8	0.0	0.0	0.0	5.0
Amauris niavus	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.3
A. ochlea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melanitis leda	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	0.9
Bicyclus safitza	0.0	0.3	0.7	0.3	1.0	0.7	1.3	0.2	0.5	5.0
Yptima asterope	0.0	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.4
Euryphura achlys	0.0	0.3	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.7
Bebearia	0.0	0.0	0.5	0.0	0.0	0.4	0.0	0.0	0.0	0.9
Euphaedra	1.4	0.6	0.8	2.8	0.9	0.4	0.3	0.0	0.0	7.5
Neptis sp.	0.5	1.0	0.8	1.6	0.8	0.3	0.5	0.7	0.3	6.4
Byblia illithya	0.3	0.8	0.0	0.6	0.4	0.3	0.0	0.2	0.3	2.9
Eurytela dryope	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.2	0.0	0.8

Table 7. cont.

Hypolimnas	2.7	7.1	3.7	0.2	0.9	1.4	0.7	0.4	0.3	17.3
H. deceptor	0.0	0.1	0.3	0.8	0.8	0.4	0.3	0.0	0.0	2.8
H. anthedon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salamis anacardii	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3
Junonia oenone	1.2	4.3	5.2	5.6	3.4	2.4	0.8	0.3	0.5	23.6
J. hierta	0.0	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.5
J. natalica	0.8	0.4	0.5	0.7	0.2	0.2	0.0	0.0	0.0	2.7
J. terea	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Phalanta phalantha	0.8	1.3	0.7	3.6	13.8	6.6	2.5	0.7	0.0	29.9
Acraea sp.	0.3	2.6	0.0	0.8	1.4	1.0	1.0	0.4	0.5	8.0
Pardopsis	0.0	0.0	0.0	0.0	0.0	0.3	0.7	1.2	1.1	3.3
Phsycaeneura leda	0.0	0.0	0.0	2.3	0.2	1.9	4.0	2.1	1.4	11.8
Charaxes varanes	0.0	0.2	0.2	0.3	0.2	0.0	0.2	0.5	0.8	2.5
C. candiope	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C. cithaeron	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.4
C. protoclea	0.0	0.1	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.6
Euxanthe	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.4	0.9
Tirumula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudacraea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.5
Harma theobene	0.0	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.0	0.7
	62.4	82.9	102.	116.	126.	88.3	60.8	54.2	44.9	738.6

Table 7. cont.

c) Cynometra zone

	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL
Papilio dardanus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P. constatinus	0.8	0.7	0.6	1.0	1.2	0.9	0.0	0.0	0.8	6.0
P. nireus	0.0	0.7	0.2	2.3	5.3	1.4	0.0	0.0	0.5	10.4
P. demodocus	0.0	0.0	0.0	2.8	1.7	0.0	0.0	0.0	0.0	4.4
Graphium philonoe	0.2	0.0	1.0	2.0	2.5	2.4	0.0	0.0	2.5	10.7
G. leonidus	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2
G. kirbyi	0.0	0.0	0.0	0.3	0.2	0.2	0.0	0.0	0.7	1.3
G. colonna	0.0	0.0	0.0	0.3	2.0	2.5	0.0	0.0	0.2	4.9
G. antheus	0.2	0.0	0.2	1.0	0.7	0.2	0.0	0.0	2.3	4.6
G. porthaon	0.0	0.0	0.0	1.0	0.8	0.0	0.0	0.0	0.3	2.2
Dixea charina	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.7
Catopsilia florella	0.0	5.0	7.0	3.5	0.8	1.0	0.3	0.0	0.0	17.7
Eurema sp.	0.7	0.8	0.0	0.0	0.7	0.3	0.0	0.0	0.8	3.4
Pinacopteryx eviphia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nephronia thalassina	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.4
Eronia cleodora	0.8	2.0	1.0	1.3	1.5	0.8	0.5	0.9	1.0	9.8
Colotis regina	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
C. ione	0.5	0.5	0.0	1.0	0.5	0.4	0.0	0.0	0.5	3.4
C. euippe	2.5	0.0	0.0	1.0	1.2	1.3	0.0	0.0	2.7	8.6
C. eris	0.0	0.2	0.0	0.0	1.7	0.9	0.0	0.2	0.0	2.9
C. auxo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C. evagore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Belenois creona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B. gidica	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.4
B. thysa	1.8	1.2	0.6	0.0	0.2	0.3	0.3	1.8	2.5	8.7
Appias epaphia	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.2	0.7
Leptosia alcesta	0.8	0.2	0.2	0.0	0.0	0.1	0.2	0.0	0.8	2.3
Mylothris agathina	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3
Danaus chrysippus	0.7	2.0	2.6	1.0	0.5	0.4	0.0	0.0	0.7	7.8
Amauris niavus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A. ochlea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melanitis leda	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Bicyclus safitza	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Yptima asterope	0.0	0.0	0.6	0.0	0.2	0.0	0.0	0.0	0.2	0.9
Euryphura achlys	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3
Bebearia chriemhilda	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2
Euphaedra neophron	0.2	0.5	0.0	0.8	0.3	0.3	0.3	0.0	0.2	2.6
Neptis sp.	7.0	7.2	4.0	2.0	0.3	0.7	2.0	0.3	7.2	30.6
Byblia illithya	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Eurytela dryope	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.6

Table 7. cont.

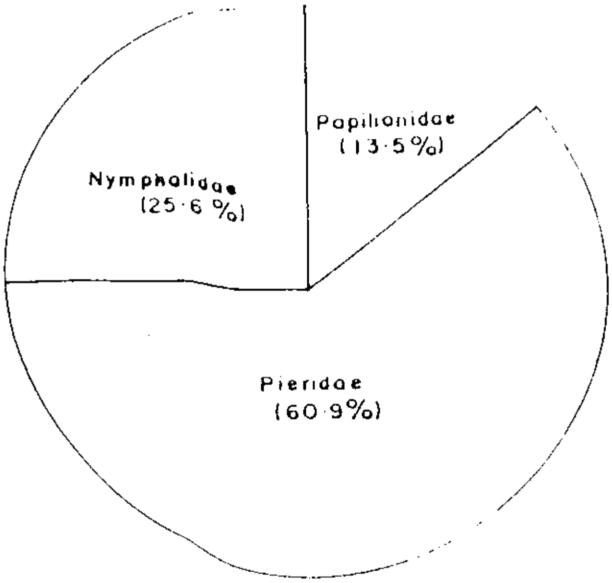
Hypolimnas misippus	9.3	7.0	5.0	1.0	0.2	1.6	[illegible]	0.8	10.5	35.9
H. deceptor	0.0	0.3	0.6	1.3	1.3	1.8	[illegible]	0.8	0.0	7.9
H. anthedon	0.0	0.0	0.0	0.0	0.2	0.3	0.3	0.0	0.2	1.0
Salamis anacardii	0.0	0.2	0.0	0.5	0.8	0.1	0.0	0.0	0.0	1.6
Junonia oenone	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
J. hierta	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4
J. natalica	2.0	1.5	1.4	0.8	0.0	0.0	0.0	0.0	2.0	7.7
J. terea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2
Phalanta phalantha	0.5	0.5	0.0	5.8	5.8	2.1	[illegible]	0.3	0.5	16.0
Acraea sp.	0.0	0.3	0.0	0.8	0.8	0.8	0.0	0.0	0.0	2.7
Pardopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3
Phsycaeneura leda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Charaxes varanes	0.0	0.2	0.8	0.8	0.5	0.1	0.0	0.0	0.0	2.3
C. candiope	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3
C. cithaeron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C. protoclea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euxanthe wakefieldi	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2
Tirumula petriverana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudacraea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Harma theobene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	28.2	31.8	26.6	32.0	32.0	21.5	8.3	6.3	37.7	224.4

Table 8 Butterfly abundance by families in the different zones of the Arabuko-Sokoke forest, Feb-Oct 1993

	Mixed Forest Zone	Brachystegia Zone	Cynometra Zone	Arabuko-Sokoke Forest
Papilionidae	1,155	750	276	2,236
Pieridae	4,253	5,496	374	10,106
Nymphalidae	2,058	1,463	729	4,251
Total(N)	7,466	7,709	1,379	16,593
Total %	44.99	46.46	8.31	
Total hours	94	95	61	250
No.per hour	79.43 +/- 20.19	81.14 +/- 27.05	22.6 +/- 10.32	66.37 +/- 18.86

FIG. 4 : RELATIVE ABUNDANCE OF BUTTERFLY FAMILIES IN ARABUKO-SOKOKE AND THE DIFFERENT ZONES

(a) Arabuko-Sokoke Forest



(b) Mixed-forest zone

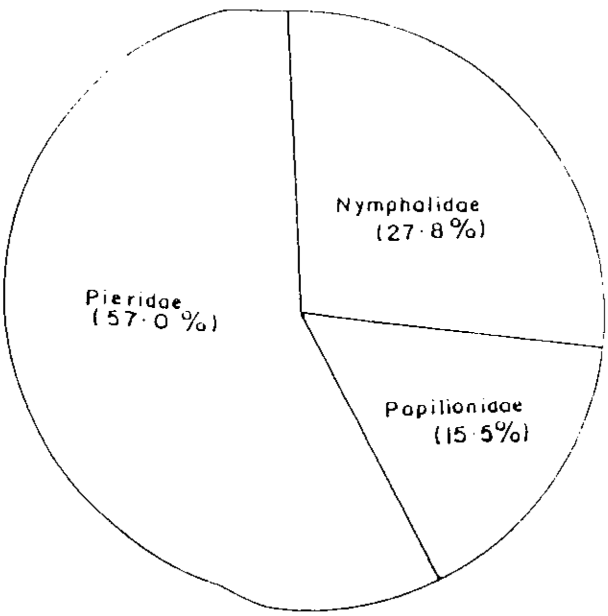
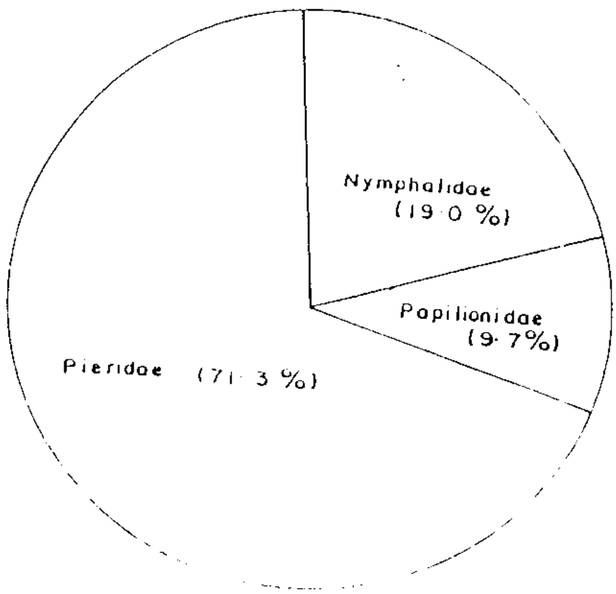
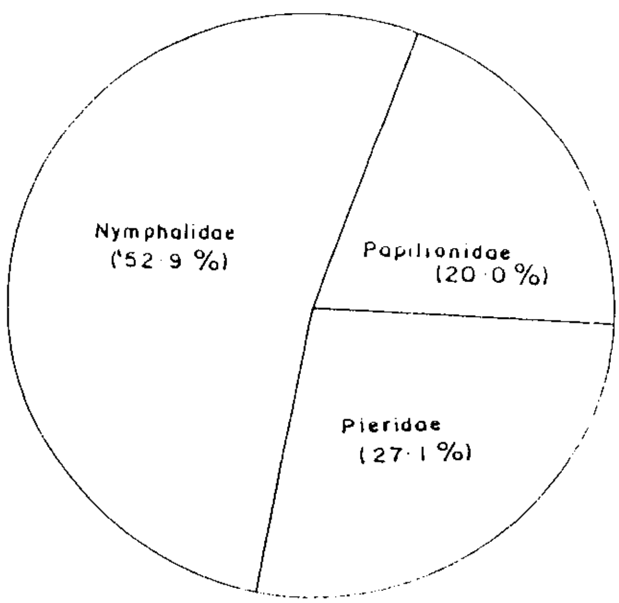


Fig. 4 cont.

(c) Brachystegia zone



(d) Cynometra zone



3.2.3 Status of butterflies

When the 60 species of butterflies encountered on the walking transects were categorized, 18 species were found to be abundant, 9 common, 11 uncommon and 22 rare (Table 9). On comparing the status of butterflies in the three different vegetation zones of the forest, the Pierids constituted a greater percentage of the species in the Brachystegia (90%) and the Mixed Forest zones (60%) (Table 10). In the Cynometra zone the Nymphalids and Papilionidae contribute a greater percentage of the most abundant species, with Pierids constituting only 30% (Table 10).

3.3 Butterfly seasonality

3.3.1 Seasonal changes in the total number of butterflies recorded.

Rain fell in all the months during the study period except February (Fig. 5). June was the wettest month with 175mm of rainfall. The highest mean temperature was that of March (32.5° C) and the lowest mean temperature was 21.9° C in July (Fig. 6).

For the entire forest the highest number of individuals counted was that of June in which the average number of individuals sighted per hour was 80.1 +/- 38.53 (Fig 7a). April came second with 76.9 + 35.44 and was followed by May with 74.9 +/- 33.52 The lowest count was that of September with only 36.5 individuals counted per hour (Fig 7a). The dry season months of February to April had higher counts compared to the cooler dry months of August to October (Fig 7a).

Status of Arabuko-Sokoke butterflies

Number per hour	Status
82.8 +/- 9.15	A
67.9 +/- 7.46	A
56.7 +/- 2.10	A
38.5 +/- 2.42	A
32.8 +/- 2.78	A
29.6 +/- 3.71	A
29.6 +/- 2.55	A
29.6 +/- 2.01	A
28.8 +/- 5.71	A
27.9 +/- 2.58	A
22.3 +/- 2.30	A
18.5 +/- 1.98	A
16.3 +/- 1.25	A
13.8 +/- 1.03	A
12.0 +/- 1.27	A
10.7 +/- 1.06	A
10.6 +/- 1.05	A
9.5 +/- 0.81	A
9.2 +/- 0.90	C
8.7 +/- 0.92	C
6.9 +/- 0.67	C
5.8 +/- 0.81	C
5.8 +/- 0.60	C
5.6 +/- 0.50	C
5.5 +/- 0.43	C
5.1 +/- 0.86	C
4.8 +/- 0.33	C
4.6 +/- 0.75	U
4.5 +/- 0.64	U
4.4 +/- 0.36	U
4.2 +/- 0.36	U
3.9 +/- 0.59	U
3.5 +/- 0.25	U
2.8 +/- 0.49	U
2.2 +/- 0.18	U
1.7 +/- 0.34	U
1.7 +/- 0.25	U
1.5 +/- 0.12	U
1.3 +/- 0.20	R
1.3 +/- 0.19	R
1.1 +/- 0.21	R
1.0 +/- 0.11	R
1.0 +/- 0.15	R
0.8 +/- 0.10	R
0.7 +/- 0.11	R
0.7 +/- 0.17	R

Table 9. cont.

