THE DIVERSITY AND ABUNDANCE OF INSECT SPECIES IN THE ABIRIW AND ODUMANTE SACRED GROVES IN THE EASTERN REGION OF GHANA

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THE DIVERSITY AND ABUNDANCE OF INSECT SPECIES IN THE ABIRIW AND ODUMANTE SACRED GROVES IN THE EASTERN REGION OF GHANA

BY

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B.SC. (HONS) ZOOLOGY.

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY ENTOMOLOGY DEGREE

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DECLARATION

I hereby declare that this research was undertaken by me, Tchuidjang Nganso Beatrice, towards the award of Master of Philosophy in Entomology in the African Regional Postgraduate Programme in Insect Science (ARPPIS), University of Ghana, Legon. All references to other people's work have been fully acknowledged and this work has not been presented in part or in full anywhere for any other degree.

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ABSTRACT

Sacred groves around the world represent a traditional form of community-based conservation. They have been adopted as one of the *in situ* strategies by many human societies, including Ghana to mitigate the loss of biological resources using complex traditional beliefs and taboos. In Ghana, there are estimated to be 2,000-3,200 sacred groves with about 80 % found in the southern half of the country, and they ranged in size from hundreds of hectares of forest to small areas of about 0.5 ha containing single trees or a few stones. Despite recent interest in sacred groves as community-based conservation areas of natural resources in Ghana, many have been completely destroyed and many others are under imminent threats from anthropogenic activities due to lack of enforcement of traditional edicts to check encroachment. To protect sacred sites and considering the fact that threats to sacred natural sites vary from region to region and even from one grove to another, several researchers have suggested that a holistic and multidisciplinary approach to sacred grove conservation should be adopted. Among these, the biological resources within sacred groves should be documented in order for the international conservation communities to better appreciate the global significance of sacred groves in biodiversity conservation. In Ghana, most surveys to document biodiversity in sacred groves have focused on their botanical values, ethno botanical or socio-cultural functions. Few attempts have been made in the country to assess the diversity of insects in sacred groves. To this end, a six month survey of the insect fauna in the Abiriw and Odumante sacred groves in the Akwapim North and South Districts, respectively of the Eastern Region of Ghana was conducted to characterize resident insect species diversity and abundance. The transect count method, sweep net, aerial net, malaise traps, charaxes traps, pit fall traps, yellow pan traps, flight interception traps and light trap were used to sample the insects. Community diversity was characterized in terms of (a) the number of species accumulated versus sampling effort, (b) nonparametric richness estimates, (c) Margalef, Simpson's and Shannon-Weiner richness and diversity indices, and (d) Complementarity of communities. A total of 4,649 individual insects were trapped across all sites, representing 409 species and 18 orders. Diversity of the insect communities, quantified in terms of species richness was higher at the 400 m^2 Abiriw grove than the 250 m^2 Odumante grove. However, the Abiriw grove harboured a resident insect community that was less diverse than that of the Odumante. Also, the Abiriw grove harboured a resident insect community that was not distinctive from that of the Odumante grove. These findings add to the body of knowledge that indicates that large groves are the foundation of successful conservation programs. Nonetheless, it was observed that both groves harbour a number of species that appeared vulnerable to dynamics of forest fragmentation based on changes in their relative abundance across sites. The findings are discussed in the context of potential indicator species and theoretical predictions of at-risk species. Additionally, it was observed that both sacred groves harbour a number of economic and ecological important insect species. This observation adds to the body of knowledge that indicates that sacred groves facilitate persistence of forest species in highly fragmented landscapes. Based on these observations, it can be hypothesized that the documentation of the insect fauna in sacred groves in the different regions of Ghana will be useful in crating global awareness of the insect diversity value of these relict forest patches and therefore facilitates their integration into the Protected Area Network (PAN).

DEDICATION

To my father, Mr. Nganso Andre and my mum, Mrs. Nganso Elize, my siblings and above all, God Almighty.

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LIST OF ABBREVIATIONS

WWF	World Wide Fund for Nature
IUCN	International Union for the Conservation of Nature
PAN	Protected Area Network
MAB	Man and Biosphere
NMK	National Museums of Kenya
KENRIK	Kenya Resource Centre for Indigenous Knowledge
UNESCO	United Nations Educational, Scientific and Cultural Organization
CBD	Convention on Biological Diversity
WHC	World Heritage Convention
GACON	Ghana Association for the Conservation of Nature
CIPSEG	Cooperative Integrated Project on Savannah Ecosystems in Ghana
CFCU	Coastal Forest Conservation Unit

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background

Man' survival on earth depends on the availability of natural resources in the ecosystem. However, the global biological resources are threatened by habitat alteration, over exploitation, pollution, global climate change and invasion by exotic species (Wilson, 1985; Khan *et al*., 2008). In view of the adverse effects of biodiversity degradation, there has been increasing interest in environmental issues throughout the world (Schaaf, 2003; Attuquayefio and Fobil, 2005), and the conservation of biodiversity has become an issue of national regional and global significance. Various *in situ* and *ex situ* conservation practices have been undertaken in different parts of the world to mitigate the loss of biodiversity. Also, many laws governing the conservation of biological resources have been enacted from time to time (Attuquayefio and Fobil, 2005; Rajasri *et al.*, 2011). Beside these formal laws, indigenous communities in different parts of the world adopted traditional conservation practices which contributed to the conservation and protection of biodiversity (Ntiamoa-Baidu, 1995; Bhagwat and Rutte, 2006; Ormsby and Bhagwat, 2010). A good example of such traditional practices is the conservation and protection of sacred groves (Barrow and Pathak, 2005; Khan *et al.*, 2008).

Sacred groves are small patches or islands of remaining original habitat (Kingdon, 1989), or forest of various dimensions partially or fully protected by local religious and/or cultural agents (Campbell, 2004; Dafni, 2007; Yadav *et al*., 2010). They are found on all continents except Antarctica (Bhagwat and Rutte, 2006). India has the highest concentration of sacred groves in the world (Ormsby and Bhagwat, 2010). Experts estimate that the total number of sacred groves in India could be in the range of 100,000-150,000 (Malhotra *et al.*, 2001). In

Ghana, this number is estimated to 2,000-3,200 among which, about 80% occur in the Southern half of the country (Gordon, 1992). Amoako-Atta (1998) reported that almost all the 240 forest reserves in Ghana have close links with sacred groves and/or socio-cultural ties with the local community in the country. Some of the well-known sacred groves in Ghana include: the Tafi Atome Monkey Sanctuary in the Volta region (Arhin, 2008), the Boabeng-Fiema Monkey Sanctuary in Brong Ahafo Region (Fargey, 1991), the Anweam Sacred Grove in the Esukawkaw Forest Reserve (Amoako-Atta, 1998) and Abiriw sacred grove (Kangah-Kesse *et al.,* 2007) both in Eastern Region and the Malshegu Sacred Grove in the Northern Ghana (Dorm-Adzobu *et al*., 1991).

It is believed that local communities across the world conserved sacred forest primarily for spiritual reasons (Sarfo-Mensah and Oduro, 2007; Ormsby and Bhagwat, 2010). Many have been allocated special dwelling places that are strictly protected by customary laws and/or beliefs and enforced by taboos and only occasionally visited for important ceremonies and religious rituals (Sarfo-Mensah and Oduro, 2007; Malhotra *et al.*, 2001; Rajasri *et al*., 2011). The traditional rules often prohibit the felling of trees, killing of animals, collection of firewood and medicinal plants by local people. These traditional beliefs and taboos with no legal backing have been strong enough to maintain the integrity of sacred sites for many generations (Hens, 2006; Ngumia and Oba, 2003).

Restrictions to natural sacred sites have led to well-conserved areas which are perceived as important nodes for habitat restoration, sources of rare species, and links between sites (Jonathan, 2008), and as such can play a critically important role in ecological conservation (Ngumia and Oba, 2003; Bhagwat and Rutte, 2006; Joanathan, 2008; Ntiamoa-Baidu, 1995). With the current increase rate of biodiversity loss, several international organizations such as the World Wide Fund for Nature (WWF) and the International Union for the Conservation of Nature (IUCN) among others have taken interest in the conservation of sacred groves and their incorporation into the Protected Area Network (PAN). Several countries, including Ghana have adopted sacred groves as one of the *in situ* strategies to mitigate the loss of biodiversity (Attuquayefio and Fobil, 2005). However, the degradation of sacred groves has been reported in different parts of the world (Ntiamoa-Baidu, 1995; Mulenkei, 2000; Malhotra *et al*., 2001). Traditional beliefs and taboos that were central to the protection of sacred groves are becoming eroded and consequently, the present status of sacred groves is rather precarious (Ntiamoa-Baidu, 1995; Kalam, 1996). Furthermore, the destruction of sacred groves due to increasing pressure from encroachment, overuse of natural resources, burning and felling of trees have escalated the loss of biodiversity within these relict forest patches (Kangah-Kesse *et al*., 2007).

To protect sacred sites and considering the fact that threats to sacred natural sites vary from region to region and even from one grove to another, several researchers have suggested that a holistic and multidisciplinary approach to sacred grove conservation should be adopted. Some advocated that government and the international conservation policy should support community based approach for biodiversity conservation (Bhagwat and Rutte, 2006; Hens, 2006; Ormsby and Bhagwat, 2010). However, Khan *et al.*, (2008) and Corbin (2008) reported that management of sacred groves through the traditional local system is now being challenged by a number of economic and social issues, and thus traditional methods are rendered less effective this indeed calls for outside support to help local community to meet their basic domestic requirements. Also, other researchers have reported that it is important to highlight the cultural, biological and ecological importance of sacred groves in the country and the threats faced by them so as to create public and governmental awareness (Malhotra *et* *al*., 2001; Bhagwat and Rutte, 2006). This may enhance their incorporation into protected area system thereby increasing their protection.

1.2 Rationale

Concerning the documentation of the biological resources found in sacred natural sites, many surveys have investigated their botanical value worldwide (Okafor and Lapido 1995; Lebbie and Guries 1995; Rajendraprasad *et al.,* 1998;; Mgumia and Oba, 2003; Ormsby and Bhagwat, 2010). In Ghana, Decher *et al.,* (2001) and Amoako-Atta (1995) reported most surveys have focused on their botanical, ethno botanical or socio-cultural functions. Few attempts have been made in the country to assess the diversity of insects in sacred groves. Short and long term studies conducted by students of the University of Ghana, Legon and researchers respectively on the diversity of specific insect groups revealed that some sacred groves in the country conceal important insect species (Ayivie, 2005; Owusu-Sekyere, 2005; Mc Ewan, 2005; Bossart *et al*., 2006). Insects are critical natural resources in ecosystems, particularly those of forests (Raina *et al*., 2011). In addition to their role as efficient pollinators and natural/biological pest control agents, some insect species are important indicators in ecosystems management (Buchs, 2003). Comprehensive and long term studies are needed to assess the diversity of insects in all sacred groves in Ghana in order to better understand their crucial role *in situ* conservation of biodiversity. The present study was, therefore, being undertaken to assess the diversity of insects in the Abiriw and Odumante Sacred Groves in the Akwapim North and South Districts respectively in the Eastern region of Ghana as an indication of their current ecological status. This will assist the conservation community and policy makers in Ghana to acknowledge the value of sacred forests in *in situ* conservation of local biodiversity and support future studies and actions to avoid the loss of these important community-conserved areas.

1.3 Objectives

The main goal of the study was to assess the abundance and diversity of the insect species inhabiting the Abiriw and Odumante Sacred Groves in the Akwapim North and South Districts in the Eastern region of Ghana as an indication of their current ecological status.

The specific objectives were to:

a) Assess the diversity and abundance of the insect species in the Abiriw and Odumante Sacred Groves in the Akwapim North District of the Eastern region of Ghana.
b) Compare the diversity and abundance of the insect species in the two sacred groves
c) Determine the effectiveness of the sacred groves in the conservation of the country's forest insect species.
d) Generate species lists of insects in the groves for conservation action and future research follow-ups.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of sacred groves

There is no standard definition of sacred groves. This is because many people use the term to describe a number of contexts including sacred trees, rivers, mountains and forests. Internationally, sacred groves are known as areas of land or water having special spiritual significance to people and communities, and are regarded as the oldest conservation areas in the world (Gomez, 2010). Laird (2011) defined sacred groves as specific forest areas imbued with powers beyond those of human. In Guatemala, sacred groves are defined as naturally or constructed places where cosmic energies are at confluence to enable communication with ancestors (Gomez, 2010). In contrast, sacred groves are defined in Japan as protected trees surrounding Shinto shrines and Buddhist temples (Hays, 2009). In Africa, Scoutter *et al.,* (2003) referred to the term sacred groves to describe specific areas recognised by people and communities as having special spiritual, religious, cultural and historical significance. In Ghana, sacred groves are defined as small patches or islands of remaining original habitat (Kingdon, 1989), or forests of various dimensions partially- or fully-protected by local religious and/or cultural agents (Campbell, 2004). Considering the fact that local communities around the world have named sacred sites differently based on their traditional links to these sites, we could expect the origin of sacred natural sites to differ across the world.

2.2 Origins of sacred groves

Globally, sacred groves originate from a range of roots (Laird, 2011) and include: sites surrounding temples (Hays, 2009); burial grounds or cemeteries housing ancestral spirits (Ntiamoa-Baidu, 1995; Adarkwa-Dadzie, 1997; Dafni, 2007); home to a powerful animal or plant (Vartak and Gadgil, 1981; Decher, 1997); forest areas that surround natural sacred features such as rivers, streams, and lakes (Appiah, 2009). Many researchers had reported that traditional communities throughout the world have preserved these sites primarily for spiritual purposes (Abayie Boateng, 1998; Anthwal *et al*., 2006; Ormsby and Bhagwat, 2010).

In India, the institution of sacred forests is very ancient dating back to the pre-agrarian societies (Kosambi, 1962). It is believed that the sacred groves conservation tradition began with the advent of agriculture in India (Hughes and Chandran, 1998). Many patches of sacred natural habitats were protected and preserved through a combination of taboos, prohibitions, beliefs and restrictions while surrounding areas were cleared for cultivation. It is therefore not surprising that many sacred groves in India are reported to be found in agricultural landscapes (Malhotra *et al.*, 2001), where they provide habitat and corridors allowing the movement of many different organisms (Decher, 1997). There is evidence that wherever sacred groves existed in India, indigenous traditional societies have spiritual relationships with them (Antwal *et al.*, 2006). In Greece and Rome, Dafni (2007) reported that sacred forests were protected because they housed gods and local people established strict regulations against any violation of their sacred forests.