Charaxes candiope	0.6 +/- 0.09	R
Charaxes protoclea	0.5 +/- 0.08	R
Graphium leonidus	0.5 +/- 0.06	R
Hypolimnas anthedon	0.5 +/- 0.07	R
Melanitis leda	0.4 +/- 0.05	R
Junonia terea	0.4 +/- 0.13	R
Charaxes cithaeron	0.4 +/- 0.05	R
Pseudacraea boisduvali	0.2 +/- 0.04	R
Belenois gidica	0.2 +/- 0.04	R
Amauris niavus	0.2 +/- 0.04	R
Amauris ochlea	0.2 +/- 0.04.	R
Harma theobene	0.2 +/- 0.03	R
Euxanthe wakefield	0.1 +/- 0.02	R
Tirumala petriverana	0.1 +/- 0.02	R

Legend:
A = abundant
C = common
U = uncommon
R = rare

Table 10 Most abundant butterfly species in the different zones

a)Mixed forest zone

Species	Number per hour
Leptosia alcesta	15.3 +/- 2.34
Phalanta phalantha	6.6 +/- 1.36
Eronia cleodora	6.3 +/- 0.51
Colotis euippe	6.2 +/- 0.48
Colotis ione	5.0 +/- 0.51
Papilio constantinus	4.6 +/- 0.63
Catopsilia florella	4.6 +/- 1.48
Hypolimnas misippus	4.0 +/- 0.57
Belenois thysa	3.5 +/- 0.51
Papilio nireus	3.0 +/- 0.49

b) Brachystegia zone

Species	Number per hour
Eurema sp.	17.0 +/- 2.22
Eronia cleodora	8.5 +/- 0.43
Colotis regina	5.2 +/- 0.69
Leptosia alcesta	4.7 +/- 0.68
Colotis euippe	3.5 +/- 0.31
Belenois creona	3.2 +/- 0.49
Catopsilia florella	3.2 +/- 0.86
Phalanta phalantha	3.2 +/- 0.50
Belenois thysa	3.1 +/- 0.30
Colotis ione	2.7 +/- 0.31

Fig. 10 cont.

c) Cynometra zone

Species	Number per hour
Hypolimnas misippus	3.30 +/- 5.688
Neptis sp.	2.54 +/- 1.504
Phalanta phalantha	1.79 +/- 1.286
Catposillia florella	1.67 +/- 1.221
Graphium philonoe	1.38 +/- 1.063
Hypolimnas deceptor	1.31 +/- 0.938
Papilio nireus	1.30 +/- 0.890
Eronia cleodora	1.11 +/- 0.589
Belenois thysa	0.97 +/- 0.568
Graphium colonna	0.93 +/- 1.021

Fig. 5 MONTHLY RAINFALL AT GEDE FOREST STATION, OCT'92 - OCT'93.

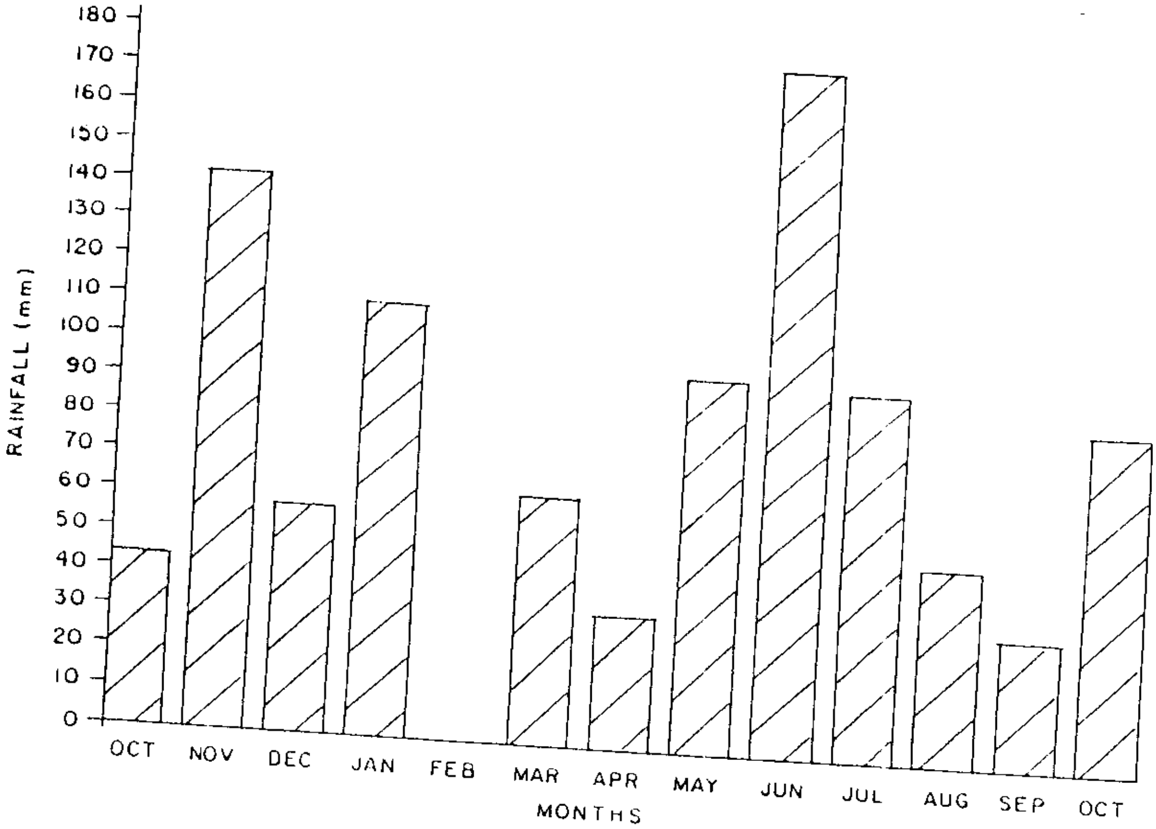


Fig. 6 MONTHLY TEMPERATURES FOR MALINDI MSABAHA MET. STATION, 1993.

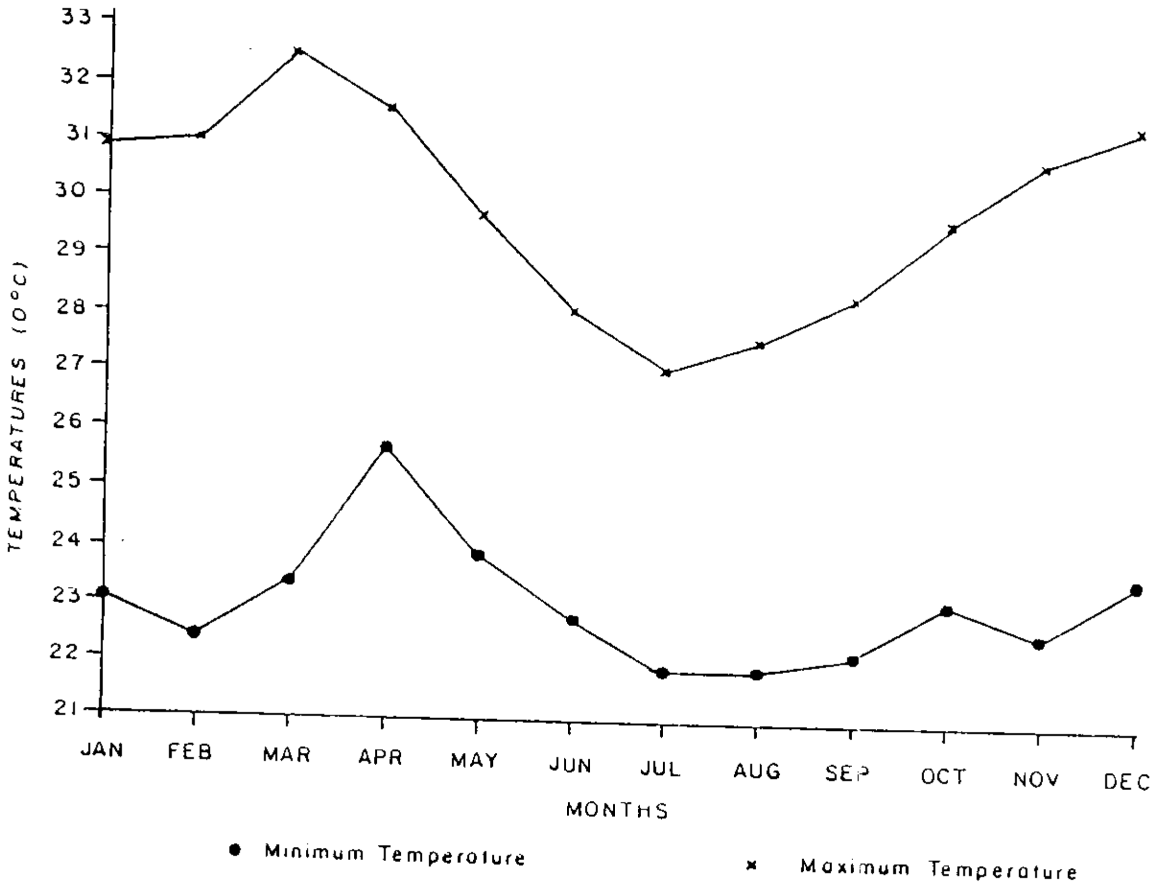
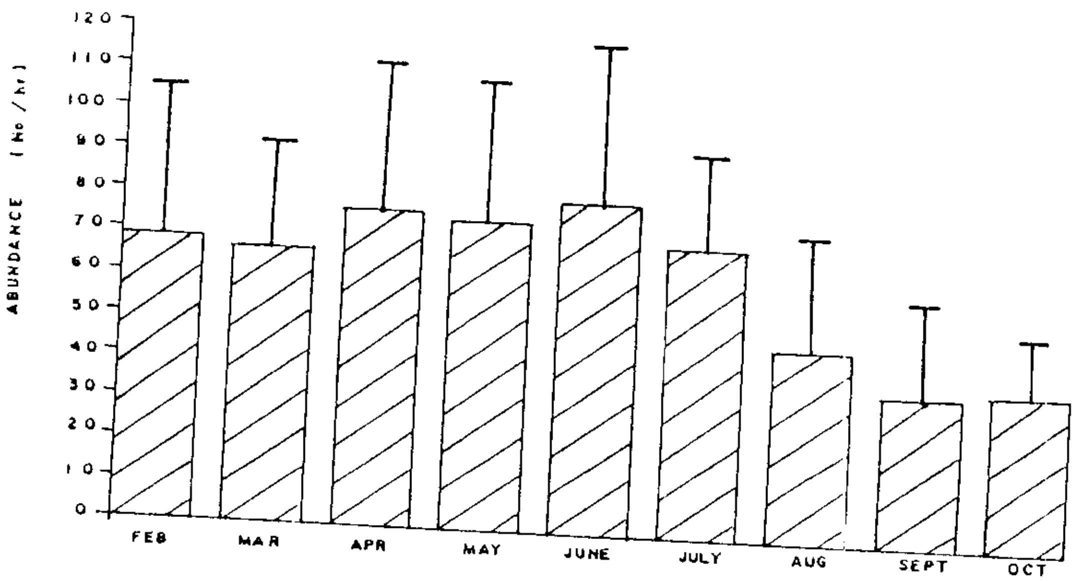


FIG. 7 : MONTHLY CHANGES IN THE ABUNDANCE OF BUTTERFLIES IN ARABUKO - SOKOKE AND THE DIFFERENT ZONES, FEB.-OCT, 1993.

(a) Arabuko - Sokoke



(b) Mixed forest zone

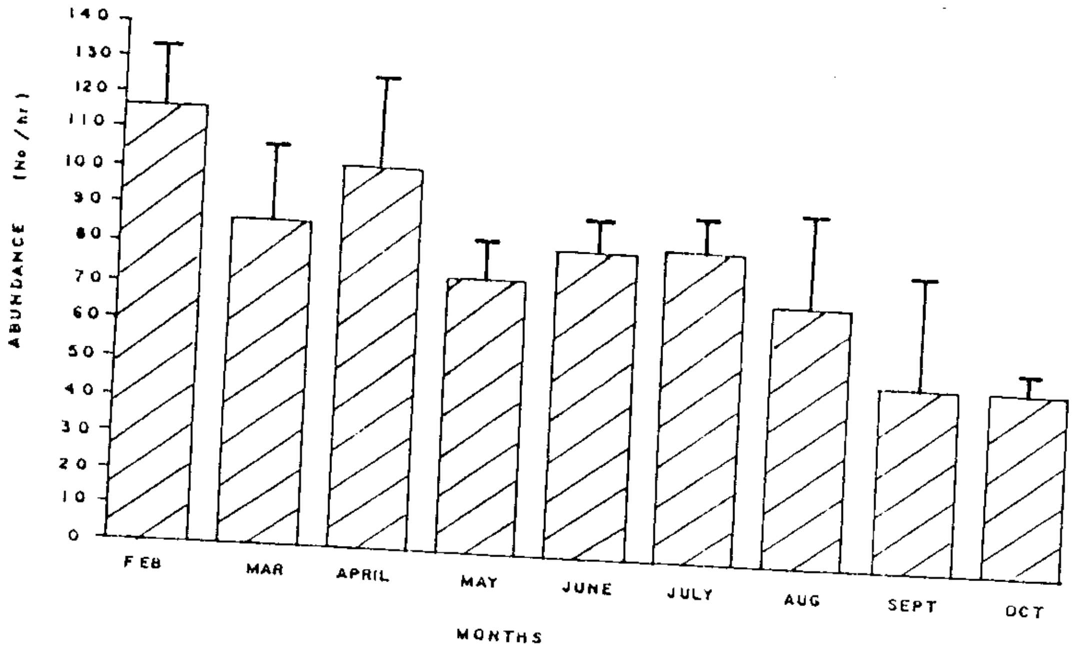
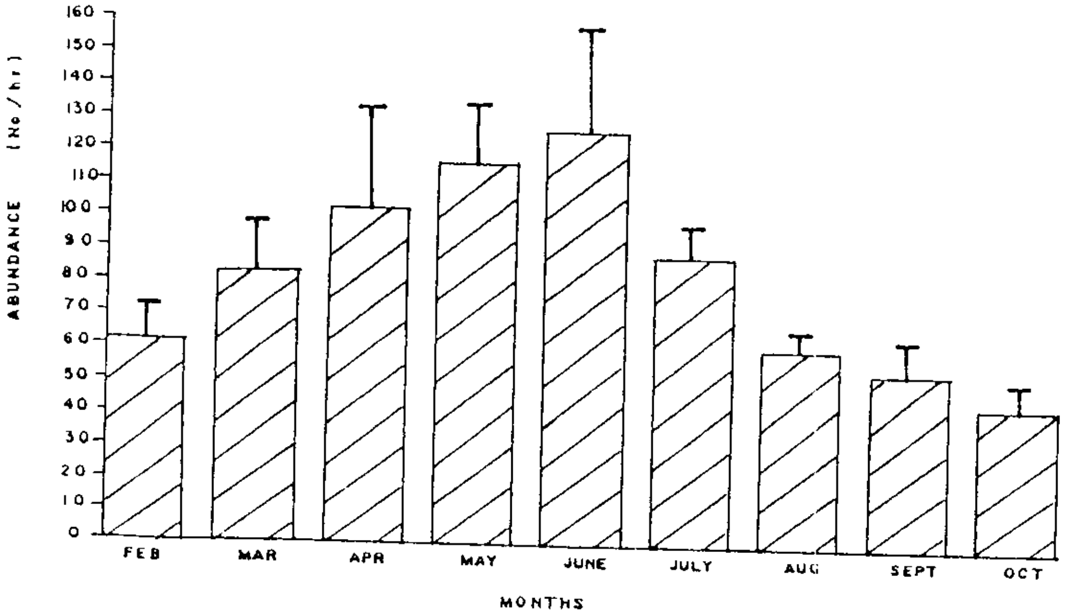
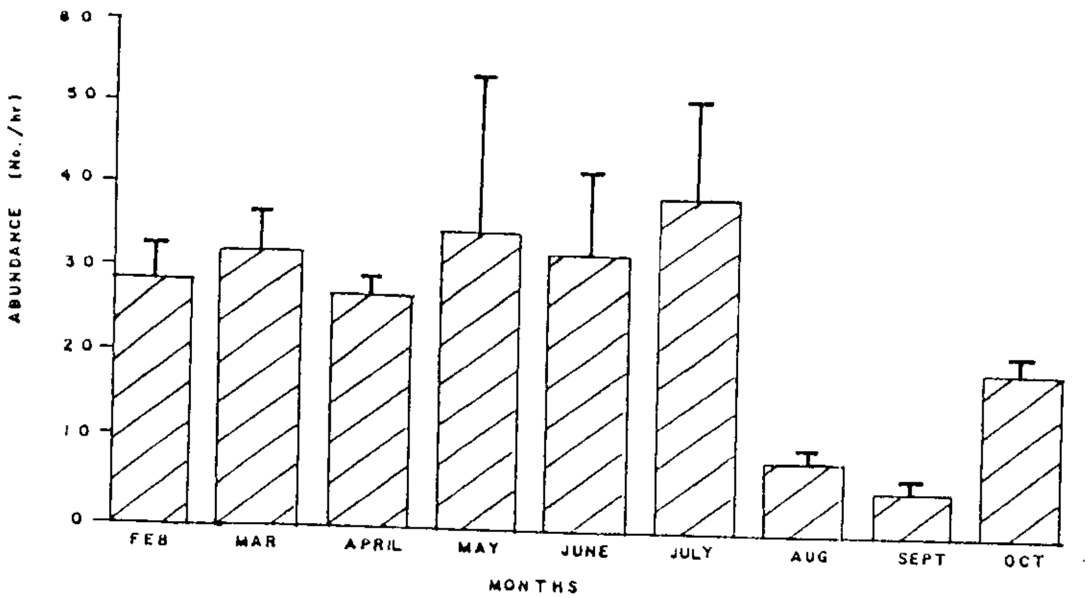


Fig. 7 cont.