In Africa, the origin of sacred natural sites varies between different belief systems, peoples and communities. In Cameroon, for example, Fisiy (1994) reported that sacred forests were reserved for the gods and on certain days of the week, access to the forests was forbidden. In South Madagascar, the Tandroy people protect their sacred forests which according to them are home to spirits, occult powers and mythical animals (Scoutter *et al*., 2003). The origin of the Kaya sacred forests situated in the coastal plains and hills of Kenya has a historical foundation. It is believed that various ethnic groups of the Mijikenda people have set aside patches of forests and began to clear and cultivate surrounding areas (Scoutter *et al*., 2003). These areas were then used as burial grounds and places of worship and the magic of each community was deeply embedded in these forest patches.

The origin and nature of Ghanaian sacred groves also varies between and within communities (Falconer, 1992; Blench *et al.*, 2004). This is probably because several traditional communities had set aside patches of forests as they have supported sacred trees, tabooed species, sacred rivers and/or streams (Ntiamoa-Baidu, 1995; Sarfo-Mensah and Oduro, 2007; Corbin, 2008). Traditionally, such areas are strictly protected and are well embedded in complex local cultures, taboos and traditional belief systems. Some sacred groves serve as royal burial grounds where the traditional chiefs and elders of a particular village are buried. Such patches of forests are protected because of respect for the dead and the beliefs that the ancestral spirit lived there (Falconer, 1992). Entry into such areas is prohibited and only a limited class of people is allowed access for burial or ritual purposes.

The sacredness of other sacred forests in Ghana originates from a river or stream that is home to water gods (Corbin, 2008). Such rivers are worshiped and protected and in some cases their surroundings, especially forests are protected on the basis that the spirit of the river resides in the area. Consequently, a variety of rules, prohibitions and regulations such as the prohibitions of use of fisheries resources within the rivers, farming around the edges of the rivers and restrictions on access to the river on certain days are used to prevent human contact with the sacred groves (Ntiamoa-Baidu, 1995; Sarfo-Mensah and Oduro, 2007). Such traditional institutions have been used in Ghana to protect several river bodies especially those that provide the main source of drinking water for a village. For example, Appiah

(2009) reported that the Pokuase sacred grove at Pokuase in the Ga West Municipal Assembly of the Greater Accra Region protects the sources of the SunKwa stream that provides drinking water for the inhabitants and water tankers serving the Ga West Municipality. Anane (1997) reported that over 80% of sacred groves in Ghana serve as watersheds for catchment areas where they protect sources of drinking water.

The sacredness of other groves in Ghana is derived from reverence for an animal, plant, tree species or deities that live there (Corbin, 2008). Such areas are highly protected because they are believed to have spiritual, cultural, medicinal values and/or association with the local communities (Sarfo-Mensah and Oduro, 2007). Human activities such as hunting, logging, and gathering of firewood, fires and cultivation are thus routinely banned and entry into some groves is restricted to some particular days (Ntiamoa-Baidu, 1995). For example, Falconer (1992) found in the village of Nanhini in the south west of Ghana, which has the Numafoa and Kobri sacred groves, that one grove cannot be farmed or used for hunting, nor can snails be collected. However, the palms can be tapped for wine and medicines can be gathered. In addition, lands adjacent to sacred groves with streams in them are not supposed to be used on the sacred days of the deities associated with the groves. The Nanamon Mpow sacred grove was established in the Central region of Ghana because it is believed that it is the home of the gods (Arhin, 2008). Human beings were thus not allowed to go into the grove and no hunting of wildlife or picking of plants was allowed. The Buobeng-Fiema Monkey Sanctuary, a sacred grove in the Brong Ahafo Region is often described as a successful traditional conservation practice in Ghana (Fargey, 1992; Colding and Folke, 1997). This sacred grove houses two tabooed species of primates namely: the ursine black and white Colobus, *Colobus vellerosus* and the Campbell’s monkey, *Cercopithecus campbelli lowei*. Community members of Buobeng consider them to be the children of the gods who protect the villages

(Saj *et al.*, 2006). Similarly, the Tafi atome Monkey sanctuary in the Volta region houses the Mona and Pata Monkeys which are believed to be the messengers to the gods and their protectors (Arhin, 2008).

Trees which have medicinal properties are protected for their usefulness in curing and are considered sacred because they have spiritual powers. In several communities in the high forest zone of the Southern Ghana, Falconer (1992) reported that most medicinal trees are considered sacred, and that there are taboos that protect them or rituals that have to be performed before they can be used.

On the other hand, there are some sacred groves in Ghana that originate from historical events (Ntiamoa-Baidu, 1995). Since 1926 the Pinkwae grove (near Katamanso) in the Ashanti region for example, was the battle ground of war between the Katamansos and Ashantis. This grove is believed to be the abode of the spirits of ancestors who died in the war and of the Afiye god whose powers enabled the Katamanso people to defeat the Ashantis (Lieberman, 1979). Another sacred grove is the Asantemanso grove (near Esumegya) in the Ashanti Region which is believed to contain the cave from which the seven clans of the Ashanti tribe originated (Ntiamoa-Baidu *et al.*, 1992). It is evident from the above observations that sacred groves are not confined in one country or one continent, but rather are distributed across the globe.

2.3 Global distribution of sacred groves

The existence of sacred groves has been reported in many different countries across the world. Gadgil and Vartak (1976) reported that they are found in Ghana, Nigeria, Syria, Turkey and Japan. Sacred groves have also been documented in Cameroon (Fisiy, 1994), Ivory Coast (Sanogo, 1983) and Indonesia (MAB, 1995). However, Bhagwat and Rutte (2006) presented a worldwide distribution of sacred natural sites by referring to 98 references. They reported that sacred natural sites are found on all continents except Antarctica (Fig. 1) and that such areas include a wide variety of habitats that they classified into 10 categories (Table 1).

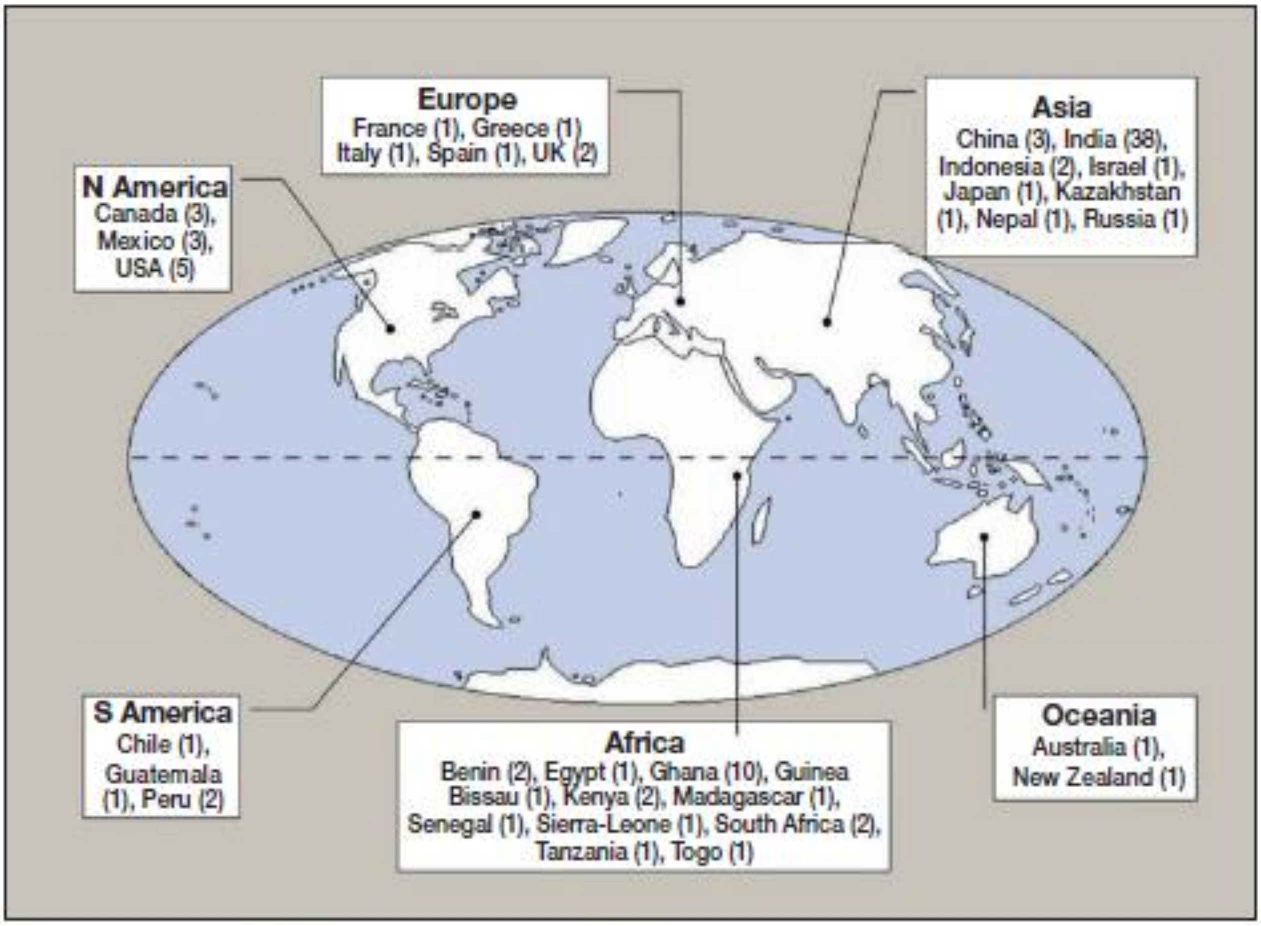


Figure 1: Distribution of sacred groves in different continents of the world. **Source** (Bhagwat and Rutte (2006).

Table 1: Habitat variation of sacred groves in different countries

Habitat protected	Countries/regions represented
Coastal	Australia, Guinea-Bissau, Japan, Togo
Cultivated	Indonesia, Mexica
Forest	Benin, China, Egypt, Ghana, India, Indonesia, Madagascar, Sierra Leone
Garden	New Zealand, USA, Europe
Lakes	Egypt, India, Kenya, South Africa
Mixed landscape	Canada, Guatemala, India, Mexico, Spain, UK, USA
Montane	Chile, China, France, Greece, India, Italy, Kazakhstan, Nepal, Peru, Russia, UK, USA, Europe, Global
Riparian	Canada, India
Savanna	Ghana, South Africa, USA
Woodlots	Ghana, India, Israel, Senegal, Tanzania

Source: Bhagwat and Rutte (2006).

Amongst the various countries mentioned above, the distribution of sacred groves has been well documented in India. India has the highest concentration of sacred groves in the world (Ormsby and Bhagwat, 2010). Sacred natural sites are reported in 19 out of 28 states (Malhotra *et al.*, 2001) suggesting that their presence or absence has not yet been reported in some states. Although no comprehensive study has been done on the sacred groves of the entire country, experts estimate that the total number of sacred groves could be in the range of 100,000 - 150,000 (Malhotra *et al.*, 2007); with many found in the Western Gnats, North Eastern and Central India (Burman, 1992). The distribution of sacred groves with the area covered in India is shown in Appendix I. According to Bhagwat *et al.,* (2005), many sacred forests in India are less than one hectare in size and cover only 0.01 % of the total geographic area. They are mainly found in tribal dominated areas (Bhakat, 1990) and are known by different names in ethnic terms such as *Sarna* or *De*v in Madhya Pradesh, *Devrai* or *Deovani* in Maharashtra, *Sarnas* in Bihar, *Orans* in Rajasthan, *Devaravana* or *Devarakadu* in Karnataka, *Sarpakavu* and *Kavu* in Tamil Nadu and Kerala, *Dev van* in Himachal Pradesh, *Law Lyngdoh* or *Law Kyntang* etc. in Meghalaya, *Sarana* or *Jaherthan* in Jharkhand and *Lai umang* in Manipur (Khan *et al*., 2008).

In Africa, much has not been done on the distribution of sacred groves. Many local communities in Kenya have also preserved patches of forests as sacred. Kenya has over 1000 traditional sacred groves that differ in their use and size and a majority of them are small (Attiti, 2001). Such sites have been reported to be an important refuge for rare and useful local biodiversity (Mulenkei, 2000).

In Nigeria, sacred groves have been reported in the rural landscapes of Isiala Ngwa North and South local government areas of Abia State (Chima and Nuga, 2011), in the Southern part of the country (Baker *et al*., 2009).

In Ghana, Gordon (1992) reported that there are estimated to be 2,000 - 3,200 sacred groves with about 80 % found in the Southern half of the country. Each sacred grove has a specific name referring to its origin and to the sacrifice carried out there (Blench *et al*., 2004). Several categories of groves exist (Dickson, 1969; Dwomoh, 1990). Many are small (less than one hectare), often comprising of an object (such as a tree, stone, or rock) considered to be a god and its immediate surroundings. They are referred to variously as *nananompow* (ancestral grove or royal mausoleum) (Adarkwa-Dadzie, 1997), *abosompow* or *asoneyeso* (shrine), *mpanyinpow* (ancestral forest), and *nsamanpow* (burial grounds) by the Akans (Ntiamoa-Baidu, 1995).

Even though Gordon (1992) reported that there are between 2000 – 3200 sacred groves in Ghana, there is no evidence on the number of sacred groves in each region along with the area covered. Also, data on the total geographic area covered by them in Ghana is not known. Table 2 shows the distribution of some of the major sacred groves in Ghana.

Table 2: The distribution of Sacred Groves in Ghana with the area they cover (**Source:** Nganso *et al*., 2012).

Region	Name of sacred grove	District	Area (ha.)	Reference
Brong Ahafo	Buoyem	Nkoranza	36.5	Fargey, 1991
	Asuonyima	Nkoranza	2.4	Sarfo-Mensah *et al*., (2010)
	Ghonno	Wenchi	100	
	Brabo	Wenchi	-	
	Ntwokom	Wenchi	-	
	Boten	Wenchi	-	
	Worobo	Wenchi	-	
Northern	Malshegu	Tamale	1	Dorm-Adzobu *et al*. (1991)
	Jaagbo	Tolon-kumbungu	-	Corbin (2008)
Eastern	Anwean	Kwaebibirem	2,000	Amoako-Atta (1998)
	Abiriw	Akuapim North	0.04	Kangah-Kesse *et al*. (2007)
	Odumante	Akuapim South	0.025	
Volta Region	Tafi Atome	Hohoe	-	Arhin (2008)
Ashanti	Nkodurom	Kumasi	500	Ntiamoa-baidu (1995)
	Gyakye	Kumasi	11.5	Bossart *et al*. (2006)
	Asantemanso	Kumasi	259	Bossart *et al*. (2006)
	Bonwire	Kumasi	8	Bossart *et al*. (2006)
	Kajease	Kumasi	6	Bossart *et al*. (2006)
	Pinkwae	-	-	Ntiamoa-baidu (2008)
Greater Accra	Guakoo	Ga West Municipal	-	Appiah (2009)
Central	Nanamon Mpow	-	-	Arhin (2008)

2.4 Importance of sacred groves

Globally, many studies have been conducted on the biodiversity and ecological values of sacred groves.

2.4.1 Biological value

Sacred groves have a long history of protection. Access to and interference with these sites has been restricted for several generations, thereby reducing human impact in terms of harvesting of natural resources. As a result of these restrictions, sacred groves are regarded today as important store houses of biodiversity.

Many sacred natural sites are regarded as the only representative of near-natural vegetation (Bossart *et al.*, 2006; Ormsby and Bhagwat, 2010) and have been reported to be the last refuge of rare, endemic and endangered plant and animal species (Bhagwat and Rutte, 2006; Khan *et al.*, 2008; Jonathan, 2008). Many are particularly rich in plants and associate groups of organisms like amphibians, mammals, birds, reptiles, and insects (Malhotra *et al*, 2001; Blench *et al*; 2004).

Recent efforts to enumerate and assess the biodiversity value of sacred groves in most countries especially in India have focused mainly on botanical aspects (Ormsby and Bhagwat, 2010). Sacred groves in India are known to be store houses of important medicinal and wild plants that may help the pool of cultivated varieties, and in some parts of India, they have much more species diversity and species richness than government protected areas (Jonathan, 2008). Factors such as restriction in resources usage, undisturbed conditions and suitable microclimate have been reported to be responsible for the species richness in Indian sacred groves (Rajasri *et al.*, 2011). For instance, in the Central Western Gnats in India, it has been reported that the density of medicinal plants was almost twice compared to that of forest reserves; and nearly 40 % of important medicinal plants were unique to sacred groves. In contrast, only 11 % were unique to forest reserves (Boraiah *et al.*, 2003). Similarly, certain relict threatened tree species (*Actinodaphne lawsonii, Hopea ponga, Madhuca neriifoli,* and *Syzygium zeylanicum*) that are not found in the formal protected areas have been reported in sacred groves in the Kodagu district of Karnataka state (Bhagwat *et al*, 2005). A number of ecologically important plant species such as *Albizia lebbeck* and *Ficus glomerata* have been reported in several sacred groves of Manipur (Malhotra *et al.*, 2001). These plants species conserve high amount of nitrogen, phosphorus, magnesium and calcium in their leaves. The sacred groves in the Kanyakumari district harbour many of the rare endemic plants of the Western Ghats such as *Antiaris toxicaria*, *Diospyros malabarica*, *Diospyros ebenum*, *Feronia elephantum*, *Butea frondosa*, *Garcinia cambogia*, *Sterculia foetida*, *Gnetum ula* and *Cycas circinalis* (Sukumaran and Raj, 1999).

Some researchers in India have attempted to document the faunal diversity values of sacred forests. Deb *et al.*, (1997) reported that a number of local bird species find refuge exclusively in sacred groves. A new species of frog, *Philautus sanctisilvaticus*, was reported from Amarkantak sacred grove in the Madhya Pradesh (Das and Chanda, 1997). Animal species like bees, lizards, snake, monkeys (*Rhesus spp*.) are common in sacred groves of Manipur (Khan, 2003).

Similarly, many surveys conducted on sacred natural sites in Africa have focused mainly on their botanical values, but very few attempts have been made on the insect diversity value. In East Africa, particularly in Kenya, there are well known residual patches of forests called

Kaya sacred forests. These forests regarded as sacred by the Coastal Mijikenda community are relict forest patches situated in the coastal plains and hills of Kenya. They are biodiversity rich and globally unique areas (Robertson and Luke, 1993) harbouring at least one endemic species per forest (Burgess *et al*, 2000). More than half of Kenya rare plants are found in the Coastal region, and many of these are endemic to the Kaya forests (Scoutter *et al.*, 2003). Two surveys conducted by the National Museums of Kenya (NMK), both funded by WWF found that more than half of Kenya's rare plants were found in the Coastal region, many in the Kaya forests (Githitho, 2003). A total of 19 sacred groves and their surrounding areas were also surveyed by the Kenya Resource Centre for Indigenous Knowledge (KENRIK) of the NMK under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO) to document plant species diversity (Mgumia and Oba, 2003). They found that these sacred forests had higher plant diversity than their surrounding areas.

In West Africa, particularly in Nigeria, 121 plant species were found in sacred groves (Okafor and Lapido, 1995). In Sierra Leone, Lebbie and Guries (1995) reported 82 plant species in sacred groves. Recent efforts in Ghana to enumerate and assess biodiversity value of sacred groves and elsewhere had focused mainly on botanical aspects (Amoako-Atta, 1995; Decher *et al*., 2001; Arhin, 2008). For example, preliminary studies indicated that the Jaagbo sacred grove in Northern Tolon-Kumbungu district in Ghana and its buffer zone had approximately 220 plant species in comparison to 60 in outlying areas, and 60 % of those plants were used as sources of medicines (Corbin, 2008). Similarly, Hall and Swaine, (1981) found the only surviving specimens of the inner zone subtype of the Dry Semi-Deciduous Forest and the southern marginal forest types to be present in sacred groves in Ghana. Studies conducted in the Anweam sacred grove subsumed into the Esukawkaw forest reserve in the

Eastern region of Ghana revealed that this grove has the highest level of medicinal plants compared to any other area sampled (Amoako-Atta, 1998).

Some researchers and scientists in Ghana and elsewhere have attempted to document the wildlife, avian and mammalian diversity values in sacred forests. The Nkodurom and Pinkwae sacred groves along the Coast of Ghana have higher numbers of mollusc (*Tympanotonus fuscatus*), 3 species of turtles (Green, dive Ridley, Leatherback) and the black heron than in areas where these species are not protected by traditional beliefs systems (Ntiamoa-Baidu, 2008). On the Accra plains in Southern Ghana, (Decher *et al*., 2001) found that sacred groves contain higher small mammal biomass (insectivores, bats and rodents) than the surrounding areas. A previous study of small mammal ecology and conservation in the Accra Plains in Southern Ghana indicated that sacred groves contain higher small mammal biomass than surrounding areas and that they function as refuges to some small mammal species no longer found anywhere else (Decher and Bahian, 1999). Studies conducted by (Kangah-Kesse *et al*., 2007) in the Abiriw sacred grove in the Akwapim North District in the Eastern Region of Ghana showed that the grove has a total of 411 individual birds belonging to 22 families and 66 species, out of which 211 individuals of 41 species occurred in the forest-cultivated land boundary, 111 (36 species) in pristine forest, and 89 (40 species) in secondary forest. They also reported that a significant proportion of species in the grove were savannahs' specialists.

In some cases, specific species of animals survive exclusively in sacred natural sites. For example, the only remaining Ghanaian population of the true Mona monkey subspecies *Cercopithecus mona mona*, lives in a small sacred grove at Tafi Atome, in the Volta region (Ormsby, 2007). The Boabeng-Fiema Monkey Sanctuary in the Brong Ahafo Region in

Ghana provides a refuge for wildlife (the ursine black and white colobus, *Colobus vellerosus*, and the Campbell's monkey, *Cercopithecus campbelli lowei*) which have been exterminated in nearby areas (Corbin, 2008). In Nigeria, Baker *et al*., (2009) reported that sacred groves in Igboland, Southern Nigeria harbour sacred primate species such as tantalus monkeys (*Chlorocebus tantalus*) and mona monkeys (*Cercopithecus mona*).

Very few attempts have been made on the diversity of insects in sacred groves worldwide. In Ghana, Bossart *et al*., (2006) conducted a year-long survey of the fruit feeding butterfly fauna of four sacred groves and two forest reserves to characterize resident species diversity and complementarity among communities in Kumasi in the Ashanti Region. The purpose of their study was to assess the extent to which sacred groves may contribute to the preservation of the country's forest endemic species. Through this study, they reported that despite their small sizes, sacred groves conceal a number of less common endemic butterfly species, and also help to foster persistence of these forest species across a landscape matrix that is largely devoid of forest habitat. They therefore advocated that these indigenous reserves should be integrated into conservation practice in order to mitigate the loss of biodiversity in degraded landscapes. Short term studies conducted by students of the University of Ghana, Legon have demonstrated the importance of sacred forests in the conservation of important insect species. Unpublished studies conducted by Ayivie (2005) and Owusu-Sekyere (2005) showed that the Abiriw sacred grove in the Eastern region of Ghana has a high diversity of Chironomids. The species of chironomids found in this grove belong to the genera (*Kiefferulus*, *Polypedilum*, and the new genera *Manisetula* and *Capillolus*). Mc Ewan (2005) reported that the same grove has a high diversity of aerial insects. All of these examples demonstrate that a scientific study of the insect diversity in sacred groves in Ghana might also increase public awareness and trigger necessary management strategies to prevent the loss of biodiversity in these sacred sites.

2.4.2 Ecological value

Perhaps water conservation is the best documented ecological service provided by sacred groves (Puspangadan *et al*., 1998; Rajasri *et al.*, 2011). Sacred groves serve as reservoirs which help to meet the water requirements of the local communities living near the groves. For example, the highland groves in the Western Gnats and Himalayan region in India are important for their water conservation activities (Singh *et al.*, 1998). These activities are beneficial for the local communities in terms of supply of water in the lean season. Also, over 80 % of sacred groves in Ghana serve as watersheds for catchment areas where they protect sources of drinking water (Anane, 1997). In the Ashanti region, the Asuo Akosua stream is protected because locals believed it is the home of a female deity, and not only is farming around the stream forbidden, but also anything that pollute the water, like washing of clothes. The Pokuase sacred grove protects the source of the Sunkwa stream that provides drinking water for the inhabitants and water tankers serving the Ga West Municipality in the Greater Accra region (Appiah, 2009).

Sacred groves also play an important role in environmental protection by controlling air pollution and cooling of the atmosphere (Amirthalingam, 2002). This is probably because transpiration from the sacred grove vegetation cover increases atmospheric humidity and reduces temperature in the immediate vicinity, thereby producing a more favourable microclimate for many organisms living nearby the groves (Kheiwtam and Ramakrishnan, 1989). They also help in improving soil fertility through efficient nutrient recycling (Antwal *et al.*, 2006). Despite, their biological and ecological significances, sacred groves are under serious threats in different countries.

2.5 Degradation of sacred groves

The degradation of sacred groves throughout the world is eminent. It has been reported in several studies that sacred groves are eroding (Ntiamoa-Baidu, 1995; Chandrakanth *et al*., 2004; Hens, 2006; Ormsby and Bhagwat, 2010). Most of the countries in Africa where sacred groves have been reported are facing tremendous degradations of their natural sacred sites. Although the causes of this degradation vary from one nation to another and even from one grove to another, some of the factors that account for the degradation of groves are similar across some nations as outlined below.

2.5.1 Threats to the degradation of sacred groves

Many sacred groves in India have been completely destroyed and/or reduced in size (Malhotra *et al*., 2001; Chandrakanth et al., 2004). Malhotra *et al*., (2001) reported that factors such as commercial forestry, development projects, shift in belief systems, sanshritization, pilgrimage and tourism, removal of biomass, encroachment, modernization and market forces, fragmentation and perforation are responsible for the degradation of sacred groves.

Ormsby and Bhagwat (2010), however, identified several key factors that have led to the reduction in size or lack of protection of sacred forests in India by referring to specific examples. Such factors include the loss of customary rights of forest management by local communities to the government, an increase demand of natural resources within the sacred forests, cultural change, change in society's structure and composition as well as economic status and religious values.

In Ghana, it has been reported in several studies that the erosion of traditional beliefs and associated taboos threaten sacred groves in the country (Ntiamoa-Baidu, 1995; Hagan, 1998; Hens, 2006). Sarfo-Mensah and Oduro (2007) identified the breakdown of traditional beliefs and associated taboos as the greatest threats to the conservation of traditional natural resources through sacred groves. This has consequently led to overexploitation and degradation of the local natural resource base of several communities. Attuquayefio and Fobil (2005) reported that the breakdown of beliefs that protect these sacred areas can be attributed to rapid population growth, urbanization, human migration, resettlement, influence of western technology, foreign religion and beliefs, encroachment, deforestation etc. Ntiamoa-Baidu (1995) reported that the lack of modern legislation to reinforce traditional rules is also responsible for the breakdown or disrespect of traditional belief systems. She also observed that, as a result of the uneven impact of these factors, human activities like farming, residential development and degradation through consumption of forest products and bush fires which were formerly taboos were affecting the ecology of the sacred groves. A number of sacred groves in the Brong Ahafo Region in Ghana have been completely destroyed and/or reduced in size (Sarfo-Mensah *et al*., 2010). For example, due to erosion in traditional belief systems, the degradation of the Asuonyima in the Nkoranza District has accelerated with opportunistic farming. Similarly, several sacred groves such as Worobo, Ntwokom, Brabo and Boten in the Nchiraa community have been cropped intensively, with their sizes drastically reduced or completely decimated. The Pokuase sacred grove in the Ga West Municipal Assembly of the Greater Accra Region of Ghana is succumbing to the activities of some state developers (Appiah, 2009).

In addition, local communities are facing economic and social challenges posed by the modern world. Even though in some cases, local communities are determined to protect their groves, they are often vulnerable to outside economic forces which intrigue them to either exploit natural resources within their sacred forests and/or accept outsiders' bribe who want to exploit their resources. Some regions in Ghana are facing alarming population growth and increasing immigration, and the resulting need for land puts some sacred groves under severe pressure. Furthermore, immigrants often retain their own cultures and customs, which might not include the values underlying the maintenance of sacred groves. Blench *et al*., (2004) observed that economic change in the Upper East region of Ghana has accelerated demand for non-renewable products such as charcoal. As a consequence, immigrants who are not part of the system of prohibitions are exploiting woodland with little fear of sanctions in sacred groves. Similarly, Corbin (2008) reported that in some areas in Ghana, new settlers who are not part of the system of prohibition are growing crops such as tomatoes, plantains, maize, cassava etc. These crops are not indigenous to the sacred groves and therefore put high strain on the soil thus, affecting the ecological niches of organisms. Poverty affects a majority of local communities thereby limiting their capacity to exploit sustainably their forest resources.