(d) Brachystegia zone



(d) Cynometra zone



The pattern of change in abundance in the three different zones did not have peaks on the same month as that for all the zones combined. The Mixed forest zone had highest number of individuals in February, the Brachystegia zone in June and the Cynometra zone in July (Fig 7b-d). Lowest numbers of individuals occurred in October for the Mixed forest and Brachystegia zones while that of the Cynometra was in September (Fig 7b-d)

3.3.2 Seasonal changes in the relative abundance of different families.

Throughout the entire study period the family Pieridae constituted the highest percentage of the three families counted on the walking transects (Fig 8). During the cooler dry months of August to October, the Pierids constituted more than 75% of the individuals counted (Fig 8). The family Papilionidae was rare constituting only 1.5% and 1.4% of the total individuals in the months of August and September respectively (Fig 8). Throughout the entire study period the order abundance in descending order was Pieridae first, followed by Nymphalidae and Papilionidae last.

The highest number of Pierids per hour was sighted in the month of February with 51.2 +/- 28.29 individuals per hour(Fig 9b). In all the families the wet season abundance was markedly greater than the dry season. The Nymphalids the peak was in the month of July and that of the Papilionids in June with 26.6 +/- 12.86 and 20.0 +/- 4.37 individuals per hour receptively (Fig. 9a &c). The lowest number of individuals per hour for Nymphalids (5.3 +/- 2.05) and Papilionids (0.5 +/- 0.52) occurred in September while that for the Pierids (29.9 +/- 13.83) occurred in October (Fig. 9).

FIG. 8 CHANGES IN THE RELATIVE FREQUENCY OF FAMILIES IN ARABUKO-SOKOKE FOREST, FEB-OCT 1993.

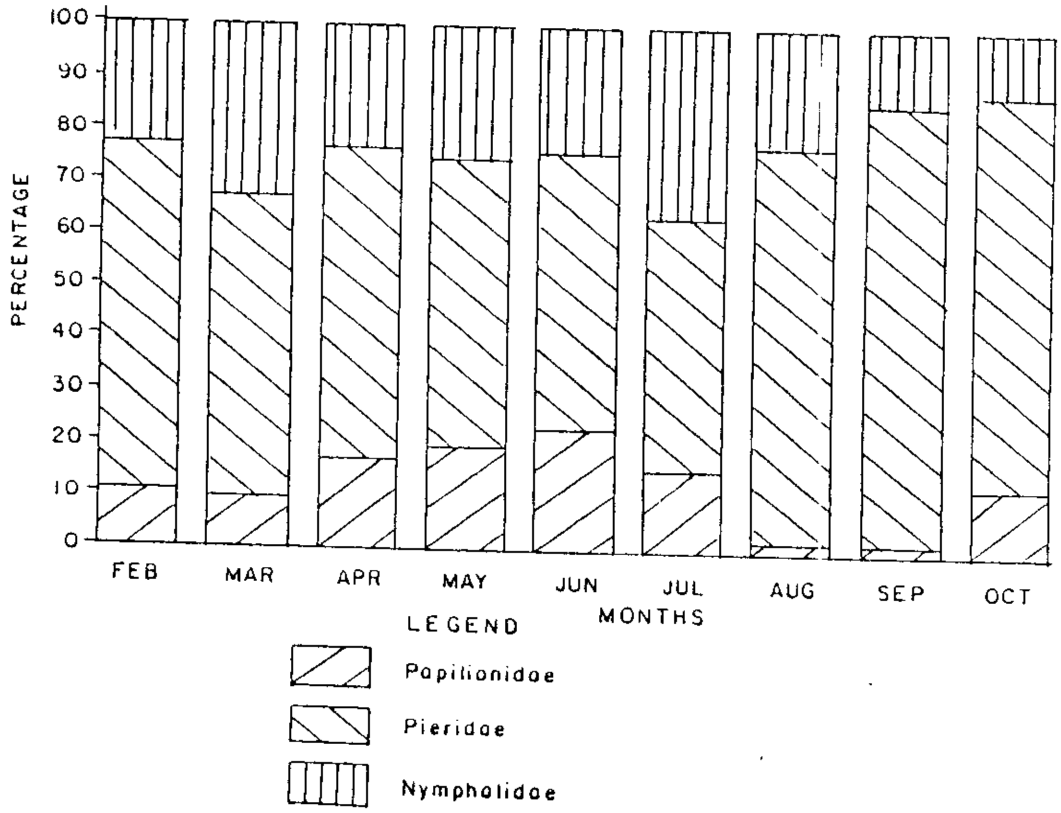
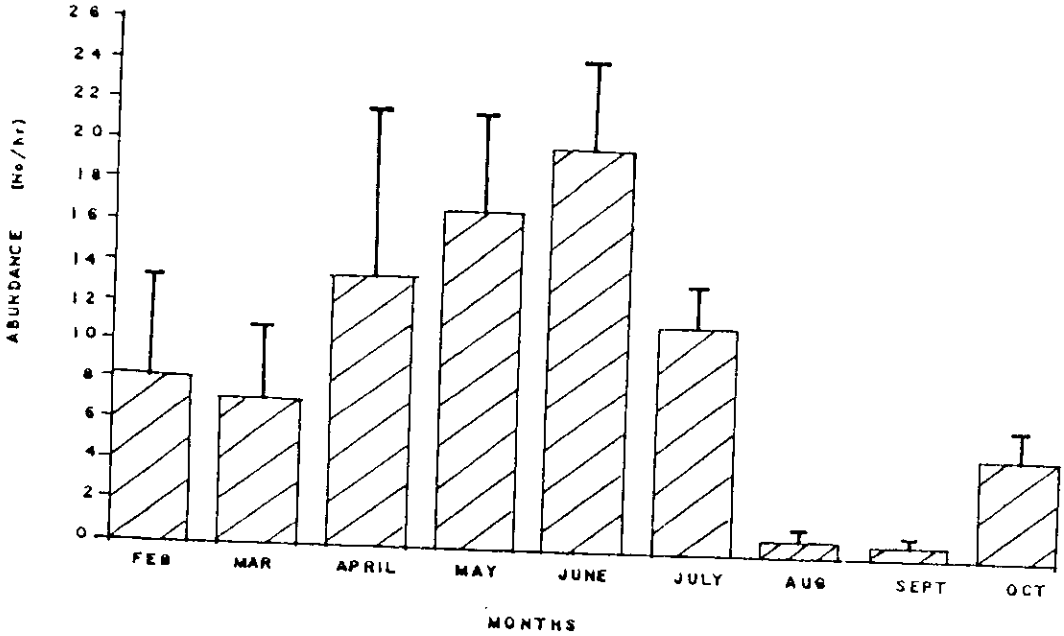


FIG. 9 : MONTHLY CHANGES IN THE ABUNDANCE OF BUTTERFLY FAMILIES IN ARABUKO - SOKOKE, FEB - OCT 1993.

(a) Papilionidae



(b) Pieridae

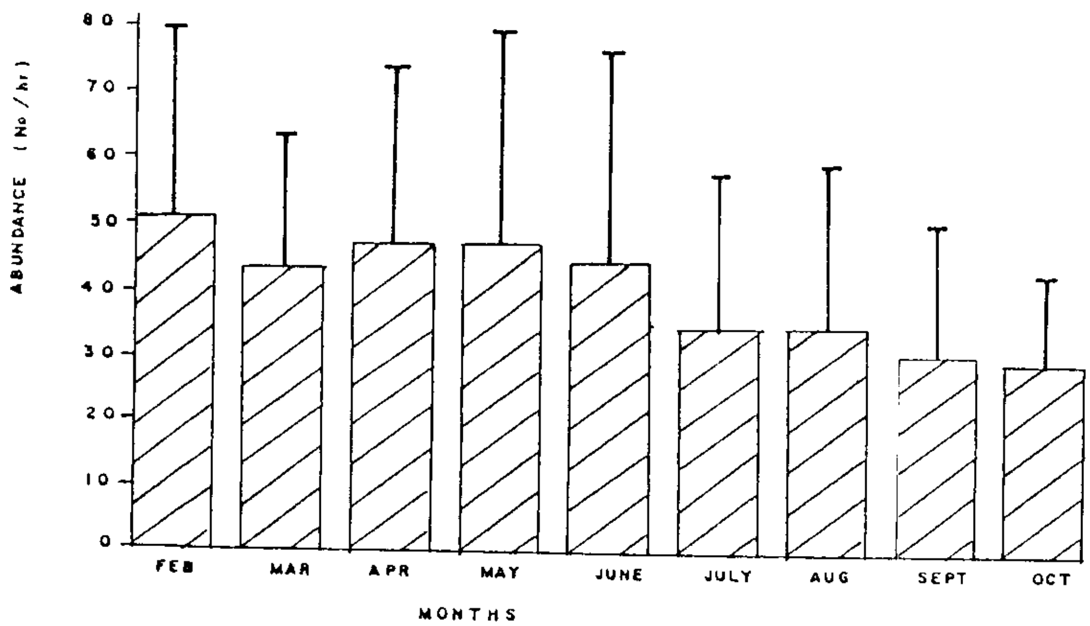
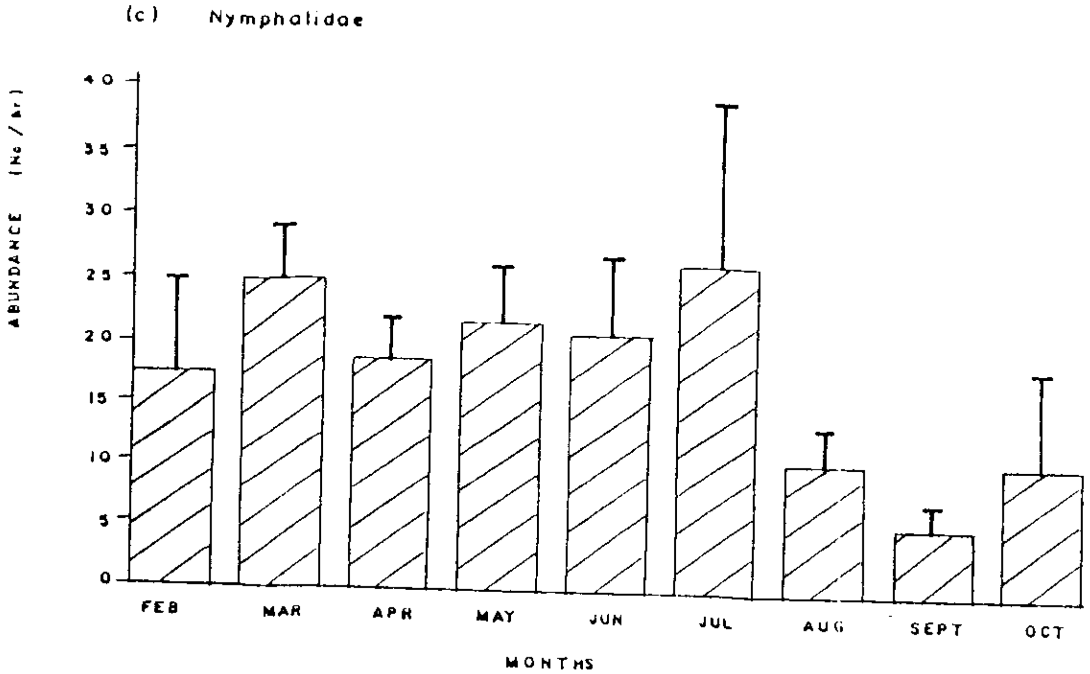


Fig. 9 cont.


(c) Nymphalidae
ABUNDANCE (No / hr)
0
5
10
15
20
25
30
35
40
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEPT
OCT
MONTHS

3.3.3 Seasonal fluctuation in the relative abundance of the commoner species

The fluctuation in the number of the nine most abundant species (*Leptosia alcesta, Eurema spp., Eronia cleodora, Phalanta phalantha, Catopsilia florella, Colotis euippe, Colotis ione, Hypolimnas misippus* and *Belenois thysa*) for the forest was looked into.

Leptosia alcesta

There was marked seasonality in the occurrence of the species with peaks in February and August-September (Fig 10a). Abundance was highest in the months just after the rains with most individuals being counted from the mixed forest transects.

Eurema species

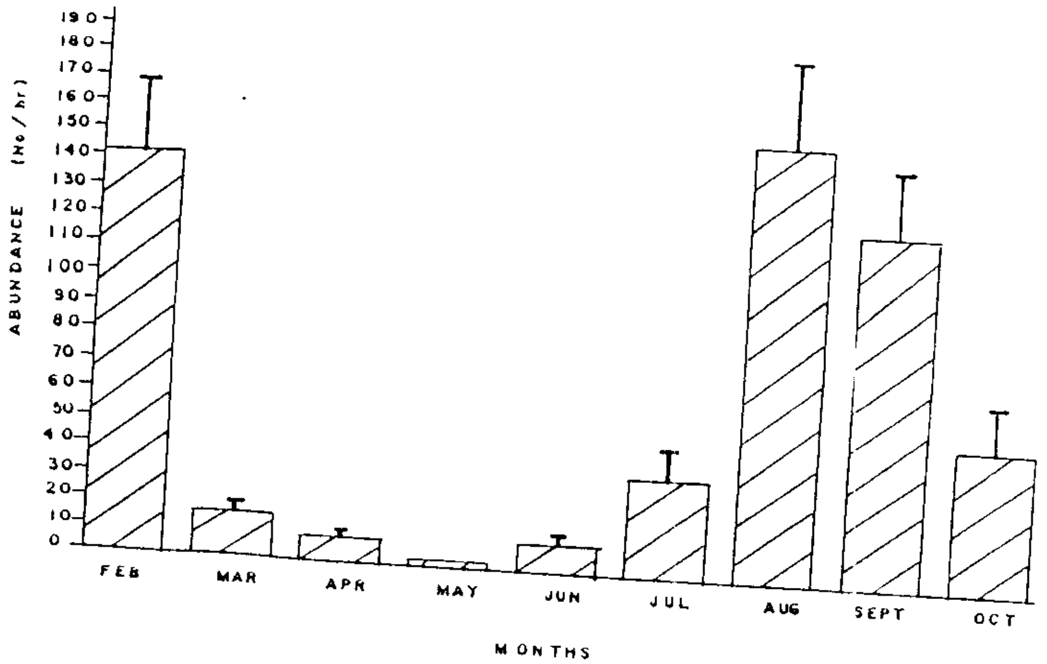
The genus constituted the species: *Eurema hecabe, E. brigitta* and *E. regularis*. These could not be distinguished in flight and were therefore clumped. Individual variation of each species was hence obscured. From the specimens collected during the study it could be deduced that *E. brigitta* and *E. regularis* were the most common. The species were present throughout the entire study period (Fig 10b). Their abundance peaked in May at the start of the rains (Fig 10b). In the warmer dry-season months of February to April abundance was much higher as compared to that of the cooler dry-season months of August to October (Fig 10b).

Eronia cleodora

The species occurred throughout the entire study period with a peak abundance in June (Fig 10c). Abundance was markedly lower in the cool dry-season months of August to October (Fig 10c).

FIG. 10 MONTHLY CHANGES IN THE ABUNDANCE OF THE MOST COMMON SPECIES, FEB - OCT 1993.

(a) *Leptosia alcesta*



(b) *Eurema* sp.

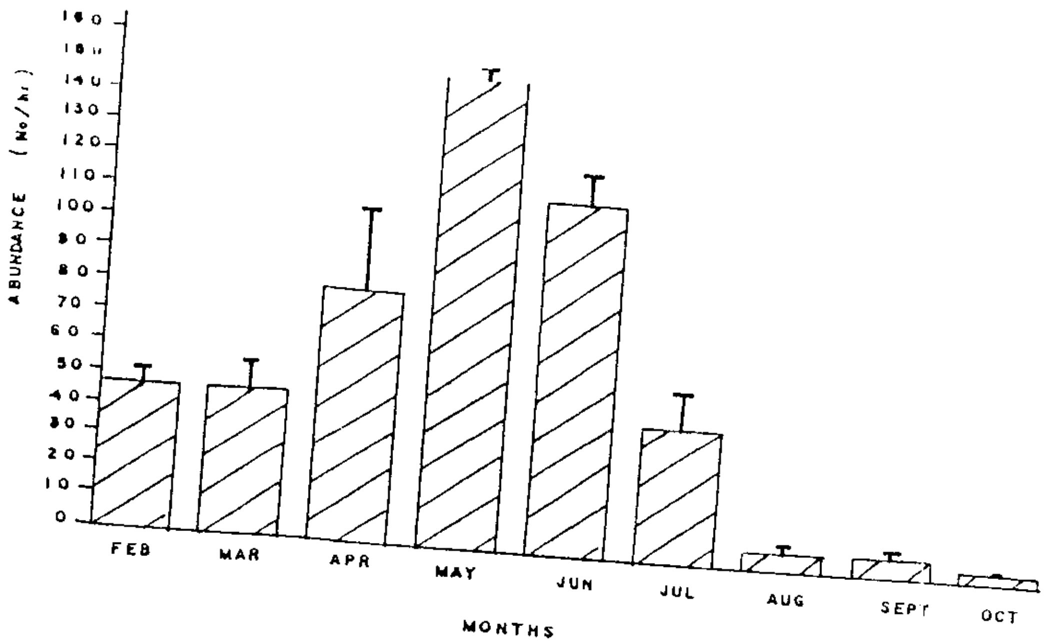
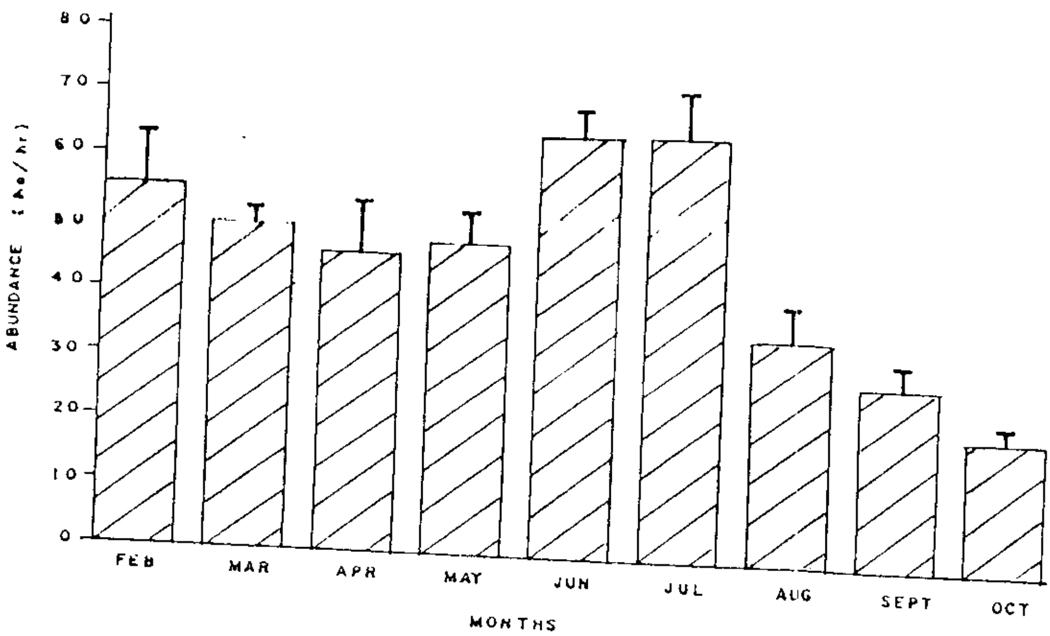


Fig. 10 cont.

(c) Eronia cleodora



(d) Phalanta phalantha

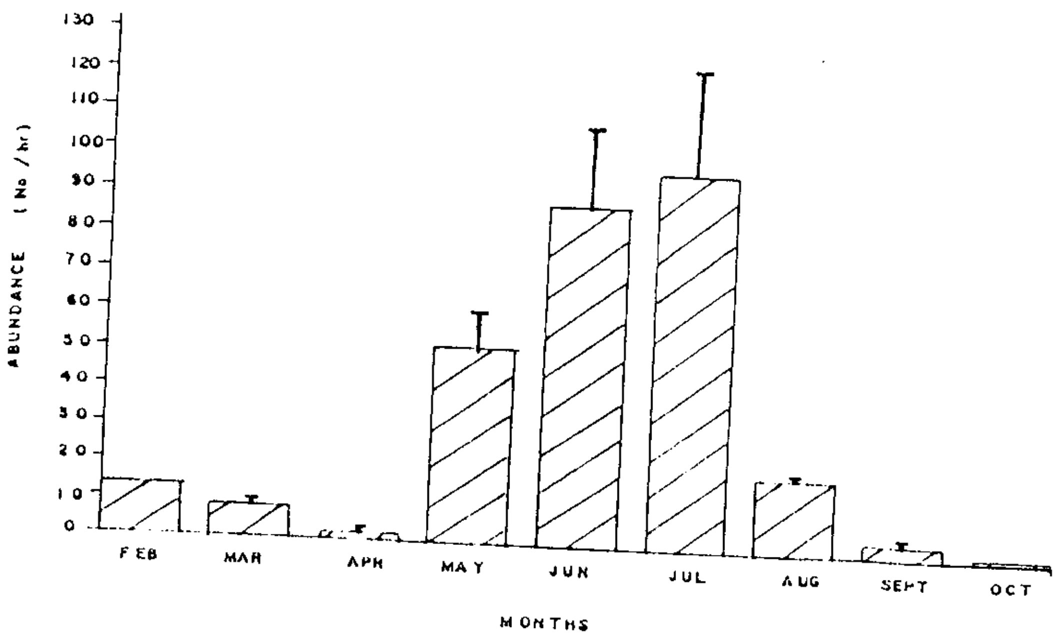
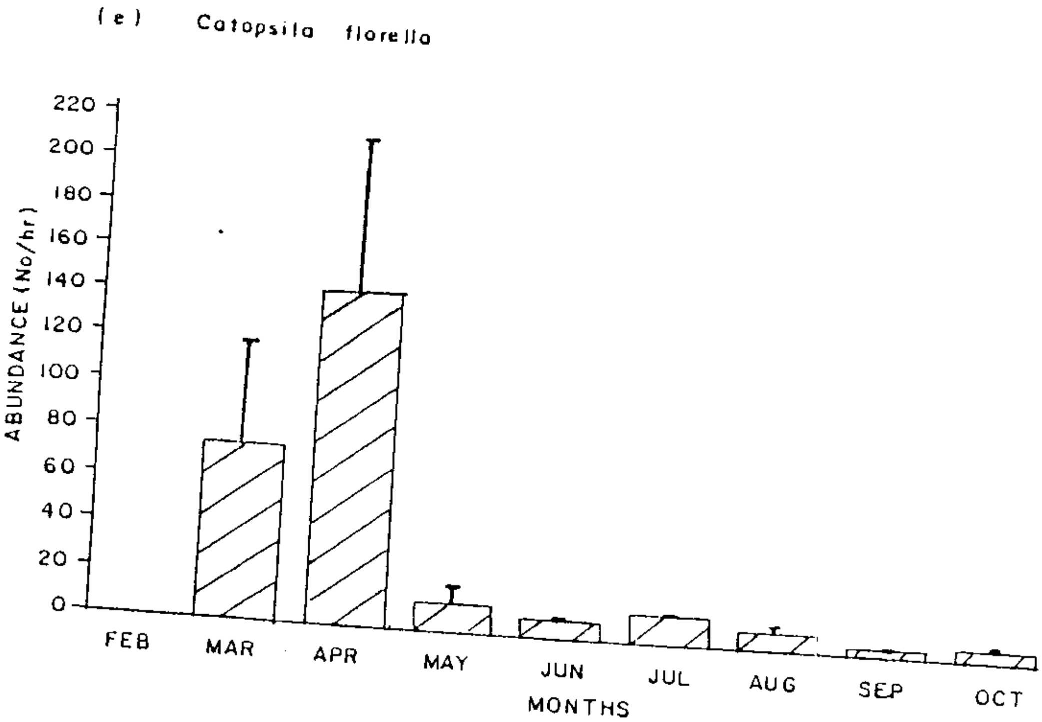


Fig. 10 cont.


(e) Catopsila florella
ABUNDANCE (No/hr)
220
200
180
160
140
120
100
80
60
40
20
0
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
MONTHS

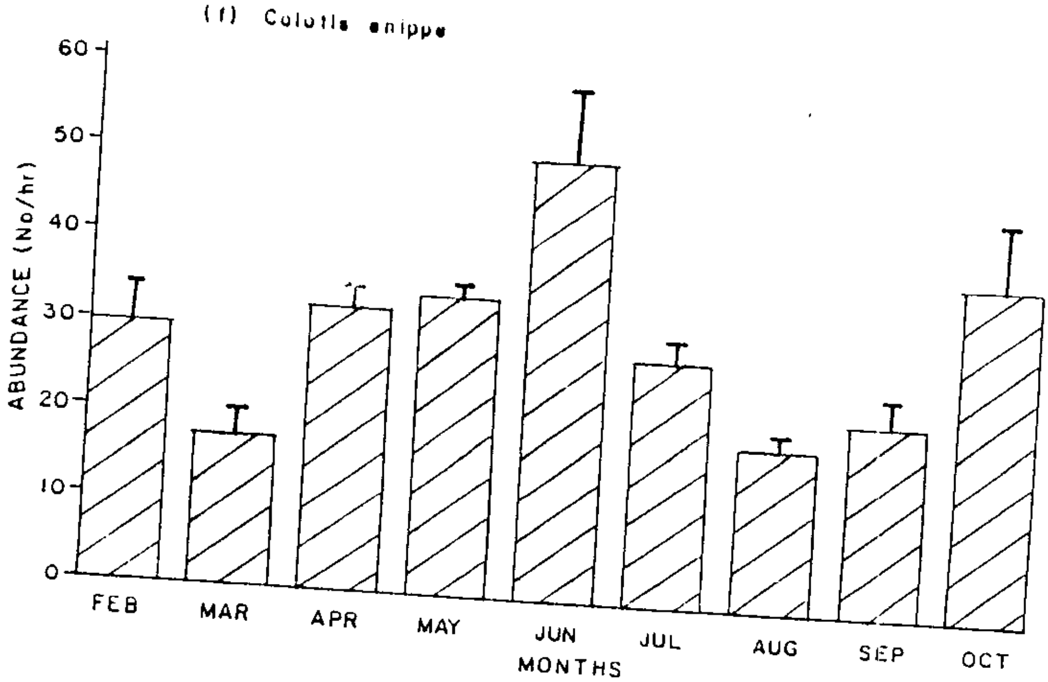
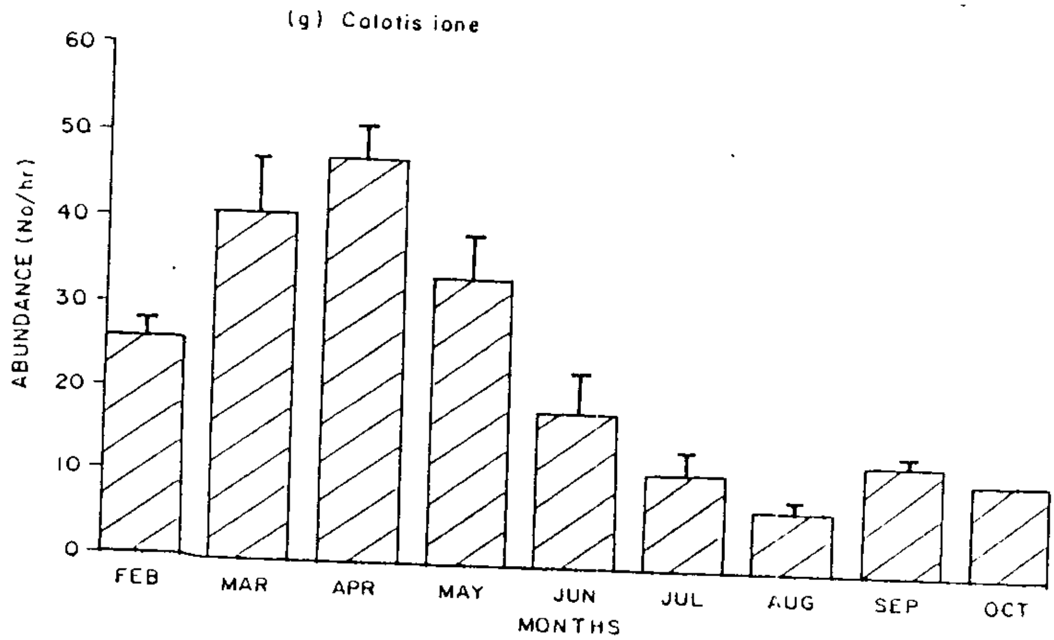

(f) Colotis enippe
ABUNDANCE (No/hr)
60
50
40
30
20
10
0
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
MONTHS

Fig. 10 cont.