Amoako-Atta (1998) reported that lack of supportive education rooted in modern concept of conservation and eco-development contribute to the degradation of sacred groves. For example, Corbin (2008) reported that with the rising cost of health in Ghana, traditional medicinal plants are becoming big business and as a result, people from outside the groves are collecting large quantities of these plants at an unsustainable rate. Sometimes, local communities help people to exploit forest resources illegally because of poverty and lack of respect for government regulations stemming from the fact that they have been unjustly denied the means to support themselves on their traditional lands (Corbin, 2008). The Boten sacred grove in the Wenchi District in the Brong Ahafo Region has been degraded because elders accepted bribes from individuals to farm in the area (Sarfo-Mensah *et al*., 2010).

The loss of property rights of forest management of local community to the government has also contributed to the loss of some sacred forests in Kenya. Many sacred groves have been reported to be threatened by the Government because of the conflict that exists between the indigenous, non-indigenous communities and the government on the issue of land (Mulenkei, 2000). The Kaya sacred forests are of exceptional importance globally due to their remarkably high level of endemism (Lovett, 1993). However, this forest habitat is declining and being replaced by areas of agricultural land and ever increasing areas of urbanization and associated tourism facilities that follow (WWF-UK, 2005). Expansion of agricultural, tourist resorts, development and mining activities are posing a serious threat to many Kaya forests due to interference from central government land tenure and development policies and external culture influence on the young generation who have no spiritual attachment to the kaya forests (Mulenkei, 2000).

Other sacred sites which are threatened in Kenya are the “Naimena Engiyo”-the lost child sacred forest protected by the Loita Maasai, a subgroup of the Maasai of Kenya inhabiting part of Narok district in the Great Rift Valley, and Endonyoormorwak sacred forests situated between Mount Kilimanjaro and Mount Meru protected by the Tanzania and Kenya Maasai. These two groves are threatened by Government Line Departments who gave leaseholds to both individuals and none Maasai in areas surrounding the groves and deny the traditional elders the right to own these sites (Mulenkei, 2000).

In Uganda, lack of policies to support the institution of sacred groves threatens their survival. Banana *et al*., (2008) reported that a large number of sacred groves that are outside state forest reserves such as those found in the Buganda, Bungoro and Tooro kingdoms are rapidly destroyed. Similarly, Banana *et al*., (2008) reported that the Magezigoomu and Mukasa sacred groves in the country were extensively being destroyed by timber harvesting, charcoal production and crop cultivation.

At Zanzibar in Tanzania, Madeweya *et al*., (2004) reported that sacred groves were declining in size and quality of their natural resources due to an increase in economic hardship that local communities are facing.

It is quite clear that measures such as the protection of biodiversity and life forms through sacred groves should be taken seriously to ensure that biological resources are used in ways that neither diminish the variety of genes and species nor destroy important habitats and ecosystems. This is because the loss of each species comes with the loss of potential economic benefits (example: natural products that increase world food supply and the medicines humans depend on), as well as a loss of ecosystem balance. It is therefore important for human society to manage our biological resources so as to enhance sustainable growth and development worldwide.

2.6 Management of sacred groves

Although currently under threat, sacred groves act as strong tradition of conservation of biological natural resource management that has existed for several years. In different parts of the world, increasing attention is being paid to their potential as a tool and model for environmental conservation (Schaaf, 2003) as a result of the high biodiversity values held in sacred groves. This is because they are not just cultural monuments; they are conservation areas that can provide a culturally sensitive model for the conservation of local, national, regional and global biological resources. Despite tremendous challenges on sacred natural sites, some have managed to survive in many countries. Sacred groves have retained high levels of biodiversity and remain largely intact in some parts of India (Laird, 2011). In Ghana, the Buabeng-Fiema Monkey Sanctuary and the Bofie sacred groves in the Northern transitional zone (Fargey, 1991; Ntiamoa-Baidu, 1995); Malshegu sacred grove in the Northern Savannah (Dorm-Adzobu *et al*.,1991); the Numafoa sacred grove in the forest zone (Falconer, 1992) and the Gyamfuase sacred grove in the Southern transitional zone (Gyasi, 1997) are typical examples. In a number of countries, especially among the African, Asian and Latin America, sacred groves have been adopted as one of the in situ strategies to mitigate the loss of biodiversity (Mgumia and Oba, 2003). This is particularly the case in Ghana (Attuquayefio and Fobil, 2005).

A number of Conventions, International Organisations and Non-Governmental Organisations (NGOs) have taken interest in both the recognition and protection of sacred groves. For example, Rajasri *et al*., (2011) reported that after the Declaration of Convention on Biological Diversity (CBD), there has been increasing interest in the importance of sacred groves in nature conservation. This convention seeks to promote community based conservation initiative for which sacred grove tradition can be portrayed as role model. Among the international organisations is the UNESCO which has at its disposal two global instruments namely the Programme on Man and the Biosphere (MAB) and the World Heritage Convention (WHC) (Schaaf, 2003). Both global instruments clearly recognised the importance of sacred sites and place them into the concept of sustainable management.

Various international NGOs have sponsored community-based projects in African sacred groves (Anane, 1997; Schaaf, 2003).

It is worth to note that in each country, there is no specific approach to sacred grove management due to the challenges that vary from region to region as well as from one grove to another. An integrated approach is, however, used to manage a particular sacred grove depending on the prevailing threats in that grove. Although the management of sacred groves differ among countries, some of the management strategies are similar across some nations as outlined below.

2.6.1 Use of legislation to reinforce the traditional regulations regarding use and access to sacred groves

Due to the degradation of traditional belief systems that have long preserved and protected the integrity of sacred groves, many researchers reported that these informal rules and regulations alone are no longer sufficient to meditate the effect of human activities on sacred groves (Gombya-Sembaywe, 2000; Corbin, 2008). Therefore, a strong legal backing is needed in order to counter the current breakdown of traditional institutions. Such legal protection will be more positive in protecting sacred natural sites from violation especially in the case where powerful individuals ignore community interest. With no effective and sustainable protective means and if there should be a future break in traditional beliefs, the richness of the grove will be seriously affected. Furthermore, lack of action will undoubtedly accentuate the extinction process within sacred groves. In recognizing the strength of local tradition and customs that have long preserved the integrity of sacred groves, a number of researchers have repeatedly advocated in international flora that traditional beliefs systems should be integrated into biodiversity policy (Hens, 2006; Dudley *et al*., 2009). Even though these traditional conservation areas are governed by complex customs and taboos rather than being bound by legal framework as the formal protection (Barre *et al*., 2009), it is important for the human society to adopt a strategy that is sensitive to local peoples' traditions, such as sacred forest conservation than an approach that alienates local people. Alongside, local people must continue to be involved in the management of their sacred forests. There are cases in many countries where such legal recognition of traditional belief systems and involvement of local people in sacred grove management has been successful. In Uganda, Banana *et al*., (2008) called for legal recognition of some sacred groves. The Boabeng-Fiema Monkey Sanctuary in the Brong Ahafo Region in Ghana provides an example of a grove that has not only been protected by customary law, but also by modern legislation (Scoutter *et al*, 2003). When the sacred monkeys at the Boabeng-Fiema Monkey Sanctuary were threatened by religious leaders who supported monkey hunting to undermine traditional belief systems, the community asked for government support for a hunting ban, which was successful (Ormsby, 2011). The Ghana Association for the Conservation of Nature (GACON), a Non-Governmental Organisation developed a successful partnership with the community of Buoyem to conserve and manage their grove (Corbin, 2008). Similarly, when the Pokuase sacred groves in the Ga West Municipal Assembly of the Greater Accra Region succumbed to some human activities, the traditional authority appealed to the Minister for Environment, Science and Technology to intervene to save their grove from the developers (Appiah, 2009). UNESCO South-South Cooperation programme involved local people in the management of the Anwean sacred grove within the Esukwakwa forest reserve in the Eastern region in Ghana (Amoako-Atta, 1998). The Mahafaly people of South-West Mada and the Tandroy people of the Deep South of Madagascar have long protected their sacred forests from the problems of overexploitation of forest resources using their traditional customs. However, Scoutter *et al* (2003) reported that the growing needs of villagers lead them to progressively encroach on once forbidden forests and they show less respect towards ancestral beliefs. In an attempt to solve this problem, the WWF started collaborating with both the local communities and Ministry of the environment, water and forests with the main goal of strengthening local cultural norms and beliefs in favour of conservation.

2.6.2 Provision of resources to improve local people's capability to manage their groves

In some cases, outside support for sacred forests conservation is needed when local communities leaving near the groves are facing economic challenges. Sometimes, local communities are eager to retain their sacred groves. Due to economic hardship, they do not longer honour the traditional and cultural respect to these sacred natural sites. In order to counter this situation, alternative livelihood should be offered to these indigenous people to enhance more effectively the protection of sacred groves. In the case of the sacred groves of Meghalaya in India, Tiwari *et al*., (1998) called for external intervention. In Ghana, Decher (1997) explained that where ecotourism is being developed as in the sacred forests at the Buabeng-Fiema Monkey Sanctuary in Central Ghana, revenue from ecotourism could be used to develop further conservation, reforestation and education projects. Also, the assistance of a the GACON in the Buoyem community has helped fortify the reverence the local community always had for the grove, and to bring in skills and devices, like fuel-efficient woodstoves, that can help the local people live without destroying the grove (Corbin, 2008). Also, at the Tafi Atome Monkey Sanctuary in the Volta region, a sacred forest in Ghana, community members elicited the support of an Accra based Non-Governmental Organization to develop ecotourism to the site and support sacred grove conservation traditions (Arhin, 2008; Ormsby and Edelman, 2010). Madeweya *et al.*, (2004) in Zanzibar, Tanzania advocated that the development of ecotourism in the sacred forests could be one of the alternative options that may attract local community to save the remaining sacred forests.

The role of education, public awareness and understanding conservation issues in sacred grove management are tackled in rural areas in Ghana (Corbin, 2008). Earlier on, (Ntiamoa-Baidu, 1995) reported that these four factors militate against protected area management in the country. Also, Amoako-Atta, (1998) reported that lack of supportive education rooted in modern concept of conservation is among one of the factors that explains the overexploitation of natural resources within sacred groves by local people. For instance, lack of conservation education has been identified as one of the challenges to sustainable land use in the Anwean grove in the Esukawkaw forest reserve in the Eastern region of Ghana (Corbin, 2008). Also, UNESCO sponsored the Cooperative Integrated Project on Savannah Ecosystems in Ghana (CIPSEG), which undertook an educational program that prepared the Jaagbo sacred grove in the Northern Tolon-Kumbungu district for ecotourism and opportunities for school groups to visit the grove (Corbin, 2008). In Kenya, the NMK created the Coastal Forest Conservation Unit (CFCU) in 1992 to collaborate with local communities in caring for the kaya forests, and CFCU, in partnership with local communities and with support from the WWF and other nongovernmental agencies, has implemented a multifaceted conservation program of Kaya forests (Polidor, 2008). An important element of the CFCU conservation program is its education and awareness activities which seek to revive interest in the Kaya forests and strengthen the status of traditional and cultural values. This program also gives access to local communities to alternative livelihoods that do not exploit the forests such as initiating programs to help farmers establish small tree nurseries or beekeeping operations. The recognition of Kaya forests by Kenyan government as national monuments was reinforced by scientific knowledge provided by the surveys carried out by the WWF and the NMK on Kaya forests. Data resulting from these surveys showed that the Kaya forests are botanically diverse and have a high conservation value despite their comparatively small collective area (Scoutter *et al*, 2003).

2.6.3 Inventory of the biological resources in sacred groves

Other researchers suggested that for effective conservation management of sacred groves, their biological importance must be highlighted in international flora (Attiti, 2001; Mgumia and Oba, 2003 and Madewaya *et al*., 2004; Schaaf, 2003; Bhagwat and Rutte, 2006; Ormsby and Bhagwat, 2010). This is because in view of the small size of most sacred groves, some researchers reported that sacred groves cannot play a significant role in mitigation the loss of biodiversity. However, (Bhagwat *et al*., 2005) reported that it is their number and spatial distribution in a country that make them so valuable for biodiversity conservation. It therefore means that sacred groves as a network in a country or region can preserve sizeable portion of local biodiversity in areas where it would not be feasible to maintain large tracts of forests. Many surveys have been conducted in different countries to demonstrate this fact. Mgumia and Oba (2003) reported that despite their small sizes, sacred groves in central Tanzania had greater woody species richness and taxonomic diversity than state managed forest reserves. In Ethiopia, Binggeli *et al.*, (2003) reported that in many parts of Ethiopia, native trees may only be found in sacred groves despite their small size. Sacred groves in Ghana have being the sites for several international and local projects to document biodiversity (Corbin, 2008). UNESCO for example funded the CIPSEG project which studied three sacred groves near Tamale in the Northern region of Ghana (Blench *et al*., 2004). This project demonstrated that these groves acted as important floristic reserves, and as important sources of medicinal plants. These groves were to be encouraged as part of an environmental recovery process in the Northern region. Also, as stated earlier, several researchers in Ghana have documented the biodiversity values of sacred groves. The recognition of Kaya forests by Kenyan government as national monuments was reinforced by scientific knowledge provided by the surveys carried out by the WWF and the NMK on Kaya forests. Data resulting from these surveys showed that the Kaya forests are botanically diverse and have a high conservation value despite their comparatively small collective area (Scoutter *et al.*, 2003). Such studies demonstrate that by increasing our knowledge of insect diversity in sacred groves in Ghana, we might have in depth knowledge of the potential of these sacred sites in mitigating biodiversity loss in the country. Such scientific studies will be able to raise public awareness of the biological significance of sacred groves in the country, and therefore persuade conservation community to promote hopefully enhance more effectively the integration of sacred groves into the Protected Area Network (PAN).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Field and laboratory equipment

Field equipment used for this study included: swept net, aerial net, malaise traps, charaxes traps, pit fall traps, yellow pan traps, flight interception traps, light trap and cutlass. Others were aerial net, a pair of forceps, ethyl acetate, 70 % alcohol, perspective bags, glassine envelopes, killing jars, and plastic containers. Laboratory equipment included: dissecting microscope, sorting/dissecting trays, hand lens, entomological pins, and a storage box.