(g) Colotis ione
ABUNDANCE (No/hr)
60
50
40
30
20
10
0
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
MONTHS

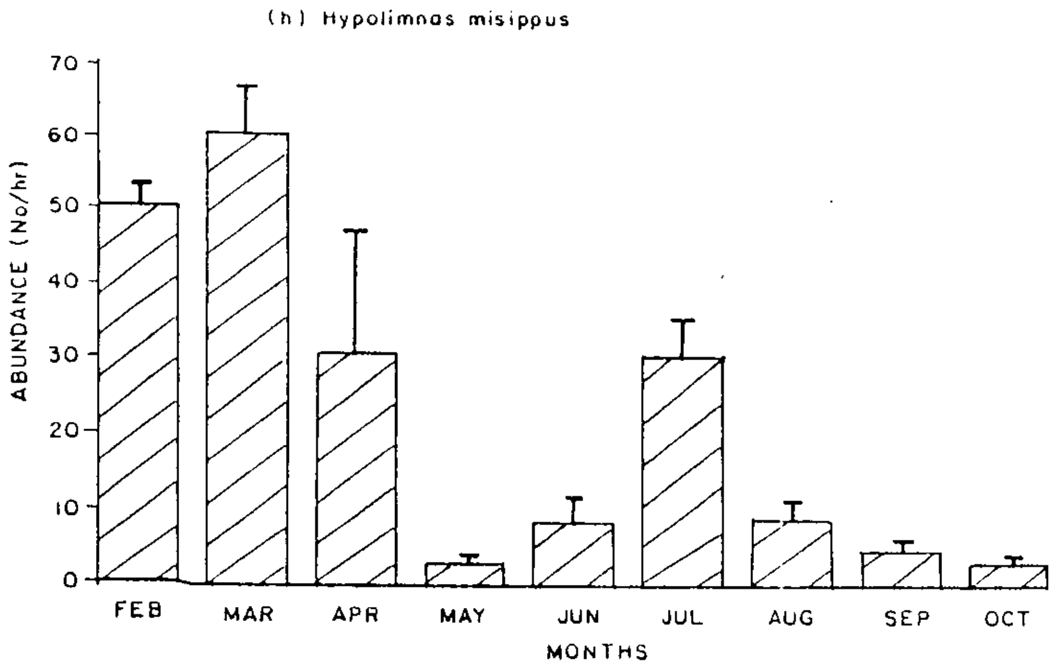
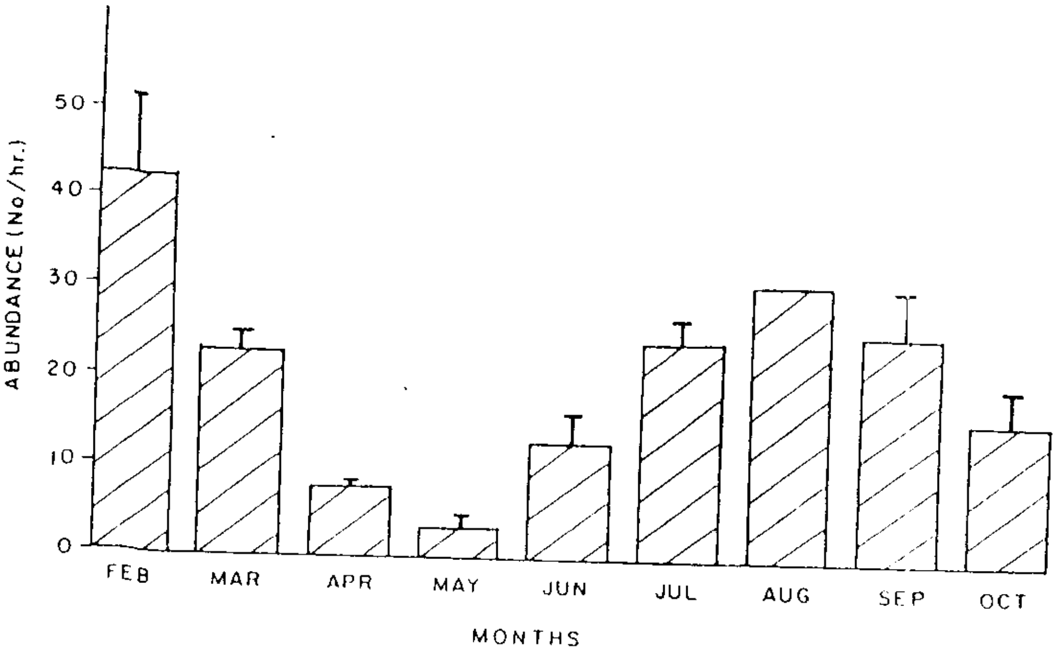

(h) Hypolimnas misippus
ABUNDANCE (No/hr)
70
60
50
40
30
20
10
0
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
MONTHS

Fig. 10 cont

(i) *Belenois thysa*



Phalanta phalantha

There was a marked seasonality in occurrence which included a sudden appearance of a large number of individuals in May (Fig 10d). The numbers increased and were highest in June maintained even into July (Fig 10d). Numbers fell drastically in August and by October the species was almost absent (Fig 10d). The species could be confused with *Phalanta eurytis* which is migratory and is on previous records for Arabuko-Sokoke Forest (Appendix I). Specimens of *Phalanta eurytis* were however not collected in the course of this study.

Catopsilia florella

The species suddenly appeared in large numbers in March (Fig 10e). Highest abundance was in April after which it fell drastically and maintained low numbers for the rest of the study period (Fig 10e).

Colotis euippe

The species was present throughout the entire period with the peak abundance in June and lowest numbers in the dry season months of March and July-September (Fig. 10f).

Colotis ione

The species was present throughout the entire study period and was quite abundant during the dry-season months with the highest numbers in April (Fig 10g).

Hypolimnas misippus

The species was most abundant in the months of February and March (Fig 10h). Abundance fell drastically in April but built up again in the rainy season after a low ebb in May (Fig 10h). In October the species was almost absent from the study area (Fig 10h).

Belenois thysa

This species was present throughout the entire study period and increased in abundance with the onset of the rains (Fig 10i). April and May had relatively low abundance compared to other months (Fig 10i).

3.3.4 Correlation of rainfall and temperature with abundance

Change in abundance was observed to occur with change in weather as seen in the sections on seasonality above. Correlation tests were carried out to determine the extent of how change in monthly abundance was influenced by the rainfall of the three previous months; the rainfall of the month; the mean maximum temperature of the month and the mean minimum temperature of the month. The ranking and Spearmans rank correlation coefficient, r, for the monthly abundance versus rainfall and temperature respectively, are shown in Table 11 and Table 12 respectively.

Rainfall from the three previous months and that of the month had positive correlation with the monthly abundance giving $r = 0.0458$ and $r = 0.4604$ respectively. The rainfall of the month had a higher correlation to monthly abundance as compared to that of the three previous months. Both r values were significant at $P < 0.05$. Correlation of monthly temperature with the monthly abundance was carried out using the: minimum mean temperatures and the

Table 11 Spearmans correlation of months abundance and rainfall

	Abundance		Previous three months rainfall		Months rainfall	
Month	No./hr	rank	mm	rank	mm	rank
Feb	68.8	5	168.2	2.5	0	1
Mar	67.1	4	173.5	4	63	5
Apr	76.9	8	96.5	1	33.5	3
May	74.9	7	192	6	95.5	8
Jun	80.1	9	304.3	7	175.3	9
Jul	70.3	6	364.5	9	93.7	7
Aug	46.6	3	318.8	8	49.8	4
Sep	36.8	1	176.1	5	32.6	2
Oct	38.1	2	168.2	2.5	85.8	6

Table 12 Spearmans correlation months abundance and temperature

	Abundance		Mean minimum temperature		Mean maximum temperature	
Month	No./hr	rank	°C	rank	°C	rank
Feb	68.8	5	22.4	4	31.0	7
Mar	67.1	4	23.4	7	32.5	9
Apr	76.9	8	25.7	9	31.6	8
May	74.9	7	23.9	8	29.7	4
Jun	80.1	9	22.8	5	28.1	3
Jul	70.3	6	21.9	1	27.1	1
Aug	46.6	3	21.9	1	27.6	2
Sep	36.8	1	22.2	3	28.4	6
Oct	38.1	2	23.2	6	29 7	4

maximum mean temperatures. The correlation of monthly abundance with the minimum mean temperature gave $r = 0.5792$ while that with the maximum mean temperature gave a lower value of $r = 0.3292$. All the r values obtained were significant at $P < 0.05$.

3.4 Species richness and diversity

3.4.1 Seasonal changes in species richness

The species richness indices were high in the wet season with most transects having their highest indices in July (Fig 11)

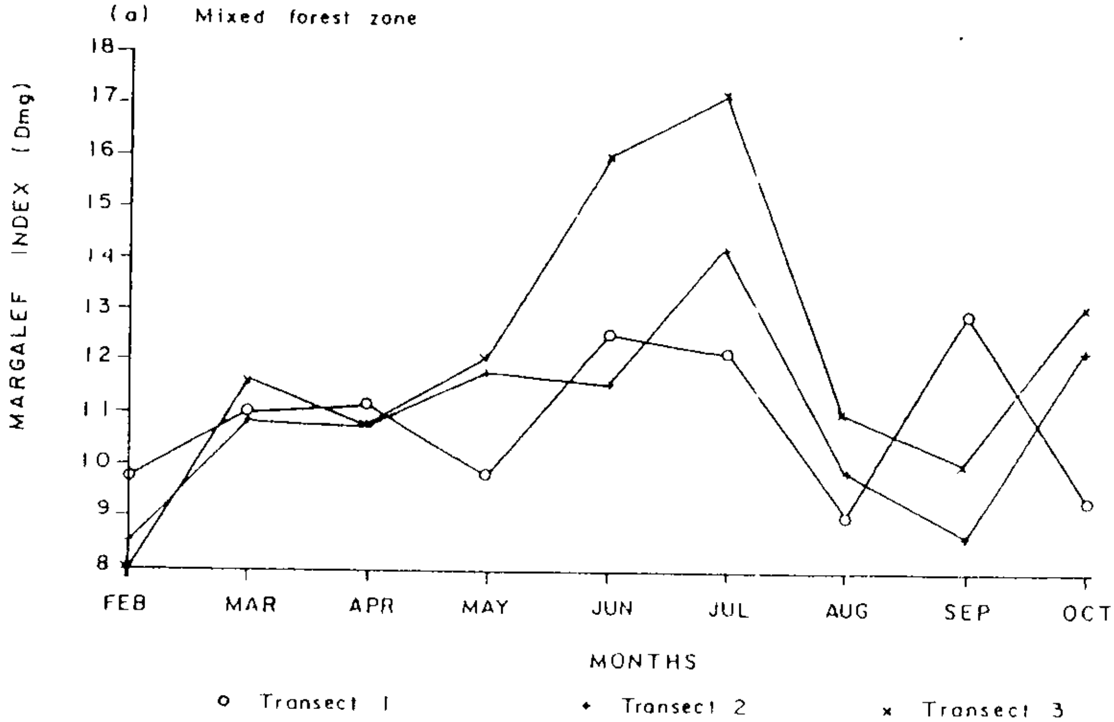
Mixed forest Zone

During the months of February, March and September there were the smallest differences in the species richness amongst the three transects (Fig 11a). The lowest species richness values were in the month of September for all three transects while highest values fell on the wet season months of May to July (Fig 11a). An ANOVA was carried out to test if there was a significant difference in the monthly trend of species richness amongst the three transects. There was a non significant difference ($F = 1.53$; $df = 2,24$; $P > 0.05$).

Brachystegia zone

The lowest species indices were those of February for all the three transects in this zone (Fig. 11b). The species richness indices fell after the rains and began to rise in September (Fig. 11b). The highest species richness indices were in June for two transects and in July for the third (Fig. 11b). An ANOVA was carried out to test if there was a significant difference in the monthly trend of species richness amongst the three transect. There was a non significant difference ($F = 3.09$; $df = 2,24$; $P > 0.05$).

FIG. II : MONTHLY CHANGES IN THE SPECIES RICHNESS IN THE DIFFERENT ZONES, FEB - OCT 1993



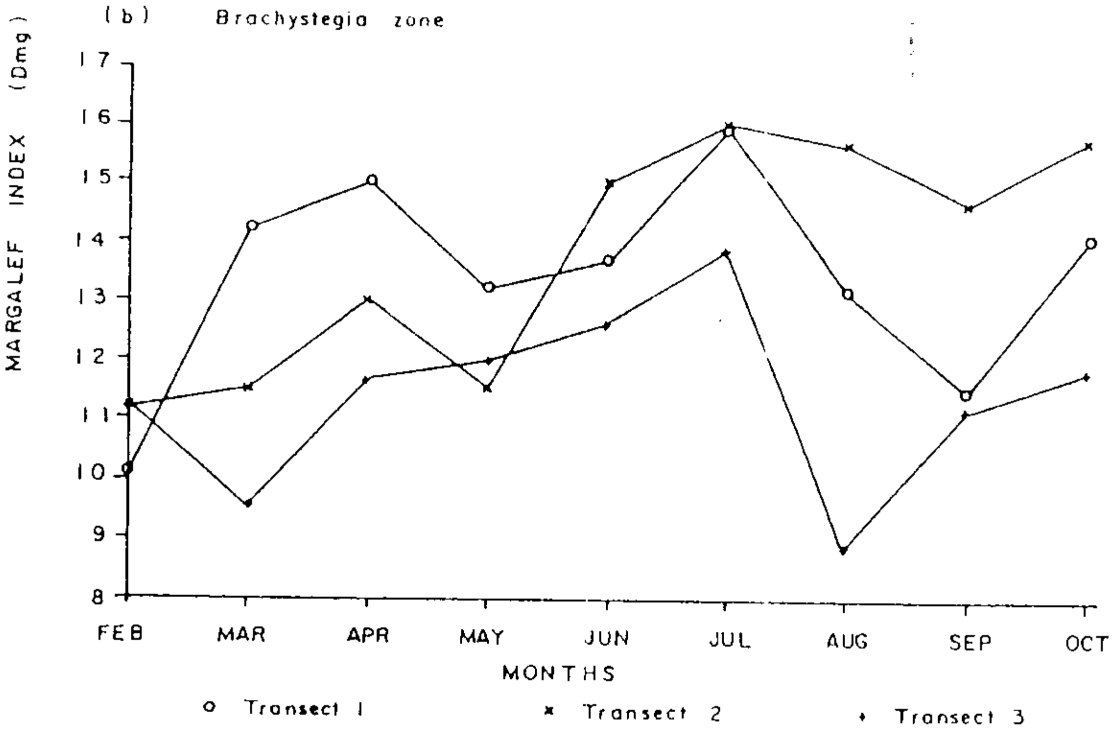
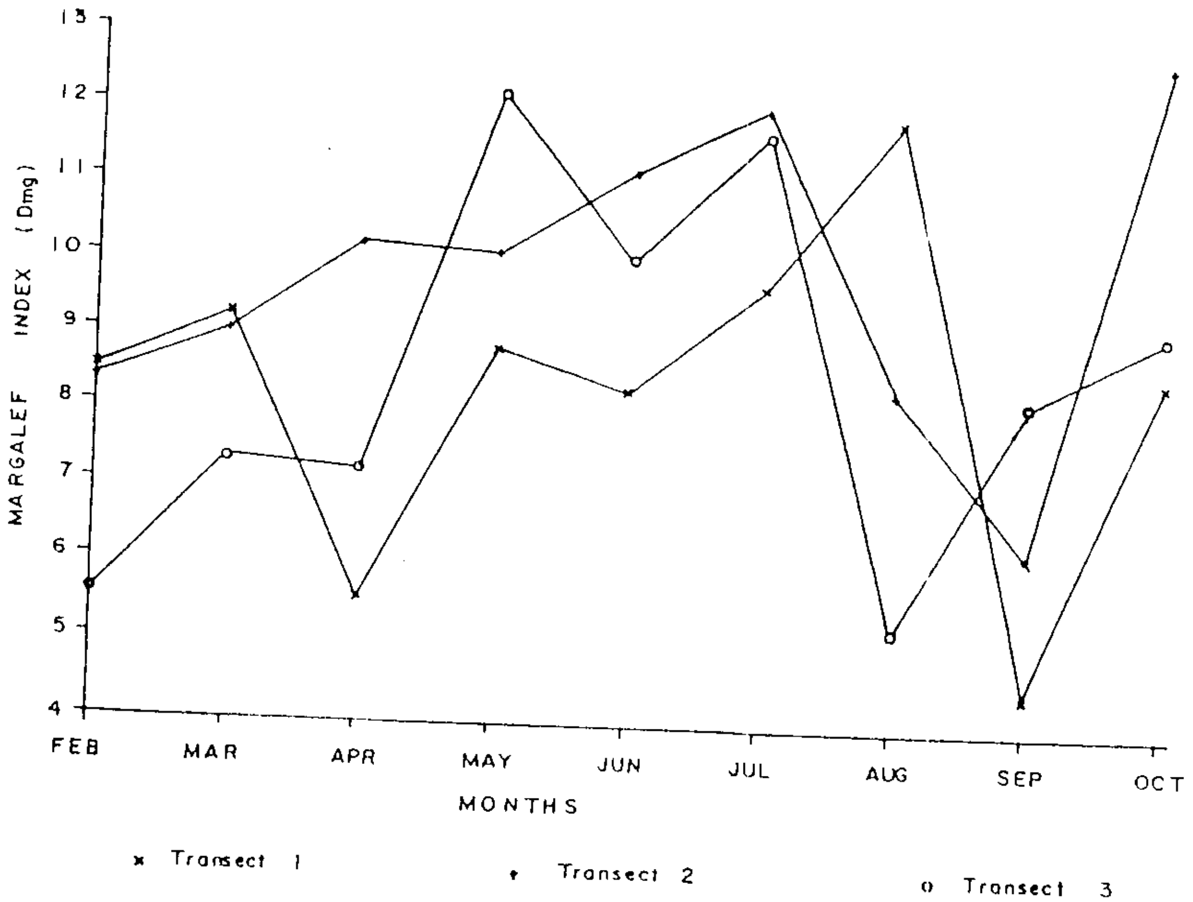


Fig. 11 cont

(c) Cynometra zone



Cynometra zone

The lowest species richness indices were in different months for the three transects: February, September and October (Fig 11c). All three transects however had the highest species richness in July (Fig 11c). An ANOVA was carried out to test if there was a significant difference in the monthly trend of species richness amongst the three transects. There was a non significant difference ($F = 1.44$; $df = 2,24$; $P > 0.05$).