3.1.2 Study sites

The forests of Ghana comprise four increasingly dry vegetation zones. These are arranged as concentric bands, beginning with the Wet Evergreen Forests in the southwest corner of the country, extending outward through the Moist Evergreen, Moist Semi-Deciduous, and Dry Semi-Deciduous Forest Zones (Hawthorne and Abu-Juam, 1995). The study was conducted in two isolated forest fragments namely Abiriw (05° - 48' N; 00° - 06' W) and Odumante (08° - 82' N; 00° - 02' W) groves both located in the moist semi-deciduous forest zone of Ghana in order to evaluate their relative conservation value. The Abiriw and Odumante groves are located in the Akwapim North and South Districts respectively of the Eastern Region of Ghana (Fig. 2). The sacred groves range in size from 400 m^2 to 250 m^2. Individual sacred groves fall under the jurisdiction of local traditional councils, and permission from village elders to enter and collect from each grove was required and secured. The Abiriw sacred grove is a gazette reserve called the Bosompra Forest Protected Area; meanwhile the Odumante sacred grove has been protected ever a long period. Each sacred grove is completely surrounded by an anthropogenically derived farm bush savanna matrix. The

Abiriw grove contains the Bosompra stream, which is the main water body draining the Abiriw township. Due to laxity in enforcing some of the customary laws that deter human exploitation of the forest resources, there has been increasing over-exploitation of these resources (e.g. logging, fuel wood harvesting, farming etc.) in the Abiriw grove. The Odumante grove has been well preserved for several generations; however, due to the economic constraints that local communities are facing, the grove is exploited for fuel wood, used as a burial ground by local people and a site for acting of local movies.

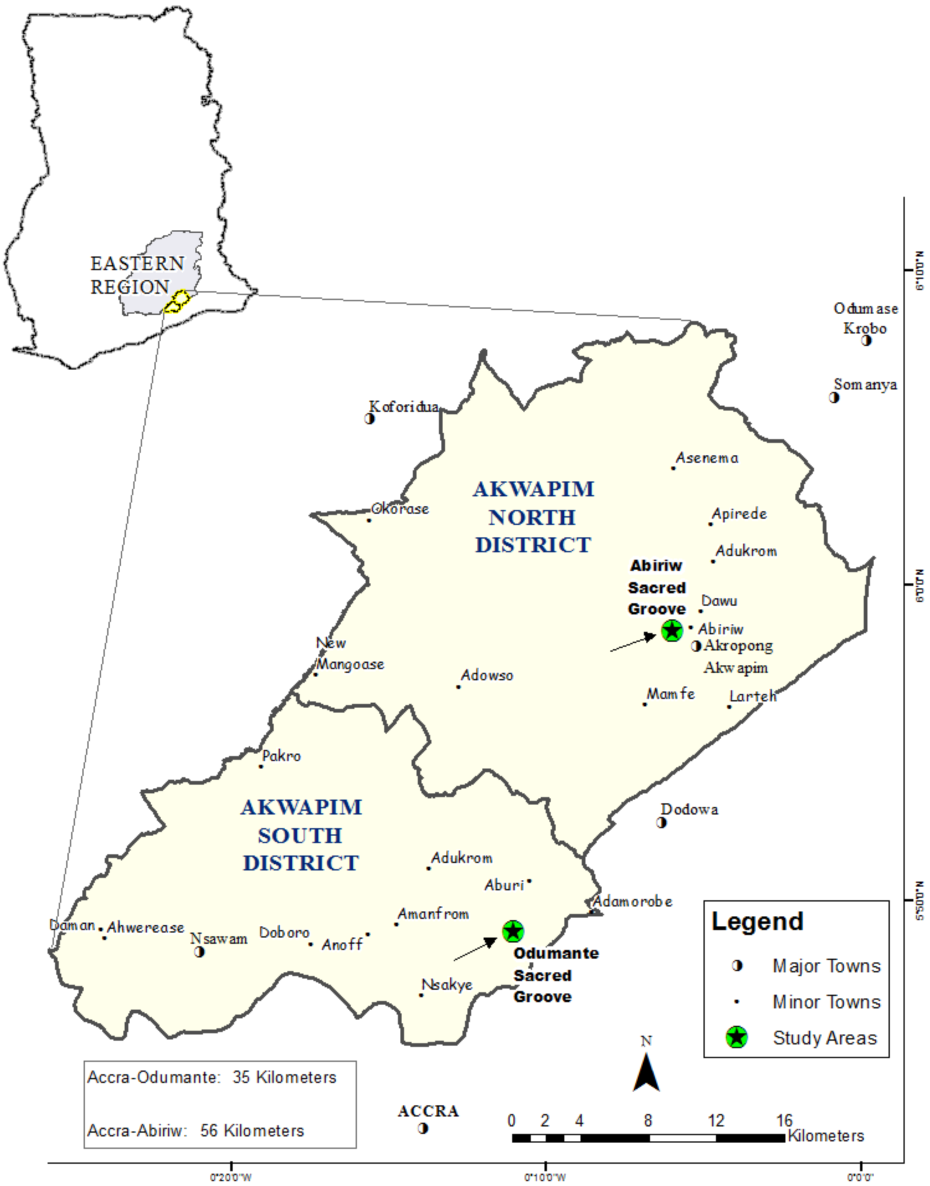


Figure 2: Map showing the study areas, Abiriw and Odumante Sacred groves in the Akwapim North and South Districts in the Eastern Region of Ghana.

3.2 Methods

3.2.1 Sampling design

Various trapping techniques including light trap, malaise trap, fruit-baited charaxes traps, pitfall traps, yellow pan traps, flight interception traps, swept net, and aerial net were used to collect insects. Transect walk-and-counts were done in the field as well. One forest edge-to-interior transect was established in each site to sample the insects. Each transect was established by walking perpendicularly from the forest edge into the forest interior using a meter tape to determine the distance. A machete was used where necessary to gain access through the understory. In each grove, all traps were set along the transect as we walked through it. Sampling was done monthly during the rainy season (June, July and October) and the dry season (December, January and February) and temperature was recorded during these seasons. Sampling was done during these months based on the availability of local field guides in the respective sacred sites.

3.2.1.1 Sampling techniques

Light traps

Flying insects are often attracted to light at dark. Various light traps are often designed and usually collect large nocturnal insects. The light trap used in this study consisted of a rechargeable lamp and a plastic bucket containing 70 % alcohol that served as a collecting jar (Plate 1). A white calico sheet was tied to two poles to form a screen. The lamp was then hanged close to the bottom of the bucket, but did not touch the alcohol while the plastic bucket was placed at the base of the white calico. One trap was set in each area. The trap was set from 7:00 pm to 10:00 pm. Insects were collected directly into the bucket with the help of a pair of forceps or tapping of the calico. Some insects fell directly into the alcohol in the bucket. Catches were poured into a perspective bag containing 70 % alcohol for subsequent identification in the laboratory.

Plate 1: A light trap

Malaise traps

Malaise traps collect flying insects. The type used during the study was made of black nylon netting and was tent-like and rectangular, supported vertically by one or more steaks (Plate 2). One trap was set in each area. The flying insects enter the net through the open sides and are directed into the collecting bottle containing 70 % by the sloping net. They were collected after 3-5 days for subsequent identification.

Plate 2: A malaise trap

Charaxe trap

Typical fruit-baited charaxes traps were used to sample butterflies. Five charaxes traps were hung in each sacred site. Individual traps within areas were separated from each other by at least 50 m and by no more than 250 m. Conscious effort was taken to install all traps in similar micro habitats within areas of closed canopy forest. Sampling at a given site consisted of baiting the charaxes traps with mashed, fermenting or rotting banana with beer and retrieving trap collections after 4 days (Plate 3). Standard field handling of specimens captured from charaxes traps consisted of firmly squeezing the thorax to disable the specimen (Oduro and Aduse-Poku, 2005). The specimens were placed in glassine envelopes and stored for subsequent laboratory processing comprising identification, drying, spreading, pinning, photographing and labeling. Each processed specimen was then labeled.

Plate 3: A charaxe trap

Pitfall traps

The pitfall traps collect ground-dwelling and crawling insects. They consisted of a straight sided container sunk in the ground until the rim is at ground level (Plate 4). Ten traps were set at 20 m intervals along the 200 m transect in each area. Each trap contained a soapy solution in order to break the surface tension so that trapped insects will not be able to fly out.

Trapped insects were collected after 3-5 days and emptied into perspective bags containing 70 % alcohol for subsequent identification.

Plate 4: A pitfall trap

Yellow pan traps

Yellow pan traps collect insects that are attracted to yellow colour. They consisted of a yellow bowl placed with the litter of the forest floor (Plate 5). Ten traps were set at 20 m intervals along the 200 m transect in each area. Each trap contained a soapy solution. Trapped insects were collected after 3-5 days and emptied into perspective bags containing 70 % alcohol for subsequent identification.

Plate 5: A Yellow pan trap

Flight interception traps

The trap is mainly used to collect flying insects which are not likely to be attracted to bait or light. It consisted of a piece of screen extended between two poles or tree, that insects fly into, whereupon they fall into a plastic filled with a preservative (70% alcohol) (Plate 6). One trap was set in each area. Trapped insects were collected after 3-5 days and emptied into perspective bags containing 70 % alcohol for subsequent identification.

Plate 6: A flight interception trap

Swept net

The swept net is used to collect insects around vegetation. It consisted of a circular metallic rim with a cloth attached to form a sac with the rim as the opening with a wooden handle attached to the rim (Plate 7). It was passed through the vegetation with alternating forehand and backhand strokes for about 20 times and the contents carefully emptied into a killing jar. The caches were later poured into a perspective bag containing 70 % alcohol for subsequent identification.

Plate 7: A Swept net

Aerial net

The aerial net consisted of a metallic rim with a woody handle and a fine mesh forming a sac (Plate 8). Swarming butterflies, dragonflies and moths were spotted and collected. The butterflies caught were killed by squeezing their thorax and placed in glassine envelopes with wings folded together. This technique prevented them from losing their scales, a feature very vital for identification. The other insects were transferred into killing jars containing ethyl acetate and kept in glassine envelopes for later identification.

Plate 8: An aerial net

Transect walk-and-counts

Transect walk-and-counts were used to sample butterflies. At each site, the transect route and sacred grove edges were walked to sample butterflies. Sampling was done under sunny conditions mostly between 9:00 am and 4:00 pm. All butterflies seen within 2.5 m on either side of the transect route and sacred grove edge and up to 5 m in front of the observer were recorded (Fermon *et al*.,2001). For those that could not be identified on the spot, photographs were taken with a digital camera for later identification.

3.2.2 Laboratory studies

3.2.2.1 Sorting and species identification

With the aid of a stereomicroscope, preserved insects collected in the field were first separated into their various orders based on morphological characters. All trapped insects were identified to the species level using a variety of taxonomic treatises, including Scholtz and Holm (1989), Carter (1992), Belcastro and Larsen (2006), Borror *et al*., (1954) and Larsen (2005). Difficult specimens were identified in consultation with Mr. A. R. Sigismund, a research assistant. Voucher specimens of species collected during the study have been deposited at the Laboratory at the African Regional Postgraduate Programme in Insect Science (ARPPIS), University of Ghana, Legon.

3.2.3 Statistical analysis of community diversity measures

To minimize variance associated with individual traps, due to differential attractiveness of traps or sporadic destruction of samples in the field (DeVries *et al*., 1999), trap data obtained at a given site on a specific date were pooled to generate a single sample for each site–date combination. Data from all the traps were pooled to obtain total insect diversity per study sites and per sampling period. The Student t-test was used to test the significant variation in the number of insect per order between sites, the total insect abundances between sites and between the wet and dry season in each grove.

For each site, the overall species accumulation curve was generated using the Estimate S program, Version 8.0 (Colwell, 2000). The number of samples was used as the index of sampling effort. Estimate S was also used to compute richness estimates based on a variety of nonparametric estimators for Abiriw and Odumante sacred groves (Appendix 2). The Margalef, Shannon-Weiner and Simpson indices were computed for each site and for the wet and dry season in each site using the GenStat program, Version 9.2 (Appendix 2). The similarity or complementarity between sites and the wet and dry season in each site based on the number of shared species among the insect fauna was measured using the Bray–Curtis index (Sjk) (Magurran, 2005). The value of the Bray-Curtis index is 1 (or 100) when two samples are identical and 0 when samples have no species in common (Magurran, 2005). The computation was carried out using the Estimate S program.

CHAPTER FOUR

4.0 RESULTS

4.1 **Insect abundance in the two sacred groves**

A total of 4,649 individual insects were recorded from both sites combined, with 3,491 and 1,158 individual insects from Abiriw and Odumante, respectively. Four hundred and nine (409) insect species were collected in total from both sites combined; belonging to 18 orders and 102 families (Appendix 3). Insects belonging to the orders Diptera, Hymenoptera, Coleoptera and Lepidoptera were particularly abundant and diverse in both groves (Fig.3; Table 3). At Abiriw, the Dipterans had the highest count with a relative abundance of about 59 %. Lepidoptera, Hymenoptera and Coleoptera recorded the next highest counts making up about 25 %, 8 % and 4% respectively. At Odumante, Lepidoptera had the highest count with a relative abundance of about 39 %. Hymenoptera, Diptera and Coleoptera recorded the next highest counts making up about 21 %, 16 % and 14% respectively. When comparing insect abundance of the different orders recorded between groves, significant differences were found in the orders Diptera and Lepidoptera (Table 3). All but thirteen of the 89 butterfly species are specialized on savanna habitat (Appendix 3). The abundance of insects did not differ significantly between sites and between the wet and dry season in each site ($P > 0.05$ using the two-sample paired t-test). At the Abiriw sacred grove, the relative abundance of Diptera, Hymenoptera, Lepidoptera and Coleoptera was higher during the wet season than the dry season meanwhile at Odumante, the relative abundance of Hymenoptera, Lepidoptera and Coleoptera was higher during the wet season than the dry season except that of the Diptera (Fig.4). Some of the commonly encountered insect species collected in both sacred groves are shown in figure 5.

Table 3: Summary of individual insects captured by order and habitat type

Oder	Abiriw	Odumante	P-probability
Diptera	2065	185	P < 0.05
Hymenoptera	281	247	P > 0.05
Orthoptera	47	41	P > 0.05
Coleoptera	124	166	P > 0.05
Homoptera	43	17	P > 0.05
Dictyoptera	11	7	P > 0.05
Hemiptera	10	6	P > 0.05
Collembola	7	27	P > 0.05
Odonata	1	1	P > 0.05
Phasmida	1	0	
Trichoptera	3	2	P > 0.05
Thysanura	4	0	
Thysanoptera	3	3	P > 0.05
Lepidoptera	890	451	P < 0.05
Isoptera	1	0	
Dermaptera	0	3	
Siphonaptera	0	1	
Protura	0	1	
Total individual number (N)	3491	1158	P > 0.05

Two-sample paired t-test indicates differences in the total number of individual insects per order. Between sites, the total number of individual insect does not differ significantly P> 0.05).