3.4.2 Seasonal changes in species diversity

The Arabuko-Sokoke Forest had an overall Shannon diversity index of 1.4220 with an eveness of 0.7997 (Table 13). Species number and abundance peaked in the wet season leading to a high value of $H' = 1.4182$ for the entire forest in July.

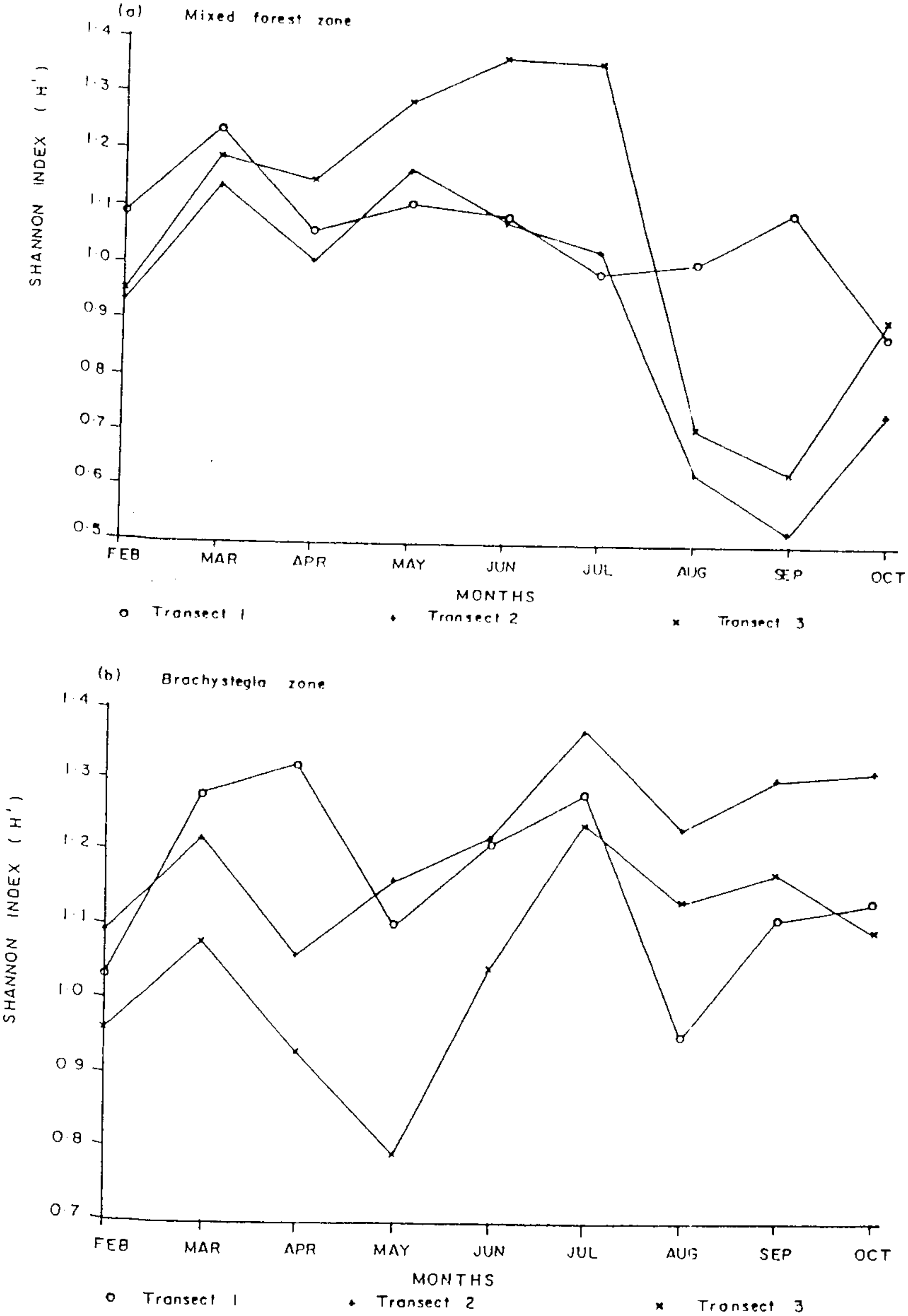
Mixed forest zone

Species diversity indices were lowest in the August and September with that of transect M1 falling far below those of the other two transects (Fig 12a). Two transects had their peak species diversity in May while the third transect had its peak in March (Fig 12a). An ANOVA was carried out to test if there was a significant difference in the monthly trend of species diversity amongst the three transects. There was no significant difference ($F=1.29$; $df = 2, 24$; $P > 0.05$).

Table 13 Shannon indices and eveness of the study area transects

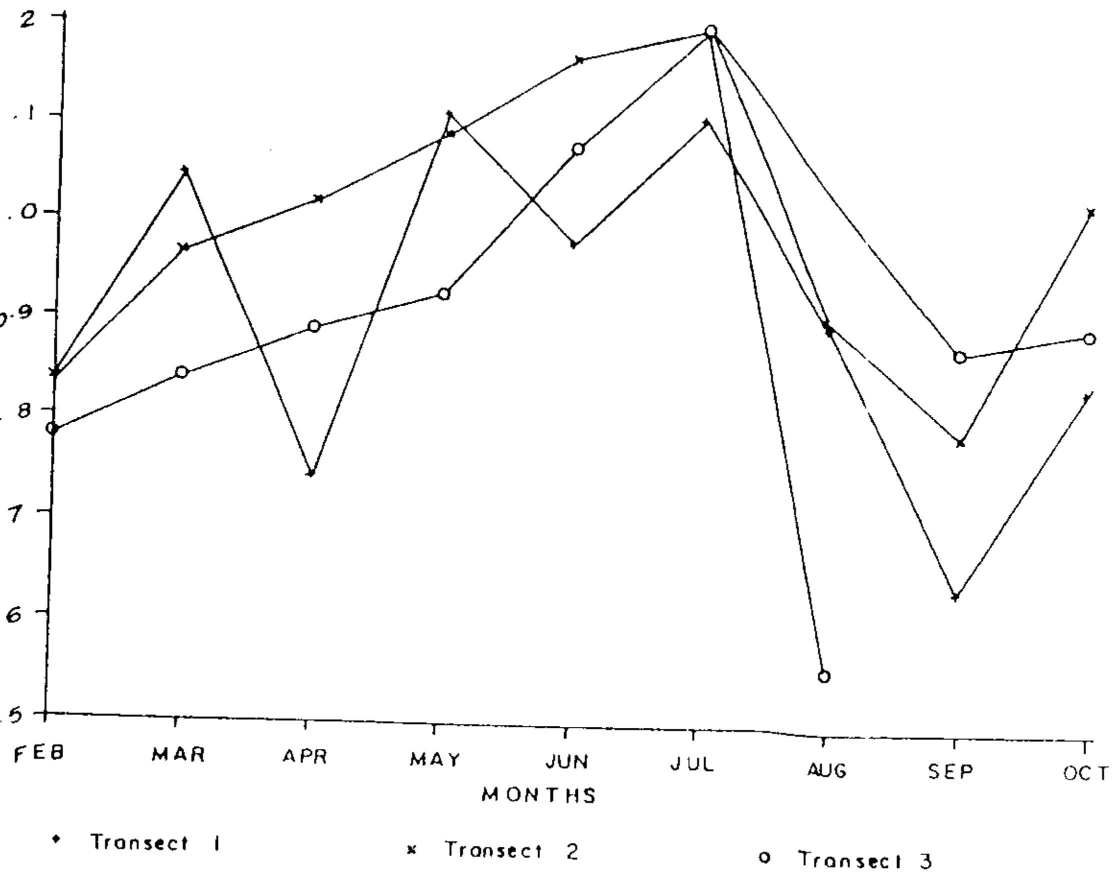
	Shannon index (H')	Eveness (E')
Mixed forest zone		
1	1.3049	0.7893
2	1.1819	0.7069
3	1.3112	0.7679
Brachystegia zone		
1	1.1993	0.7095
2	1.3881	0.8171
3	1.3652	0.7881
Cynometra zone		
1	1.2458	0.8519
2	1.3606	0.8279
3	1.2746	0.8128
Arabuko-Sokoke Forest	1.42198	0.7997

FIG 12 MONTHLY CHANGES IN THE SPECIES DIVERSITY IN THE DIFFERENT ZONES, FEB - OCT 1993.



12 cont.

(c) Cynometra zone



Brachystegia zone

The three transects had their highest species diversity in the month of July (Fig 12b). The lowest species diversity however fell on different months. April, May and August (Fig 12b). The species diversity in transect B3 was much lower than those of the other two transects for most of the months. An ANOVA was carried out to test for the difference in the monthly trend of species diversity amongst the three transects. There was a significant difference ($F = 4.64$; $df = 2,24$; $P < 0.05$). This could have resulted from the markedly visible different occurrence of high and low diversities in the three transects (Fig 12b).

Cynometra zone

The lowest species diversity indices for the three transects fell on different months: February, September and October (Fig 12c). All the transects however had their highest species diversity in July (Fig 12c). The species diversity in transect C2 markedly rose and fell in a pattern quite dissimilar to the other two transects which had steady rise and falls (Fig 12c). On carrying out an ANOVA to test for the difference in the monthly trend of species diversity, there was a non significant difference ($F = 2.55$; $df = 2.24$; $P > 0.05$).

3.4.3 Species diversity in different zones

Shannon diversity indices (H') were then tested statistically using the Hutcheson t -test against the null hypothesis that there are no difference between indices from the different transects. Out of 36 tests there was a greater number of significant associations than expected by chance at $P= 0.05$ (Table 14).

Table 14 Hutcheson t-test values for the different transects of the study area

	M1	M2	M3	B1	B2	B3	C1	C2
M2	8.6545 (4194)							
M3	0.4940* (5203)	8.6656 (4684)						
B1	7.5813 (5120)	1.0865* (5020)	7.6376 (1316)					
B2	6.6523 (4755)	14.0163 (4403)	5.7799 (5226)	13.0731 (5257)				
B3	4.6533 (4687)	12.1392 (4514.29)	3.9332 (5160.08)	11.1824 (5296)	1.6947* (4800)			
C1	2.6359 (462)	2.6961 (573)	2.8589 (500)	1.9791 (559)	6.2629 (488)	0.1924* (510)		
C2	2.9187 (916)	8.6793 (1196)	2.5183 (1017)	7.9057 (1171)	1.4158* (985)	0.2349* (1040)	4.2647 (765)	
C3	1.5043* (753)	4.3032 (968)	1.7729* (829)	3.5289 (946)	5.5469 (805)	4.367 (847)	1.0421* (770)	3.4340 (1097)

Value in parentheses are degrees of freedom

* = non-significant values at P=0.01

M1, M2 ... C3 = walking transects

CHAPTER 4

DISCUSSION

A total of 136 butterfly species were inventoried over the nine month period (Table 5). This was just over 51% of the species listed to occur along the Kenyan Coast (Appendix 1). The list was compiled primarily from a list given to KIFCON by Steve Collins (I. J. Gordon, pers. comm.) with additions from those in the KIFCON/NMK survey (Bagine, 1992). The duration over which the Collins list was compiled is however not known, neither the extent of the range the butterflies covered.

Notably missing from the study's inventory were members of the families Lycaenidae and Hesperidae (Table 5, Appendix 1). This could have resulted from the fact that they were under sampled as they were difficult to capture and identify in flight. Sweep netting could have been biased towards the larger and more easily identified species. Hence the collection of data on their distribution and abundance was not as detailed as for other butterfly taxa. In most past surveys a similar bias is often found to occur and therefore these two families tend to be under sampled.

In Table 5 the habitat from which the specimens were collected is indicated. This does not imply that their ranges were only confined to these habitats. Some species could be observed in flight to extend into the habitat not indicated but at times positive identification was not possible without capture, for example in the Neptis and Acraea genera. Hence habitats indicated in Table 5 were restricted to only those in which specimen were captured.

Similar studies have not been carried out on the Kenyan forests and therefore the results I obtained could not be compared to any other. However, in Uganda Omoding (1992) and Trewick (1989) carried out studies that generated data for the genera Papilio, Graphium and Charaxes. When the Arabuko-Sokoke species composition in these genera is compared to that of the 11 forests they studied, the Arabuko-Sokoke Forest ranks eleventh for the number of species in these genera (Appendix II). This could be as a result in the disparity in the climatic conditions and vegetation composition which play an important role in determining biodiversity. A 10 day survey carried out by Bagine et. al. (1992) in the Arabuko-Sokoke Forest in the month of August 1991 resulted in the capture of 49 species. This compared well with 60 species netted and trapped in late July and August of 1993, during the course of my study.

The two new species recorded for the Forest, *Colotis auxo* and *Eronia leda*, were not new to science. Their absence from previous records could mainly be explained in line with an increase in their ranges. These are open grassland butterflies whose spread must have resulted from the clearing of the environs of the Forest for other land uses thus enabling the species to spread their ranges. *Eronia leda* for example is common in Kilifi Town and its environs which lie to the South of the Forest. Its presence in January only could have resulted from the occasional good climatic conditions that favour the expanding of ranges for certain species. Larsen (1991) states that *Colotis auxo* had in the past been considered to be a subspecies of *C. evenina*. This could be a reason for its absence from the list compiled at the start of the study (Appendix I), which includes *C. evenina*, as the butterfly is quite abundant in the Brachystegia zone when in season.

It would have been expected that the endemic species listed to occur along the Coast would be easily encountered. Only 50% of these were captured (Table 5) and even these 3 species were not easily encountered except for *Charaxes lasti lasti* which was often caught in the baited traps. *Charaxes blandae kenyae* was captured in the traps on only two occasions throughout the entire study period and was confined to the Brachystegia zone. The Lycaenid, *Baliochila minima*, was also captured, in localized areas within the Mixed and Brachystegia zones when netting in the mid afternoons. It is difficult to deduce which factors really determine the abundance of these species because a species like *Charaxes blandae kenyae* which has *Brachystegia spiciformis* as one of its larval food plants can be expected to be quite common, even if seasonally.

Difficulty was encountered in the analysis of the data in that the three replicate transects from each of the study zones were found to be heterogeneous when a goodness of fit test was carried out. Therefore the replicate transects could not be clumped to allow for the comparison of the different zones as single units by the use of classical statistics. However to obtain a picture of the pattern in the abundance of the butterfly community clumping was carried out and descriptive statistics applied to the data. From this patterns of abundance were obtained for the Arabuko-Sokoke butterflies.

The Brachystegia zone which had the highest count of individuals and was closely followed by the Mixed forest with an average of 81.3 +/- 27.05 and 79.4 +/- 20.19 individuals per hour respectively (Table 8). The high numbers in the Brachystegia zone must have been as a result of the openness of the woodland as compared to the other zones in the Arabuko-Sokoke Forest. This open nature also makes it a suitable habitat for species often refereed to as savanna species, these being mostly the Pierids such as *Eurema* and *Colotis*.

Insolation of the paths in this part of the Forest was also far better than in the other two zones and therefore must have allowed for greater butterfly activity. The lower canopy vegetation is also well developed in this zone and hence allowing for a greater diversity of larval food plant. Of the total butterflies counted during the census the Pierids were observed to be the most abundant accounting for 61 % (Fig 7a) of the individuals counted. The Brachystegia zone Pieridae population constituted 71.3 % (Fig 7c) of the total individuals counted in the zone and must have contributed to the high numbers.

It would have been expected that the Mixed forest zone have much higher numbers of individuals than the Brachystegia due to its visibly diverse vegetation resultant of higher rainfall and better soils. The paths were however quite cool and dark in the wet season, as a result of the shading of transect paths by trees, thereby making butterfly activity considerably lower due to the reduced sunlight on the transects. Abundance was high due to the presence of the species *Leptosia alcesta* which was observed to be particularly very abundant at the end of the rainy spell in February and July (Fig. 11a). This butterfly was mainly found in the less sunny paths of the Mixed forest zone. *Colotis euippe* and *Hypolimnas misippus* could also have contributed to this high numbers. The two zones are habitats for the most abundant species in the forest hence the similarity in the species composition and abundance within them (Table 9; Table 10).

The Cynometra zone on the other hand had the lowest abundance and its population was found to constitute of Nymphalids mainly. This low diversity could be attributed to the poor soil conditions in this zone which tend to support mainly the Cynometra trees and Croton thickets. There is hardly any undergrowth and even the deciduous trees die back early due to the relatively little rainfall in this zone. The Nymphalidae population was enhanced by the large numbers of *Hypolimnas misippus* and *H. deceptor* that persisted for quite a while in the zone. Occasional high abundance with the appearance of the migrant species raised the count in the often butterfly less zone. The Papilionidae appearing at the onset and after the rains resulted in the high seasonal abundance within Cynometra zone between May and July. Graphiums suddenly appeared and in very large numbers making the area quite butterfly rich as compared to the dry season months.

The most common species in the study area were found to be present in the forest throughout the entire study period (Table 9). Species such as *Leptosia alcesta* increased to numbers as high as about 300 per hour and at times fell to very low numbers. The migrant species such as the *Phalanta phalantha* and *Catopsilia florella* suddenly appeared in hundreds only to later fall in number to the point of being considered rare in the forest. The species that persisted at reasonably constant numbers belonged to the family Pieridae (Table 7).

Owen (1975) noted that forest butterflies are considerably less seasonal as compared to the savanna species. Peaks in abundance are although known to occur for most insects usually with the onset of the wet and dry seasons within the tropics (Owen, 1975; Wolda, 1982). In

Arabuko-Sokoke an average of 66.4 +/- 18.84 butterflies were sighted in an hour for the entire census period. The peak abundance which occurred during the May to July wet season was as high as 88.8 +/- 6.12 individuals per hour. The dry season months of February to April were also found to have an average greater than that for the enti·e sample period as compared to the average for the cooler dry season of August to October, 77.6 +/- 1.64 and 41.0 +/- 4.17 respectively (Table 7). There was a noticeable change in abundance resulting from the climatic changes. This is best shown by the average numbers sighted per hour falling to about half of what they were in the wet season in the cool dry season months of August to October. The relative high abundance in the warm dry season months of February to April must have been as a result of the prolonged short rains into January of 1993 thus buffering the drastic change in abundance that would have been expected to have occurred.

Similar patterns of abundance were found to occur in the three vegetation zones with the abundance peaks highest in the wet season. This was with an exception of the Mixed forest zone that had its highest abundance peak in February (Fig. 7). This resulted from the high numbers of *Leptosia alcesta* and *Hypolimnas misippus* towards the end of the January rains (Table 7). This rainy season starting in November of 1992 extending into January of 1993 must have lead to a build up of numbers in the various species and their persistence into those months that are usually dry and hot. The Mixed forest maintained its population at high numbers as a result of its lower canopies being more shaded and hence experiencing less of the die back in certain larval food plants and adult nectaring plants as was the case in the more open Brachystegia zone and rainfall poor Cynometra zone.

For example the weed feeding Pierids such as *Leptosia alcesta* and *Eronia cleodora* maintained high numbers (Fig. 11). The rainy season butterfly *Hypolimnas misippus* also maintained high numbers well into March. This butterfly commonly occupies the open habitat and the high numbers found in the Forest after the rains are believed to be as a result of the population retreating into the Forest from the more open habitats (Smith D. A. J. in litt to I. J. Gordon, pers. comm.).

In April at the onset of the rains the overall numbers were also observed to be high. The sudden emergence of two migrant species, *Catopsilia florella* and *Phalanta phalantha*, must have contributed greatly to this high numbers (Fig. 10d,e). The increase in undergrowth with the onset of then rains resulted in an increase in food plants for several Pierids and Nymphalids, and hence an increase in their numbers (Fig 8). Wolda (1980) notes that with the onset of the rains the activity level of many insects is found to increase as they move to optimum breeding areas within their habitats meaning that the noticeable increase in numbers and calls in many species may not necessarily be as a result of an increase in abundance but could also be as a result of increased activity levels. This can be evidenced in that the females of most species that are often quite uncommon along the Forest paths and open areas were encountered more during the census and specimen collection exercises. This resulted from their increased activity as they went about egg laying on plants along the paths and in these open areas.

A sudden drop in the number of individuals observed in the cooler dry season months of August to October (Table 7) must have arisen from the increase of factors that adversely affected the butterfly community. Favourable climatic factors must have resulted in the increase of natural enemies; predators and parasitic organisms. This is best shown by the drastic fall in the number of the members of the genus Papilio from 3 to almost none.(Fig. 9a). Few species were found to persist into September and even those that did had very few individuals in flight (Table 7). The favourable conditions that enabled the butterflies to increase in number may also have led to the increase in abundance of their natural enemies. Conditions may also have become suitable for the spread of diseases within the butterfly population and hence resulting in a further reduction in their abundance.

Owen (1975) notes that changes in the total abundance of the butterflies may be reduced due to the resource partitioning patterns in time that occur between intergeneric or interspecific competitors. With the disappearing of certain species comes an increase in abundance of conspecifics. It would have been of interest to test this hypothesis but this would require the use of methods that can determine the exact densities of species in the genera in question. This in turn requires that sampling be carried out within an area in which the sample points will be homogenous so as to allow for sufficient data collation. However this did not seem the case in the Arabuko-Sokoke butterfly populations when the abundance in some of the genera was

"No sun no butterflies' is a common saying among many butterfly enthusiasts. This implies that for butterfly activity a clear sunny day is a prerequisite. Sunshine affects butterfly activity through insolation and irradiation. Rainfall and temperature are the main weather conditions thought to play a major role on the abundance of butterflies. Rainfall has an effect on the phenology of the larval foodplants and nectaring sources, while temperature affects the amount of heat available to warm body temperatures to the threshold necessary for butterfly activity. Throughout the study period air temperatures were always above that considered necessary for butterfly activity and therefore were never a determining factor as to whether sampling was to be carried out or not.(Fig. 6).

Correlation tests between temperature and abundance were mainly aimed at determining their association. This was positive and significant for both the minimum and maximum monthly temperatures. Maximum temperature had the weaker association which must have arisen from butterflies seeking shade away from the hot pathways. The higher the minimum temperature the earlier the time of day at which butterfly activity began and therefore more butterflies counted. The association of abundance with rainfall was also positive and significant for both rainfall from the three previous months and rainfall of the month.

Although temperature and rainfall had positive associations these were too weak to suggest that these climatic factors could be the direct cause in the fluctuation of abundance. Studies on the effects of weather on butterflies have been carried out but with very little general analysis. Pollard (1988) attributes this to the shortness of the durations over which data collection is done, thereby limiting the identification of the effects only to major features in the environment. In the Arabuko-Sokoke several other factors must have played an important role in determining the abundance in that even the three replicate transects chosen within the three vegetation zones were not homogenous when a goodness of fit test was carried out. These factors must act even within the transect level as sections within any given transect could be observed to be distinct in composition and abundance. The influence of these factors could be indirect even making them more difficult to identify.

The Margalef index was employed in an effort to try and effectively differentiate between the Mixed and Brachystegia forests which could not be effectively differentiated on the basis of species number alone from the census data (Table 8). These two zones were found to be habitat for nearly all the butterflies censused. Species composition obtained from netting and trapping ranked the Brachystegia zone as the most diverse with 114 species. Next came the Mixed forest zone and lastly the Cynometra zone with 105 and 48 species respectively. The Margalef index takes into account the abundance of the species sampled and thus can help to further differentiate in situations where the species number of the sample areas are very similar.

In all the zones the species composition was similar within transects as the seasons progressed. Species number increased as the wet season set in and then fell after the rains in all transects. When the trend of species richness (Margalef indices) within the zones was tested statistically to determine if the difference among transects was significant, non significant results were obtained (Sec. 3.4.1). Thus implies that all the transects experienced similar changes in species richness.

Similar results were obtained with the Shannon species diversity indices with exception in the Brachystegia zone in which there was a significant difference in the trend. This was due to the dissimilarity of transect 3 which had Shannon diversity indices lower than those for the other two replicate transects for several months.

Shannon diversity indices for the different transects were subjected to the Hutcheson t-test and showed that there were significant differences between the diversity indices (Table 14). Thus shows that each of the transects had its distinct population structure that made it different from other transects although this was not physically evident to the observer. Eveness was greatest amongst the Cynometra transects which could lead to ranking the Cynometra zone as the most diverse. This would not be the case if species composition alone was taken as the ranking factor.

Forests are habitats to many species of organisms which may be lost or diminished if their structure are changed. Changes in the socio-economic activities of the local population living around the Arabuko-Sokoke Forest threaten the future existence of this Forest in its present condition. Poverty is prevalent throughout the entire region and coupled with an increase in population, the attitude of the locals towards the Forest as a reservoir for future farm is understandable (Mogaka,1991). Although the Forest coverage remains the same, poaching of trees both for commercial and domestic use has markedly lowered the quality of the Forest (Wass, 1994). KIFCON (1992) carried out surveys in which timber and non-timber products, biodiversity and socio-economic factors were studied. This information can be instrumental in the formulation and planning of the Forests future management.

Most needed is the participation of the local community in monitoring the use of the Forest. This could be most effective if they would willingly inform forest authorities on any illegal activities taking place in the parts of the Forest that they neighbour. Problems of on farm damage from forest animals, for which there is no compensation, alienate locals from the Forest. Many are offended by their restriction from entry and utilisation of the Forests resources. Activities that enable locals to elevate their living standards by extracting forest products at sustainable levels coupled with environmental education programmes are a must if the local communities are expected to be more understanding of the importance of the forest. The present and future gains from the forest must be perceived to outweigh the misery inflicted upon the community by wildlife and restricted use of its vegetation.

The Arabuko-Sokoke Forest Management Team (ASFMT) formed to ensure the coordinated working of all the parties interested in the forest's conservation is a step in the positive direction. This team charged with the responsibility of trying to develop means of earning revenue in addition to that obtained from the Government can help in ensuring that there is adequate funding for the proper management of the forest. Ways must be sought through which the surrounding communities can be represented in this team so as to incorporate their views when management policies are drawn. The local interest though at times extremely antagonistic to the conservation of the Forest must be given due consideration as they pose the greatest threat to the conservation of the Arabuko-Sokoke Forest.

Recommendations

1. Long term study of the Arabuko-Sokoke butterflies so as to obtain a more detailed inventory. Greater effort being directed towards the families Lycaenidae and Hesperidae.
2. Long term monitoring of the butterfly abundance in the Arabuko-Sokoke coupled with detailed study of the population biology of certain species. This will help in determining the extent to which increased activity due to seasonal change in climate affects abundance.
3. Inventories of butterflies from other parts of Kenya should be developed or updated. The species richness and diversity of these ecosystems/regions worked out in order determine their importance as suitable butterfly habitats.
4. Further research should be carried out on the foodplants of butterfly most butterflies which in many instances are known only to the genus level. Investigation into the influence of plant phenology on the abundance of butterflies should also be looked into.

5. Research aimed at identifying butterfly species that can be used as ecological indicators of various ecosystems should be initiated. Also research should be carried out aimed at determining the conditions most suitable for census counts coupled with the development of standard methods for the regional forests. This could help in generate data that is comparable for the different ecosystems/regions.

Ways must sought through which the local community can be enlightened on the global importance of the Arabuko-Sokoke Forest and the benefits its conservation holds in store for the local and global community in future.

References

Anon, 1981. The Wildlife (Conservation and Management) Act. Legal Notice No.152, Cap 376, Government Printer, Nairobi.

Barnes, R. D.,1980. Invertebrate Zoology. Holt-Saunders, Philadelphia.

Bagine,R., Muhangani, J. M. and J M Ruthiri ,1992. Arabuko-Sokoke Forest, Invertebrate Report pp 13. Unpubl. KIFCON/NMK, Report, Nairobi.

Beentje, H. J., 1990. The Forests of Kenya. In Mitt. Inst. Allg. Bot. Hamburg Band 23a, pp265-286

Bennun, L. A. and E. M. Waiyaki,1991. Arabuko-Sokoke Ornithological Report pp 15. Unpubl. KIFCON/NMK/ICBP, Report, Nairobi.

Biodiversity Support Program, 1992. Central Africa: Global Climate Change and Development - Synopsis. Corporate Press, Landover, Maryland.

Blackett, H. L., 1994. Forest Inventory Report Number 2: Arabuko-Sokoke. KIFCON, Report. Nairobi. Kenya.

Britton, P. L. and D. A. Zimmerman, 1979. The Avifauna of Sokoke Forest, Kenya. Jour. of EANHS and NMK 169:1-15

Burgess, N. D. and C. Muir (Eds), 1994. Coastal Forests of Eastern Africa: Biodiversity and Conservation. London , UK: The Society for Environmental Exploration.

Carpenter, G. D. H., 1920. A naturalist on Lake Victoria. T. Fisher Union.

Carpenter, G. D. H., 1925. A naturalist in East Africa . Claredon Press, Oxford. 187 pp.

Carpenter, G. D. H. and E. B. Ford, 1933. Mimicry. Methuen, London.

Chira, R. M., 1993. Ecological study of the Herptofauna in the Arabuko-Sokoke and Gede Coastal Forests of Kenya M.Sc. Thesis, University of Nairobi.

Clark, P., Gabara, C., Garara, W., Kisokou, K., Kwapena, N., Laufa, M., Ning, L., Orari, R., Parsons, M. and B. Rairi,1983. Managing Animal Resources-Butterfly farming in Papua New Guinea. National Academy Press. Washington D. C..

Collar, N. J. and S. N. Stuart, 1985. Threatened birds of Africa and related islands: the ICBP/IUCN Red Data Book, Part 1, Third edition, Cambridge, UK: ICBP/IUCN.

Collar, N. J. and S. N. Stuart, 1988. Key Forests for the Threatened Birds in the Afrotropical and Malagasy Realm. ICBP Monograph No. 3. Cambridge, U.K.

Collins, N. M., 1987. Butterfly Houses in Britain, The consevation implications.Report IUCN, UK.

Collins, N. M. and M. G. Morris, 1985. Threatened Swallowtail, Butterflies of the World. The IUCN Red Data Book. IUCN Gland and Cambridge. vii + 401 pp + 8 pls.

Collins, N. M. and J.A. Thomas (Eds), 1991. The Conservation of Insects and their Habitats. 15 th Symposium of the Royal Entom. Soc. of London, Academic Press, London, pp

Courtney, S. P., 1984. Habitat versus foodplant selection. In The Biology of Butterflies Symposium II of Royal Entomological Society of London. (Eds) Vane-Wright, R. I. and P. R. Ackery. Academic Press, London. pp 89-90.

Dethier, V. G., 1970. Chemical interactions between plants and insects. In Chemical ecology. (Eds) Sondheimer E. and J. B. Simeone. New York. pp 83-102.