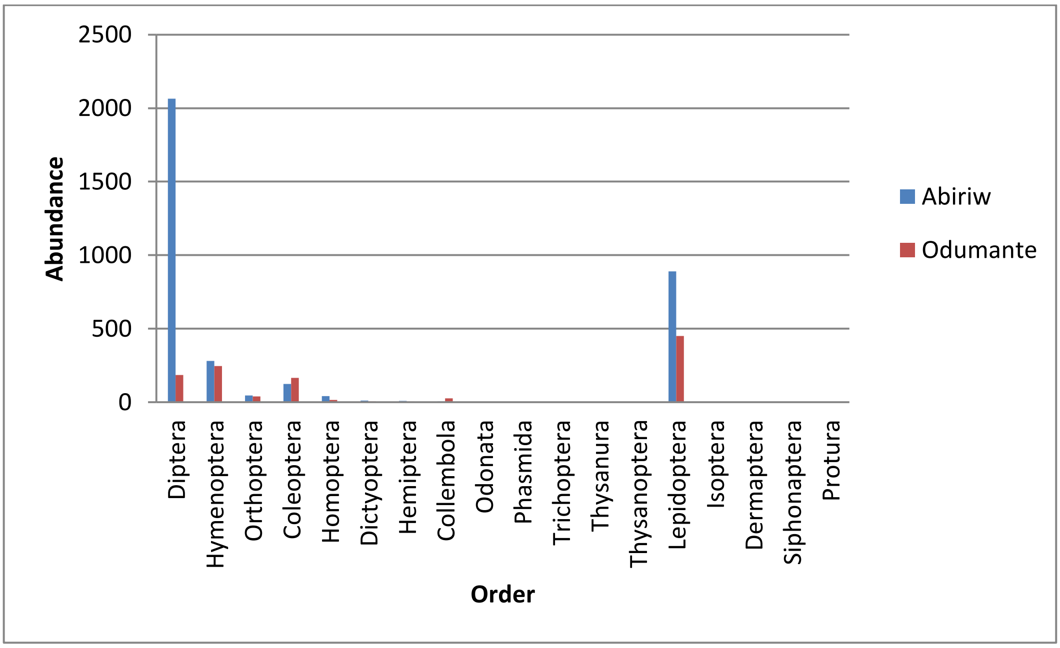
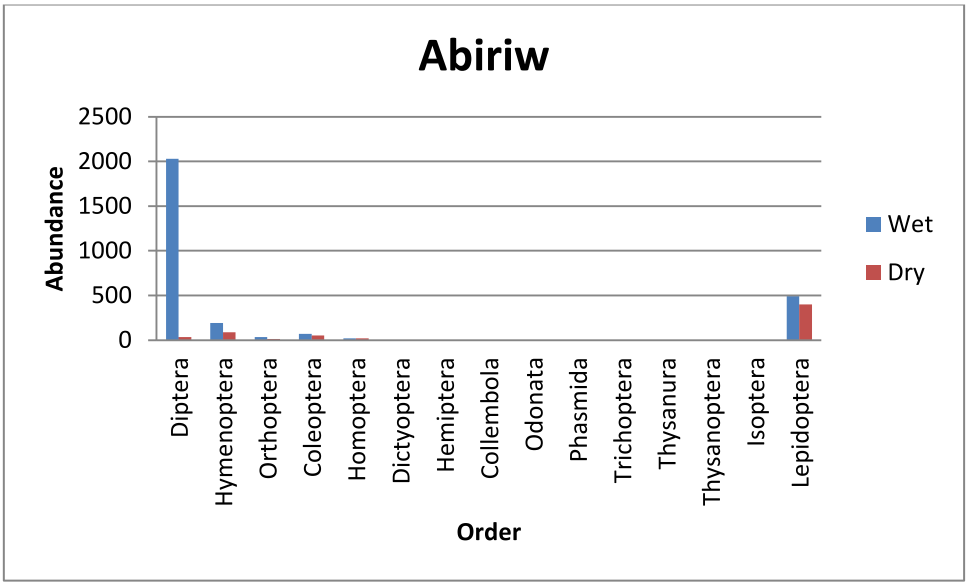


Figure 3: Relative abundance of insect orders at both sites



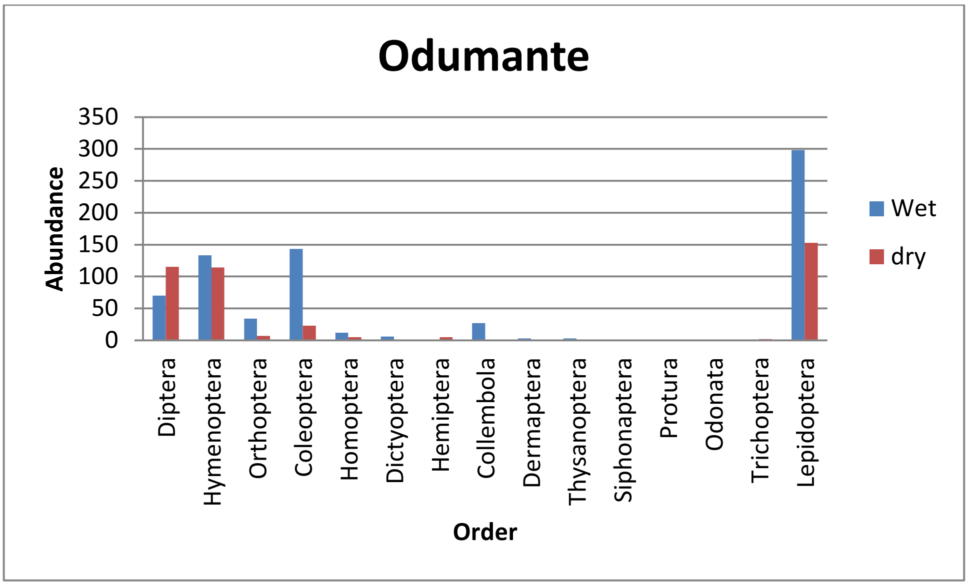


Figure 4: Relative abundance of insect orders between wet and dry seasons at both sites

Camponotus pennsylvanicus

Pogonomyrmex occidentalis

Evania sp.

Euphaedra harpalyce

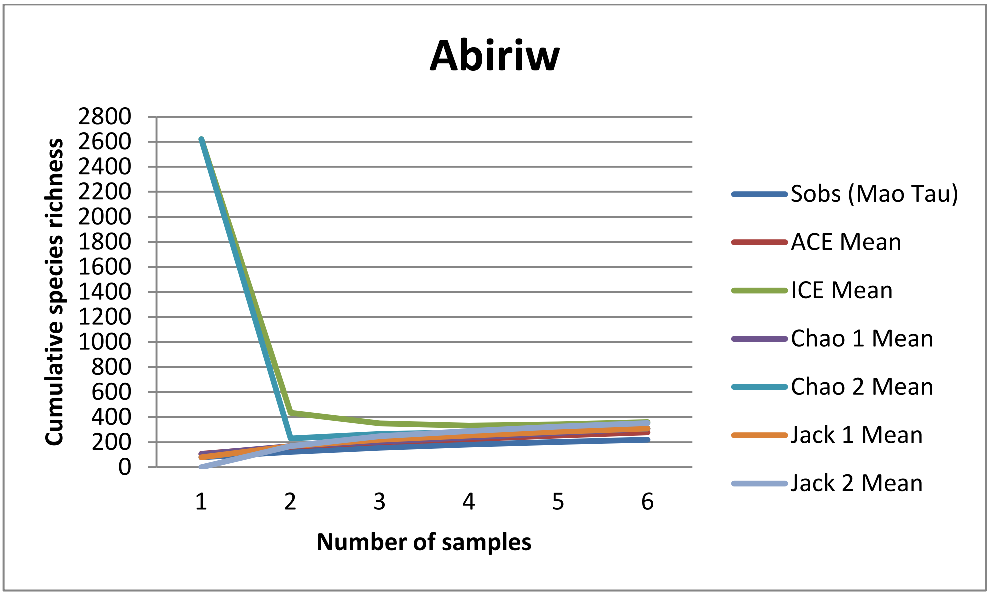
Nepheronia thalassina

Leptosia alcesta

Figure 5: Some common insect species collected in both sacred groves

4.2 Observed species richness

The observed species richness was higher at Abiriw than Odumante grove (Table 4). At both sites, the species accumulation curves were clearly approaching an asymptote, indicating that species saturation had been reached and sampling effort was adequate (Figure 6).



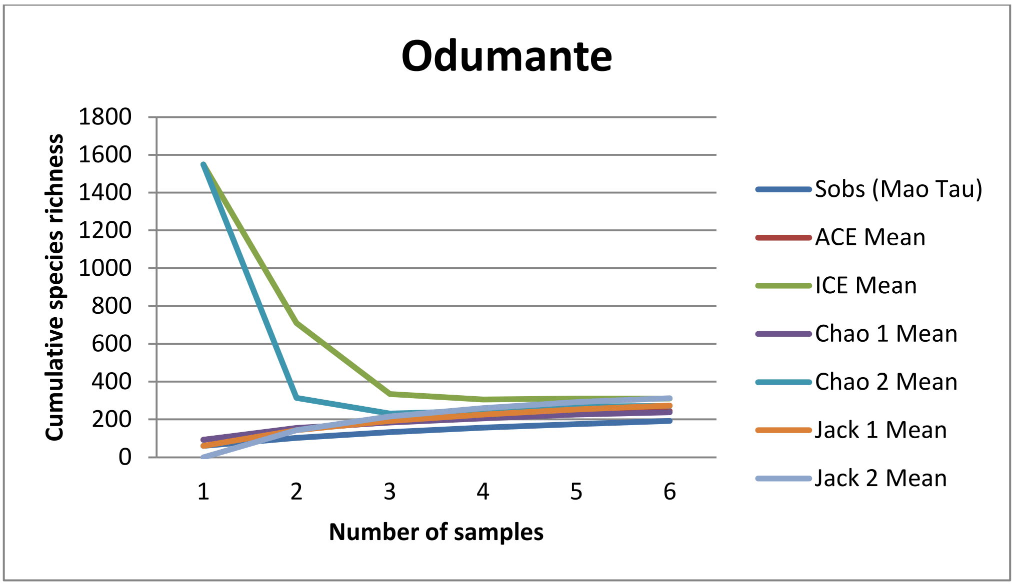


Figure 6: Randomized species accumulation curves. Number of observed and estimated species at each site as a function of increasing numbers of samples. ACE, Chao1 and Jack1 = non-parametric estimates of species richness; Sobs = actual species observed in samples.

4.3 Estimated species richness

At both sites, the ICE (Incidence-based) coverage estimator and Chao2 (Incidence-based) estimators produced stable and broadly accurate estimates at small numbers of samples (Figure 6). The Jack2 produced a lower estimate at small number of samples and eventually produced stable and accurate estimates at large numbers of samples.

Estimates of total species richness were more variable at both sites and depended upon the richness estimator used (Table 4, Figure 6). At Abiriw, Chao1 and Jack1 estimators were identical or almost identical, predicting a species richness of 310 (Table 4). Similarly, the Jack2, ICE and Chao2 estimators were identical or almost identical, predicting a species richness of 350. ACE estimator predicted a species richness of 280. This indicates that the true species richness in the Abiriw grove is in the range of 280-350. At Odumante on the other hand, Chao1 and ACE estimators were identical or almost identical, predicting a species richness of 240. ICE and Chao2 estimators were as well identical or almost identical, predicting a species richness of 350. Jack1 estimator predicted a species richness of 270 and Jack2 predicted a species richness of 310. This indicates that the true species richness in the Odumante grove is in the range of 240-350. At Abiriw, the estimators predicted 10-520 additional species, meanwhile at Odumante; they predicted 12-394 additional species (Table 4).

Table 4: Values of species richness estimates at both sites

Sites	Total species trapped	Singletons / Doubleton	Unique/ Duplicates	Estimates of total richness			Additional species predicted	Diversity indices	Richness index
				ACE/ ICE	Chao1/ Chao2	Jack1/ Jack2		Simpson/ Shannon	Margalef
Abiriw	220	53/25	29/18	204/740	216/666	219/230	10-520	3.13/2.72	27.09
Odumante	192	51/28	87/30	186/586	183/480	191/204	12-394	58.62/4.52	26.93

Singletons and doubletons are the number of species represented by one or two individuals, respectively. Uniques and duplicates are the number of species occurring in only one or two samples, respectively. Nonparametric richness estimators were used to estimate total species richness at a site. ACE and Chao1 are abundance-based richness estimators. All others are incidence-based estimators. The number of additional species estimated to be at each site is the difference between estimated total richness and the number of species actually collected from traps. Simpson/Shannon diversity indices below the diagonal and Margalef richness index, where larger number indicates greater species evenness and richness.

4.4 Species richness and diversity indices

The Margalef richness index was slightly higher at Abiriw than Odumante, indicating higher species richness at Abiriw than Odumante (Table 4). However, the Shannon-Weiner and Simpson diversity indices were higher at Odumante than Abiriw, indicating that species are more evenly distributed in Odumante than Abiriw. In Abiriw, the Margalef richness index, the Shannon-Weiner and Simpson diversity indices were higher in the dry season than the wet season (Table 5). Meanwhile, in Odumante, these indices were higher in the wet season than the dry season.

Table 5: Diversity and richness indices for each season in each sacred grove

Sites	Indices		
	Simpson (1/D)	Shannon-Weiner (H')	Margalef
Abiriw wet	2.12	1.92	17.34
Abiriw Dry	72.33	4.53	23.28
Odumante Wet	42.17	4.18	19.56
Odumante Dry	32.85	4.08	18

Simpson (1/D), Shannon-Weiner and Margalef indices were calculated, where larger numbers indicate greater species evenness and richness.

4.5 Site complementarity

A number of species were trapped at only one site (Appendix 3). Abiriw had, by far, the largest number of these at 110, most of which were fairly well represented. About 78 species were exclusive to the Odumante grove but nearly all of these were represented by one or two individuals. The insect community at Abiriw and Odumante were slightly similar (Table 6). In each sacred grove, the insect community fauna trapped during the wet and dry season were not similar.

Table 6: Complementarity of species assemblages between sites and seasons.