Dethier, V. G., 1980. Evolution to receptor sensitivity to secondary plant substances with special refernce to deterrants. American Naturalist. 115: 45-66.

Eltringham, H., 1890. Afican mimetic butterflies. Claredon Press, Oxford. 176pp.

Eltringham, H., n.d.. Monograph of the African species of Lepidoptera. Transanctions of the Entomological Society. London.

Erhardt, A. and J. A. Thomas, 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) Collins, N. M. and J.A. Thomas, 15 th Symposium of the Royal Entom. Soc. of London, Academic Press, London, pp. 213-236.

FAO, 1988. An Interim Report on the state of Forest Resources in the Developing Countries. FAO , Rome.

Feeny, P., 1975. biochemical coevolution between plants and their insect herbivores. In Coevolution of animal and plants. (Eds) Gilbert, L. E. and P. H. Raven. Austin, Texas. pp 3-19.

Heath, J., 1981. Threatened Rhopalocera in Europe. Council of Europe. Nature and Environment Series No. 23. Strasbourg.

Houghton, R. A.,1993. Role of Forests in Global Warming. In.World Forests for the Future: their use and conservation (Ed) Ramakrishra, k. and G. M. Woodwell. Yale University.New York.

Houghton, J. T., G. J. Jenkins and J. J. Ephraums (Eds), 1990. Climate Change: the IPCC Scientific Assessment. Cambridge University press, Cambridge, England.

IUCN, 1995. Kenya's Indigenous Forests: Status , Management and Conservation. (Ed) P. Wass. IUCN, Gland, Switzerland and Cambridge, UK. xii + 205pp.

Kelsey, M. G. and T. E. S. Langton, 1984. The conservation of the Arabuko-Sokoke Forest, Kenya. ICBP Study Report No. 4, Cambridge, UK.

KIFCON, 1992. Working Papers of Arabuko-Sokoke Forest, Vol 1 and 2. Unpubl. Report, KIFCON, Nairobi.

KIFCON/ BLI, 1993. Arabuko-Sokoke Forest Pilot Project Implementation Document. Unpubl. Report, KIFCON, Nairobi.

Larsen, T. B., 1991. The Butterflies of Kenya and their Natural History. Oxford University Press, Oxford.

Larsen, T. B., 1993. Butterfly Conservation Symposium - Keele University, September 1993.

Matthes, D., 1976. Food and Relationships with other species. In Encyclopedia of Ecology (Ed in chief) G. Bernhard. Van Nostrant Rienhold. New York. 705 pp.

Magurran, A. E., 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, New Jersey. pp179.

Maundu, P. M., 1993. Socio-economic survey and forest attitude report of the community bordering Arabuko-Sokoke Forest and Game Reserve. Unpubl. report

Mellanby, K., 1967. Pesticides and Pollution, Collins, London.

Mogaka, H., 1991. Local utilisation of Arabuko-Sokoke Forest Reserve. Unpubl. report, KIFCON, Nairobi.

Moomaw, J.C., 1959. A Study of the Plant Ecology of the Coast Region of Kenya Colony. Department of Agriculture, EAAFRO.

Munir, V., 1993. Golden Cat in Arabuko-Sokoke ? EANHS Bulletin, 23:51

Myers, N., 1989. Deforestation rates of Tropical Forests and Their Climatic Implications. Friends of the Earth, London.

Munasinghe, M., 1992. Biodiversity protection policy: Environmental valuation and distribution issues. Ambio 21(3):227-236.

New, T. R., 1991. Butterfly Conservation. Oxford University Press. Melbourne.

Omoding, J., 1992. Status, Distribution and Ecology of Butterflies in the Bwindi Impenetrable Forest, South-Western Uganda. M.Sc. Thesis, Makerere University, Kampala.

Owen, D. F., 1971. Tropical Butterflies. Claredon, Oxford Univ Press. 214 pp.

Parker, S. P. (Ed),1982. Synopsis and Classification of Living Organisms. McGraw-Hill, New York. 2 Vols.

Plotkin, M. J. and L. M. Falmolene, 1992. Sustainable harvest and Marketing of Rain Forest Products. Island Press, Washington, D.C.

Pollard, E., 1977. A method of assesing changes in the abundance of butterflies. Biological Conservation 12, 115-124.

Pollard, E., 1982. Monitoring butterfly abundance in relation the management of a nature reserve. Biological Conservation, 24, 317-328

Pollard, E., 1988. Temperature, Rainfall and Butterfly Numbers. Journal of Applied Ecology 25,819-828

Pollard, E. and T. J. Yates, 1993. Monitoring Butterflies for Ecology and Conservation. Chapman and Hall, London. pp 274.

Posey, D. A., 1993. Indigenous knowledge in conservation and use of World Forests. In World Forests for the Future: their use and conservation (Ed) Ramakrishra, k. and G. M. Woodwell. Yale University. New York

Poulton, E. B., 1884 -1903. Papers on Lepidopterous larvae. Transanctions of the Entomological Society. London.

Poulton, E. B., 1904. African butterflies. Transanctions of the Entomological Society. London.Vols 1 and 2.

Poulton, E. B., 1913. Mimicry and inheritance of small variations. Bradbury, Agnew. London.

Pratt D. J. and M. D. Gwynne, 1977. Rangeland Management and Ecology in East Africa. Hodder and Sutton. London.

Pyle, R. M.,1976. Conservation of Lepidoptera in the United States. Biological Conservation. 9: 55-75.

Robertson, S. A. and W. R. Q. Luke, 1993. Kenya Coastal Forests. Report of the NMK/WWF Coast Forest Survey. Nairobi, Kenya: WWF.Coastal Forest Survey. Unpubl. report. WWF, Nairobi.

Robinson, J. G. and K. H. Redford, 1991. Neotropical Wildlife Use and Conservation. University of Chicago Press, Chicago.

Rowe, R., Sharma, N., and J. Browder, 1992. Deforestation: Problems, causes, and concerns. In Managing the World's Forests: Looking for the balance between conservation and development.(ed) N. P. Sharma, Dubuque, I.A. , Kendall /Hunt Publishing Company.

Samways, M. J., 1994. Insect Conservation Biology. Chapman & Hall. London.

Sharma, N., Rowe, R. N. and J. Browder, 1992. World forests in perpective. In Managing the World's Forests: Looking for the balance between conservation and development.(ed) N. P. Sharma, Dubuque, I.A. , Kendall /Hunt Publishing Company.

Thomas, J. A., 1984. The conservation of butterflies in temperate countries: past efforts and lessons for the future The Biology of Butterflies. (Eds Vane-Wright, R. I. and P. R. Ackery), pp 333-353. Symposium II of Royal Entom. Society of London. Academic Press, London.

Torben et al (1980). The butterfly fauna of a secondary bush locality in Nigeria. J. Resp. Lep. 18(1):4 -23.

UN-FAO, 1992. The Forest Resources of the Tropical Zone by Main Ecological Regions. Forest Resources Assessment 1990 Project. Rome.

Vanclay, J. K., 1993. Saving the tropical forest: needs and prognosis. Ambio 22: 225-231.

Vane-Wright, R. I. and P. R. Ackery(1984).The Biology of Butterflies. Symposium II of Royal Entomological Society of London. Academic Press, London.

Vietmeyer, N. D., 1979. Butterfly ranching is taking wing in Papua New Guinea. Smithsonian 1979:19-130.

Waas, P., 1994. A Forest with a Future? Swara. Volume 17, No. 3.

Wairungu, S., Awimbo, J. and B. Kigomo, 1993. An ecological survey of the nature reserve within the Arabuko-Sokoke Forest Reserve. in Robertson, S. A. and W. R. Q. Luke. Kenya Coastal Forests. Report of the NMK/WWF Coast Forest Survey. Nairobi, Kenya: WWF.

Williams, J. G., 1969. A fieldguide to the butterflies of Africa. Collins, London. pp 1-229.

Wilson, E. O., 1992 The Diversity of Life. Havard Univ. Press. Masachusetts.

Wolda, H., 1980. 1. Seasonality of tropical insects. Leafhoppers (Homoptera) in Lascumbers: Panama. Journal of Animal Ecology 49,277-290.

Woodwell, G. M., 1993. Forests: What in the world are they for? In .World Forests for the Future: their use and conservation (Ed) Ramakrishra, k. and G. M. Woodwell. Yale University. New York.

World Bank, 1992. World Development Report 1992 Development and Envoronment. World Bank, Washington DC.

Zar, J. H., 1984. Biostatiscal analysis. Second edition. Prentince-Hall International, Inc. Englewood cliffs, New Jersey.

Appendix I

Previously recorded butterflies for Arabuko-Sokoke forest and its environs

Family	Species	
Papilionidae	*Papilio dardanus*	*Graphium leonidas*
	P constantinus.	*G. kirbyi*
	P. nireus	*G. colonna*
	P. ophidicephalus	*G. polistratus*
	P. demodocus	*G. policenes*
	Graphium philonoe	*G antheus*
	G. angolanus	
Pieridae	*Catopsila florella*	*Colotis eucharis*
	Eurema regularis	*C. daira*
	E. brigitta	*C. evagore*
	E. hecabe	*C. eris*
	Pinacopteryx eviphia	*C. euippe*
	Nephronia argia	*Belenois aurota*
	N. thalassina	*B. creona*
	N. buqueti	*B. gidica*
	Eronia cleodora	*B. thysa*
	Colotis antivippe	*Dixeia charina*
	C. amatus	*D. spilleri*
	C. phisadia	*Appias sabina*
	C. vestalis	*A phaola*
	C. vesta	*A. lasti*
	C. ione	*A. epaphia*
	C. haetare	*Leptosia alcesta*
	C. danae	*Mylothris agathina*
	C. regina	
Nymphalidae	*Libythea labadaca*	*Charaxes saturnus*
	Danaus chrysippus	*C. castor*
	Tirumula petriverana	*C. brutus*
	Amauris niavius	*C. numenes*
	A. ochlea	*C. violetta*
	Melanatis leda	*C. cithaeron*
	Bicyclus safitza	*C. etesipe*
	B. anynana	*C. achaemenes*
	Henotesia perspicua	*C. jahlusa*
	Ypthima asterope	*C. blanda*
	Y. rhodesiana	*C. ethalion*
	Y. jacksoni	*C. kirki*
	Y. granulosa	*C. contrarius*
	Physcaeneura leda	*C. guderiana*
	Charaxes varanes	*C. zoolina*
	C. candiope	*Euxanthe wakefieldi*
	C. protoclea	*Euryphura achlys*
	C. lasti	*Bebearia chriemhilda*

Appendix I cont.

Nymphalidae	*Bebearia cocalia*	*Junonia hierta*
	Euphaedra noephron	*J. natalica*
	Hamanumida daedalus	*J. terea*
	Harma theobene	*Precis octavia*
	Euptera kinugnana	*Vanessa cardui*
	Pseudathyma lucretioides	*Lachnoptera ayresii*
	Pseudacraea lucretia	*Phalanta phalantha*
	P. biosduvali	*P. eurytis*
	P. eurytus	*Acraea perenna*
	Neptis saclava	*A. pharsalus*
	N. laeta	*A. encedon*
	N. serena	*A. esebria*
	N. kiriakoffi	*A. eponina*
	N. rogersi	*A. petraea*
	N. trigonophora	*A. egina*
	N. carcassoni	*A. acrita*
	N. melicerata	*A. braesia*
	N. goochi	*A. equitorialis*
	Sallya garega	*A. oncaea*
	Byblia illithya	*A. natalica*
	B. envatora	*A. caldarena*
	Neptidopsis fulgurata	*A. rabbai*
	Eurytela hiarbas	*A. satis*
	E. dryope	*A. zetes*
	Hypolimnas misippus	*A. anemosa*
	H. deceptor	*A. pseudolycia*
	H. anthedon	*A. cuva*
	H. dubia	*A. insignis*
	H. usambara	*A. neobule*
	Salamis parhassus	*A. matuapa*
	S. anacardii	*A. aganice*
	S. cacta	*A. epaea*
	Junonia oenone	*Pardopsis punctatissima*
	J. orithya	
Lycaenidae	*Pentila tropicalis*	*Spalgis lemolea*
	P. rogersi	*Lachnocnema bibulus*
	Ornipholidotos peucetia	*Myrina silenus*
	Teriomima subpunctata	*M. dermaptera*
	T. micra	*Aphnaeus coronae*
	T. parva	*A. flavescens*
	Baliochila hildergarda	*Spindasis victoriae*
	B. dubiosa	*S. homeyeri*
	B. stygia	*S. tavetensis*
	B. minima	*Chloroselas pseudozeritis*
	B. latimarginata	*C. minima*
	Eresinopsides bichroma	*Axioxerses tjoane*
	Deloneura ochrascens	*A. styx*
	Aslauga pupurascens	*A. punicea*

Appendix I cont.

Lycaenidae	*Axioxerxes amanga*	*Anthene lasti*
	Iolaus sidus	*A. pitmani*
	I. aemulus	*A. lunulata*
	I. diametra	*A. amarah*
	I. silanus	*Neurellipes gemmifera*
	I. mermis	*Cupidopsis iobates*
	I. pallene	*Pseudonacaduba sichela*
	I. maritimus	*Lampides boeticus*
	I. silarus	*Leptotes pirithous*
	I. lalos	*L. babaulti*
	I. crawshayi	*Tuxentius calice*
	I. poultoni	*T. cretosus*
	I. bowkeri	*Tarucus grammicus*
	Hemiolaus caeculus	*Zizina antanossa*
	Hypolycaena philippus	*Z. hylax*
	H. pachalica	*Actizera lucida*
	H. buxtoni	*Azanus ubaldus*
	Leptomyrina hirundo	*A. jesous*
	L. gorgias	*A. mirza*
	Philodeudorix caerulea	*Eicochrysops hippocrates*
	Deudorix antalus	*Euchrysops malathana*
	D. diocles	*E. osiris*
	D. dinochares	*E. barkeri*
	D. dinomenes	*Lepidochrysops peculiaris*
	D. dariaves	*Freyeria trochylus*
	Anthene lemnos	
Hesperidae	*Coeliades anchises*	*Gorgyra subflavidus*
	C. forestans	*G. diva*
	C. pisistratus	*G. johnstoni*
	C. sejuncta	*Pardaleodes incerta*
	C. keithloa	*Teniorhinus herilus*
	Celaenorrhinus galenus	*Acada biseriatus*
	Tagiades flesus	*Acleros ploetzi*
	Eagris nottoana	*A. mackenii*
	Sarangesa motozi	*Semalea arela*
	S. lucidella	*Zophopetes dysmephila*
	S. maculata	*Z. nobilior*
	Caprona pillaana	*Gretna carmen*
	Netroblane canopus	*Fresna nyassae*
	Abantis venosa	*Pelopidas thrax*
	Spiala confusa	*Borbo fatuellus*
	S. spio	*B. detecta*
	S. kituina	*B. micans*
	S. dromus	*B. borbonica*
	Gomalia elma	*B. gamella*
	Astictopterus stellata	*Geneges niso*
	Kedestes callicles	

Source: Bagine *et. al.* (1992) and Steve Collins' list (I. J. Gordon, pers. comm.)

APPENDIX II

Comparison of Papilio, Graphium and Charaxes butterfly species richness in 12 Uganda forests with Arabuko-Sokoke,Kenya.

Forest	Graphium sp.	Papilio sp.	Charaxes sp.	Total
Bwindi Impenetrable	6	18	32	56
Semliki	7	15	28	50
Itwara	5	13	26	44
Kibale	5	17	21	43
Bugoma	6	12	24	42
Budongo	4	12	25	41
Maramagambo/Kalinzi	5	15	19	39
Mabira	3	13	22	38
Elgon	3	11	22	36
Sango Bay	4	12	22	30
Arabuko-Sokoke	6	4	14	24
Kasyoha-Kitomi	3	8	10	21
Rwenzori	0	5	10	15

Source: Omoding (1992).