Site	Odumante (192)	Dry season Abiriw (65)	Dry season Odumante (40)
Abiriw (220)	52	-	-
Wet Season Abiriw (65)	-	42	-
Wet Season Odumante (31)	-	-	35

Bray-Curtis quantitative index of similarity (expressed as percentages) below the diagonal. The total number of species trapped at each site is in parentheses for ease of comparison.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Insect abundance in both sacred groves

The survey revealed high levels of biodiversity among the general insect populations with both sacred grooves rich in insect fauna. It should be noted that many of the species are terrestrial and this is a reflection of the general habitat variability that is found in forest areas in early/recovery stages of disturbance (Hill and Curran, 2001). There was a significant difference in the abundance and diversity of Lepidopterans at both sites, with Abiriw being more diverse and abundant in Lepidopterans than Odumante. This study represents the first comprehensive insect survey in the Odumante grove. Although butterflies and aerial insect surveys have been conducted in the Abiriw grove in the past, butterfly species and aerial insect species and numbers recorded were lower than that obtained in this study. Boafo (2010) recorded 207 individuals belonging to 51 species from 8 families during a 2-day survey with no Lycaenidae and Riodinidae recorded. The family Nymphalidae and Pieridae had the highest number of individuals as well as species and only one charaxes species (*Charaxes protoclea*) was recorded. On the other hand, Mc Ewan (2005) recorded 895 individual aerial insects belonging to 4 orders (Diptera, Hymenoptera, Lepidoptera, and Neuroptera). No species of the order Odonata were recorded. The dominant order was Diptera followed by Lepidoptera, Hymenoptera, and Neuroptera. The relative low species richness recorded during Boafo and Mc Ewan's surveys is consistent with theoretical expectation of short term insect inventory, whereby rapid assessment tends to be biased toward common, well known species (Summerville and Crist, 2002). The rapid survey might have missed important rare species, which in ecological studies are very important from the conservation viewpoint. It can therefore be deduced that, this study represents the first comprehensive and long term insect survey in the Abiriw grove because more species were recorded with increasing sampling effort.

No significant differences were found between the relative abundance of insects in the Abiriw and Odumante trap collections, and also between the wet and dry seasons in each grove. The precise reason for this would require further and more detailed examination of populations. However, one possible explanation could be that both groves are located in the same geographical zone and sampling was done under the same environmental conditions.

5.2 Observed species richness

The insect community trapped at Abiriw generally had more species than that at Odumante, which is consistent with theoretical expectation of species-area relationship, whereby small areas tend to support fewer species (Schoener, 1976; May and Stumpf, 2000). Not surprisingly, the Margalef index of species richness was higher at Abiriw than Odumante. Interestingly, the Simpson and Shannon indices of overall diversity proved to be lower for the Abiriw sample than for the Odumante sample indicating that the insect community at Abiriw was generally less diverse with respect to the relative abundance of member species than that at Odumante. In communities, such as Abiriw, that are dominated by a few very abundant species, the vast majority of individuals in the community will be of these few predominant species whereas in communities, such as Odumante, where species are equitably represented, randomly encountered individuals are more likely to be derived from different species. This according to Purvis and Hector (2000) is a defining characteristic of a diverse community. These diversity measures, especially the Simpson index, are heavily weighed by the relative abundance of the most abundant species, which at Abiriw accounted for 56 % of all individuals trapped, that is, *Dolichopus sp*. Hence, in a broad sense, these findings add to the already substantial body of data that indicate that the primary success of biodiversity conservation hinges on protection of large habitat areas.

The Abiriw grove has retained much of its closed canopy most probably due to its distance from the Abiriw village as well as its rural setting which may have probably helped preserve the grove's integrity and resident biodiversity. Abiriw, unfortunately, also proved to be imperiled due to laxity in enforcing some of the customary laws that have helped in the past to deter human exploitation of the forest resources (Kangah-Kesse *et al.*, 2007). Before the beginning of the dry season collection, local communities cleared the route along which sampling at the grove was done, uprooting virtually every old growth and trees during the festival ceremony. This could be one of the possible explanations for the fewer number of individual insects collected during the dry season compared to the wet season. This event increased the enhanced vulnerability of small isolated forests to further degradation (Laurance *et al.*, 1998).

Trapping at the smaller grove yielded the smaller sample community. Relatively fewer species were collected at this grove. The low observed species richness at Odumante is somewhat surprising, because the forest has retained much of its closed canopy. However, the landscape matrix surrounding the grove is uniquely characterised by intensive residential and farming activities adjacent to, and in some cases very close to the premises of the grove. The grove is also used as a burial ground by the local communities and as a site for acting local movies. All of these activities have undoubtedly led to the degradation or disruption of key ecological processes in the groves. This highly transformed landscape matrix has most likely served to hinder emigration from and immigration of insects to this isolated forest.

At Abiriw, insects were more abundant and diverse in the dry season than the wet season. Meanwhile, at Odumante, insects were more abundant and diverse in the wet season than the dry season. One possible explanation in the variation observed in the Abiriw grove could be tied to the lowering of humidity with the harmattan. The temperature was generally high during the dry season, reaching 31°C compared to the wet season, where the temperature was generally below 26 °C (Ghana Meteorological Service). The dry weather reduced the prevalence of fungal diseases which attack insects. In the Odumante sacred grove, it was observed that the abundance and diversity of predaceous insects belonging to the Asilidae, Bombylidae, Phoridae, Dolichopopidae, Conopidae, Anthomyiidae, Sarcophagidae, Tachinidae, Braconidae, Ichneumonidae, Evaniidae, Reduviidae, Carabidae, Staphylinidae, and Coccinellidae was higher in the dry season than the wet season (Appendix 3). This could account for the low diversity and abundance of insect recorded during the dry season. As noted by Pinheiro *et al*., (2002), the abundance of predators, parasitoids and the prevalence of diseases determine insect diversity and abundance at a particular habitat. It should be noted that the abundance and diversity of the predaceous insects mentioned above was also higher in the dry season than the wet season in the Abiriw sacred grove; and the variation of temperature recorded in the Abiriw grove during the wet and dry season was the same in the Odumante grove. The precise reason thus, for this variation in insect abundance and diversity during the wet and dry seasons in both groves would require further and more detailed examination of populations. This is because the abundance and diversity of insects at a particular habitat depends on a wide range of factors including, the availability of food, climatic conditions, the abundance of larval food plants, conditions suitable for egg laying, and suitable flowers for feeding of adults (Allan *et al*., 1973; Pollard and Yates, 1993).

5.3 Estimated species richness among sites

The observed number of species in any sample of individuals from a community underestimates the true number of species present. In statistical terms, observed species richness (S_{obs}) is a biased estimator of the true richness for the assemblage sampled. Thus, a critical element of evaluating the performance of a species richness estimator is to assess how nonparametric richness estimators behave as a function of the number of samples (Colwell and Coddington, 1994). These estimators helped in comparing the sampling effort and species realised to the estimated species richness.

At both sites, the observed species richness clearly underestimated the true species richness. Only two of the measures tested the Chao2 and the ICE produce estimates that are no longer incrementing when all the samples have been accumulated, although the Jack2 graph also shows some sign of leveling off. In several studies that attempted to evaluate the performance of nonparametric estimators, ICE and Chao2 have been reported to be the estimators that give promising estimates of the total species richness because they perform well at small sample size and are relatively insensitive to sample density and species patchiness (Chazdon *et al*., 1996; Magurran, 2005). What is intriguing is that these 3 approaches generate estimates that are not only markedly larger than the observed species richness, but that are also broadly different (Table 4). Based on this analysis, we view ICE, Chao2 and Jack2 as the most suitable estimators for further examination within the other forest sites. These estimators are all based on incidence pattern of species among samples and require only presence/absence data. The Jackknife2 estimator performed better than the Jackknife1 when comparing the estimators in terms of the ability to underestimate or overestimate (Bias) the true species richness (Table 4). The Jack2 estimator yielded estimates of species richness larger than Jack1 and underestimated species richness at small sample sizes, but eventually overestimated species richness as sample size increased (Figure 6). Similar results have been reported for a variety of studies that attempted to compare the Jack1 and Jack2 estimators in their ability to underestimate or overestimate (Bias) the true species richness (Palmer, 1991; Colwell and Coddington, 1994). In this study, it appears that Jack2 is a less bias estimator than Jack1 even though little consensus on estimator variability has arisen from a broad collection of estimator performance studies.

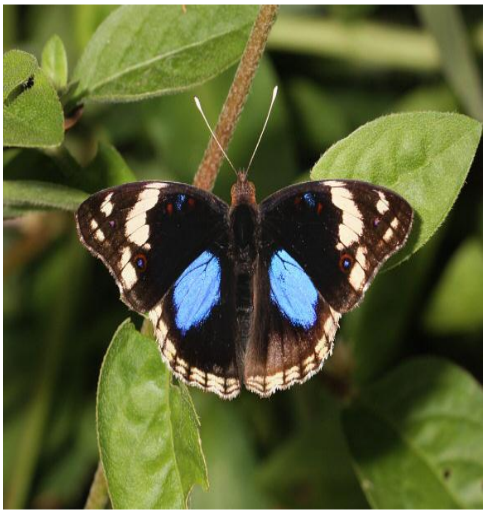
Richness estimators, in general, are highly influenced by the number of rare species and observed and estimated richness will diverge considerably if the ratio of singletons to doubletons or uniques to duplicates is large. Additionally, the ranking of different sites based on relative richness will change unless this ratio remains approximately constant across sites. The Odumante sample had the smaller ratio of singletons to doubletons than the Abiriw sample (Table 4). Consequently, estimates of total species richness at Odumante showed the least divergence from the number actually collected than that of Abiriw. However, when viewed in the context of the species actually trapped and estimated total species richness, Abiriw had more species than Odumante.

5.4 Species composition and site complementarity

According to Bossart *et al*., (2006), a comparison of species assemblages among forest patches of markedly different sizes should reveal clues about “winners” and “losers” with respect to species persistence and extinction in highly fragmented landscapes. This is because factors such as, species-area relationship, differential tolerance of individual species to relative habitat isolation and fragmentation, population size and extinction risk dynamic affect are responsible for the difference in resident communities among forest fragments (May and Stumpf, 2000; Gaston, 1998; Lande, 1988). This survey yielded a number of biodiversity indicator and ecologically important insects groups that play key roles in monitoring habitat change and maintaining balance of nature.

Concerning the biodiversity indicator insect groups, six butterfly species (*Papilio demodocus* Esper, *P. nireus* Linné, *Bicyclus dorothea* Cramer, *Hypolimnas anthedon* Doubleday, *Junonia oenone* Linnaeus and *J. terea* Drury) were trapped at both sites despite differences in forest size and condition of individual grove (Fig. 7). These species are known to be much more common in West Africa now than they ever were due to the widespread destruction and fragmentation of forest cover that has taken place in this part of Africa (Larsen, 2005). They are specialized in degraded habitats and open spaces and very few would ever be met within forests of good condition. The abundance of these species was higher at Odumante than Abiriw. This is somehow not surprising given the extent of habitat degradation that has taken place within the Odumante grove. The presence of these species however at Abiriw also tells us that some level of forest degradation has taken place within the grove; hence, these six species can be considered as indicator species of forest disturbance. In theory, these species are known to be generally common, to have fairly wide ranges and to colonise both intact and disturbed forests (Larsen, 2005). These are all characteristics, which according to Bossart *et al*., (2006); facilitate persistence of forest butterfly species in highly transformed landscapes. The grass-feeding butterflies belonging to the family Satyridae are also known to be good biodiversity indicators of forest condition. According to Larsen (1994), their increased presence is an apparent sign of forest disturbance. More satyrine species were trapped at Abiriw than Odumante, which is in agreement with earlier observation that the Abiriw grove has also undergone some level of fragmentation. Larsen (2005) found that certain butterfly species are vulnerable to habitat degradation. Seven species, *Papilio phorcas* Cramer, *P. menestheus* Drury, *Cymothoe mabillei* Overlaet, *Catuna angustatum* Felder, *Euriphene* *simplex* Staudinger, *E. barombina* Aurivillius and *Charaxe protoclea* Feisthamel, were found to be those most sensitive to the effects of forest fragmentation (Fig. 7). Only three of the seven species were collected at Odumante, while only one of these species was not collected at Abiriw. The abundance of these species in the Abiriw grove was five times greater than that collected at Odumante. Unlike rare species, whose absence could relate to their lower overall probability and rate of capture, the decreased numbers of these common species are difficult to explain except in the context of sensitivity to dynamics of forest fragmentation. Ground ants and some beetles, such as carabid bettles and dung beetles are also known as good indicator taxa to assess impact of environmental change on biodiversity because they are sensitive to changes in habitats both in time and space and have specific habitat requirements (Carlton, 1999; Agosti *et al*., 2000; Schulze *et al*., 2004; Cole *et al*., 2005) (Fig. 7). More ground ants were trapped at the Abiriw grove than the Odumante grove. This supports earlier observations that the Odumante grove has undergone more degradation than the Abiriw grove.

Ecologically important insect groups, such as termites, carpenter ants and dung beetles were trapped in both groves. These insects are known to breakdown animal and plant remains thereby releasing organic nutrients for plant use and rid the environment of obnoxious materials. A number of entomophagous insects belonging to Asilidae, Bombylidae, Dolichopopidae, Phoridae, Conopidae, Anthomyiidae, Sarcophagidae, Tachinidae, Braconidae, Ichneumoniade, Evaniidae and Gasteruptiidae were also trapped at both sites. Insects belonging to these families prey and/or parasitise other insects and hence, help to keep the ecological processes in a balanced state. Efficient pollinator species belonging to order Hymenoptera, Lepidoptera were also recorded in both sacred groves. For example, insects belonging to the Syrphidae, Apidae, Bombylidae families and butterflies are known to conduct natural pollination services that rejuvenate forests and give rise to new and diverse seeds and seedlings by pollen dispersal between flowers of different species (Raina *et al*., 2011). Five butterfly species, *Bicyclus safitza* Hewitson, *Melanitis leda* Linnaeus, *M. Libya* Distant, *Ypthimomorpha itonia* Hewitson, and *Charaxes varanes* Mabille, which are forest habitat endemics were collected in four sacred groves and two forest reserves during a yearlong survey of fruit-feeding butterfly conducted by Bossart *et al*., (2006) in Kumasi in the Ashanti Region of Ghana. Three of these species, *B. safitza*, *M. leda and C. varanes* were recorded in the Abiriw and Odumante sacred groves (Fig. 7). More than 60 % of butterfly collected are considered either moist forest specialists or species found in all forest subtypes, which is as expected given the location of our study sites well within the Moist Semi-Deciduous Forest Zone. It therefore appears that biodiversity rich sacred groves are of immense ecological significance necessary for human survival.



Junonia oenone

Junonia terea

Bicyclus safitza

Papilio demodocus

Charaxe varanes

Cymothoe mabillei

Charaxes protoclea

Melanitis leda

Canthon pilularius

Papilio nireus

Figure 7: Some indicator and endemic species collected in both sacred groves

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Our preliminary assessment of insect diversity in sacred groves adds to the burgeoning evidence that sacred groves are potential storehouses of biodiversity in highly transformed landscapes (Bhagwat and Rutte, 2006; Tscharntke *et al*., 2002). The Abiriw and Odumante sacred groves support resident populations of some butterfly species, such as *Charaxes sp*., which are known as large and robust butterflies. In addition, a number of forest species endemic to the entire forest area west of the Dahomey Gap and West Africa (*Papilio horribilis* Butler, *Hallelesis halyma* Fabricius, *Euriphene simplex* and *Pyrrhiades lucagus* Cramer respectively) were collected from the sacred groves. They are storehouses of economic important insect species, insects that have been used in scientific research (e.g. Cockroaches, bees, houseflies and *Drosophila melanogaster*), insects used in monitoring changes in habitat and those used in certain criminal investigations especially murder such as blowflies (Dipetera: Calliphoridae). There is therefore enough evidence that sacred groves in Ghana hold considerable potential for biodiversity conservation. This observation was also made by Bossart *et al*., (2006), Kangah-Kesse *et al*., (2007) and Bossart and Opuni-Frimpong (2009). There are indications, however, that with the breakdown of traditional belief systems coupled with rapid socio-economic changes, many sacred groves have been completely destroyed and many others are under imminent threat in Ghana. The nature and extent of this damage in the country varies from region to region as well as from one grove to another. Local people living near the Abiriw grove, for example, go in the grove to harvest firewood, swim in the water fall and farm without fear of any traditional beliefs and taboos that formerly deter humans from exploiting natural resources within the grove in the past. The situation is even more severe in the Odumante sacred grove. People in this community farm and build houses very close to the grove, harvest firewood and use the grove as a burial ground and site for acting of local movies. To remedy or prevent the complete destruction of the few sacred groves that have managed to survive in the country, Government, NGOs and international organizations should recognize that despite their small sizes, these relicts of old growth forest are serving to foster persistence of some forest faunal species across a landscape matrix that is largely devoid of forest habitation, and therefore incorporating them into the Protected Area Network (PAN). This would perhaps enhance more efficiently their contribution in *in situ* biodiversity conservation in Ghana.

6.2 Recommendation

Based on our findings, the following recommendations are made:

- A buffer zone of about 20 m should be created along the boundaries of the groves to prevent encroachment by estate developers who may build too close to the grove.
- Existing regulations should be vigorously enforced by the traditional authorities in the area and the government with severe sanctions applied to offenders to serve as a deterrent.
- Traditional award ceremonies should be instituted as one of the highlights annual festivals to serve as incentives to individuals and organizations which contribute to biodiversity initiatives involving the groves.
- Further research needs to be carried out on the insect diversity in sacred groves in the different regions of Ghana in order to establish their significance for conservation. Such an approach will be useful in creating global awareness of the insect diversity value of sacred groves in Ghana.

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APPENDICES

Appendix I: Distribution of sacred groves in India with the area covered.

Location	Number of sacred groves	District	Area (ha)
Andhra Pradesh	800	-	-
Andhra Pradesh	750	23	-
Arunachal Pradesh	58	2	-
Arunachal Pradesh	101	4	-
Assam	40	1	-
Gujarat	29	1	0.42
Harayana	248	18	-
Himachal Pradesh	11	-	-
Karnataka (Coorg)	1214	-	2407
Kerala	2000	-	500
Madhya Pradesh	275	-	-
Maharashtra	1600	-	-
Maharashtra	483	10	3570
Maharashtra	250	1	-
Manipur	365	-	-
Manipur	166	4	756.42
Meghalaya	79	-	26,326
Orissa	322	-	50
Rajasthan	1	-	83
Rajasthan	9	-	158
Sikkim	56	4	-
Tamil Nadu	10	-	127
Tamil Nadu	3	-	-
Tamil Nadu	1	-	-
Tamil Nadu	448	28	-
Uttar Pradesh	6	-	5500
West Bengal	7	-	2
West Bengal	190	-	15
West Bengal	670	5	-

Source: Adopted from Malhotra, 1998 and Malhotra *et al.*, 2001; cited in Khan *et al.*, 2008

Appendix II: Formulas for measures of Diversity

1. Nonparametric estimators

The following nonparametric estimators were computed:

Chao 1: the Abundance-based estimator

$$S_{\text{Chao 1}} = S_{\text{obs}} + \frac{F_1^2}{2F_2}$$

Chao 2: Incidence-based coverage estimator

$$S_{\text{Chao 2}} = S_{\text{obs}} + \frac{Q_1^2}{2Q_2}$$

ACE: the Abundance-based coverage estimate

$$S_{\text{ACE}} = S_{\text{abund}} + \frac{S_{\text{rare}}}{C_{\text{ACE}}} + \frac{F_1}{C_{\text{ACE}}}\gamma_{\text{ACE}}^2$$

and the estimate of coefficient of variation of the F_i's, is:

$$\gamma_{\text{ACE}}^2 = \max\left\{\frac{S_{\text{rare}}}{C_{\text{ACE}}}\frac{\sum_{i=1}^{10} i(i-1)F_i}{(N_{\text{rare}})(N_{\text{rare}}-1)} - 1, 0\right\}$$

ICE: Incidence-based coverage

$$\boxed{S_{\text{ICE}} = S_{\text{freq}} + \frac{S_{\text{infr}}}{C_{\text{ICE}}} + \frac{Q_1}{C_{\text{ICE}}}\gamma_{\text{ICE}}^2}$$

and the estimate of coefficient of variance of the Qi's, is:

$$\gamma^2_{\text{ICE}} = \max\left\{\frac{S_{\text{infr}}}{C_{\text{ICE}}}\frac{m_{\text{infr}}}{(m_{\text{infr}}-1)}\frac{\sum_{i=1}^{10} i(i-1)F_i}{(N_{\text{infr}})^2}-1, 0\right\}$$

Jacknife 1 and Jacknife 2: First-Order and second-order jacknife estimators of species richness.

$$S_{\text{Jack 1}} = S_{\text{obs}} + Q_1\left(\frac{m-1}{m}\right)$$

$$S_{\text{Jack 2}} = S_{\text{obs}} + \left[\frac{Q_1(2m-3)}{m} - \frac{Q_2(m-2)^2}{m(m-1)}\right]$$

Key to variables of the above mentioned nonparametric species richness estimators

S_{obs} Total number of species observed in all samples pooled

S_{rare} Number of rare species (each with 10 or fewer individuals) when all samples are pooled

S_{abund} Number of abundant species (each with more than 10 individuals) when all samples are pooled

S_{infr} Number of infrequent species (each found in 10 or fewer samples)

S_{freq} Number of frequent species (each found in more than 10 samples)

m Total number of samples

m_{infr} Number of samples that have at least one infrequent species

F_i Number of species that have exactly i individuals when all samples are pooled (F_1 is the frequency of singletons, *F₂* the frequency of doubletons)

Q_j Number of species that occur in exactly *j* samples (Q_1 is the frequency of uniques, Q_2 the frequency of duplicates)

N_{rare} Total number of individuals in rare species

N_{infr} Total number of incidences (occurrences) of infrequent species

C_{ace} Sample abundance coverage estimator

C_{ice} Sample incidence coverage estimator

2. Index of complementarity of community composition

Similarity was measured using the Bray-Curtis coefficient given as:

$$C_{BC} = \frac{2\sum_{i=1}^{S_{12}} \min(N_i, M_i)}{\sum_{i=1}^{S_1} N_i + \sum_{i=1}^{S_2} M_i}$$

and the sample version is:

$$\hat{C}_{BC} = \frac{2\sum_{i=1}^{D_{12}} \min(X_i, Y_i)}{\sum_{i=1}^{D_1} X_i + \sum_{i=1}^{D_2} Y_i}.$$

Where Ni = Total individuals in sample i

Mi = Total individuals in sample i

($N_1, N_2, \ldots, N_{S1}$) and ($M_1, M_2, \ldots, M_{S2}$) = total number of individuals for each species in the two complete assemblages

3. Species richness indices

Species richness was measured using the Margalef index.

$$D_{Mg} = \frac{(S-1)}{\ln N}$$

Where S = Number of species recorded

N = Total number of individuals in the sample

4. Species diversity indices

Species diversity indices were measured using the Shannon (H') and Simpson indices:

Shannon-Weiner index is given as:

$$H' = -\sum p_i \ln p_i$$

Where p_i = Proportion of individual found in the ith species

Simpson's (inverse) index of diversity is given as 1/D, where

$$D = \sum \left(\frac{n_i[n_i - 1]}{N[N - 1]} \right)$$

Where Ni = Number of individuals in the *i*th spesies

N = Total number of individuals

Appendix III: List of species recorded at both sacred groves.

Species/Forest zone categories	Sacred groves	
	Abiriw	Odumante
Diptera		
Syrphidae		
Syrphus ribesii	5	0
Syrphus sp	5	0
Eristalis sp	1	0
Metasyrphus americanus	2	0
Asilidae		
Promachus sp.	0	2
Promachus vertebratus	0	2
Leptogaster flavipes	0	1
Phoridae		
Megaselia rufipes	11	54
Megaselia sp.	8	2
Megaselia scalaris	2	1
Pipunculidae		
Pipunculus sp.	7	0
Delichopodidae		
Delichopus sp.	1	1
Calliphoridae		
Phormia sp.	0	1
Calliphora sp.	0	2
Phaenicia sp.	2	13
Phormia regina	1	2
Calliphora vicina	0	6
Drosophilidae		
Drosophila sp.	6	2
Drosophila melanogaster	0	2
Tabanidae		
Tabanus atratus	1	1
Tabanus lineola	0	1
Diopsidae	0	1
Tephritidae		
Rhagoletis cingulata	1	3
Rhagoletis sp.	3	1
Rhagoletis pomorella	0	1

Simulidae		
Cnephia sp.	1	0
Cnephia pecuarum	0	1
Simulium vittatum	0	2
Empididae		
Dolichopus sp.	1961	0
Therevidae		
Psilocephala aldrichi	1	7
Psilocephala sp.	0	8
Tachinidae		
Spoggosia claripennis	2	3
Bombyliopsis abrupta	1	0
Chironomidae	30	0
Bombylidae		
Sparnopolius sp.	1	0
Tipulidae		
Tipula abdominalis	0	1
Muscidae		
Musca domestica	2	3
Stratiomyidae		
Stratiomys meigenii	0	1
Otitidae		
Delphinia picta	0	11
Tetanops myopaeformis	0	6
Sarcophagidae		
Helicobia rapax	0	1
Sarcophaga haemorhoidalis	0	1
Anthomyidae	1	0
Culicidae		
Aedes sticticus	4	12
Anopheles quadrimaculatus	2	10
Anopheles punctipennis	1	0
Culex pipiens	1	13
Culex tarsalis	0	2
Conopidae		
Physocephala sp.	1	0
Sciomyzidae		
Sepedon fuscipennis	0	2
Hymenoptera		
Braconidae		

Apanteles glomeratus	2	5
Chelonus texanus	2	6
Chelonus sp.	2	1
Macrocentrus sp.	0	3
Apanteles sp.	0	2
Colletidae		
Hylaeus sp.	0	1
Hylaeus modestus	1	0
Vespidae		
Vespula maculata	1	0
Evaniidae		
Evania sp.	12	30
Evania appendigaster	8	9
Evania condominium	0	28
Formicidae		
Iridomyrmex sp.	25	3
Formica fusca	5	7
Labidus sp.	1	0
Formica sp.	3	3
Camponotus sp.	140	59
Pogonomyrmex occidentalis	24	17
Monomorium sp.	9	1
Camponotus abdominalis	0	1
Pogonomyrmex sp.	0	5
Tetramorium sp.	2	24
Camponotus pennsylvanicus	18	0
Agromyrmex versicolor	3	4
Acromyrmex versicolor	1	1
Monomorium pharaonis	0	14
Aphaenogaster sp.	1	2
Oecophylla longinoda	3	0
Iridomyrmex humilis	1	8
Ichneumonidae		
Megarhyssa macrunus	7	2
Megarhyssa sp.	1	0
Enicospilus merdarius	1	0
Gelis sp.	1	0
Coccygomimus pedalis	3	0
Apidae		
Apis mellifera	1	1
Sphecidae		
Cerceris clypeata	2	5

Sphex ichneumoneus	1	0
Adrenidae		
Andrena sp.	0	1
Pompylidae		
Episyron sp.	0	2
Orthoptera		
Tridactylidae		
Ellipes minuta	3	0
Ellipse sp.	1	0
Tetrigidae		
Tetrix arenosa	1	2
Gryllidae		
Gryllus sp.	14	26
Allonemobius fasciatus	5	9
Gryllus pennsylvanicus	5	2
Acheta domesticus	1	0
Tettigonidae		
Scudderia furcata	3	1
Acrididae		
Brachystata sp.	11	0
Melanoplus bivittatus	1	0
Brachystata magna	2	1
Coleoptera		
Staphylinidae		
Philonthus sp.	3	1
Philonthus lomatus	0	9
Tachyporus jocosus	0	3
Staphylinus sp.	0	2
Pelecomalium testaceum	0	2
Scolytidae		
Scolytus sp.	5	22
Carabidae		
Harpalus sp.	3	2
Bembidion quadrimaculatum	2	0
Galerita sp.	1	0
Harpalus pennsylvanicus	1	1
Cicindela sp.	0	1
Pasimachus sp.	0	4
Stenolophus sp.	0	9
Scarabaeidae		

Canthon sp.	34	53
Phyllophaga sp.	3	0
Onthophagus sp.	0	1
Phyllophaga fervida	0	1
Canthon pilularius	24	20
Geotrupes splendidus	5	0
Galerita janus	1	0
Phyllophaga fusca	2	2
Aphodius distinctus	4	0
Serica vespertina	1	0
Aphodius sp.	1	1
Aphodius fimetanus	3	0
Curculionidae		
Hypera sp.	3	0
Hypera punctata	1	0
Cerambycidae		
Strangalia sp.	1	0
Callidium antennatum	4	0
Prionus laticollis	0	3
Strangalia famelia	0	1
Coccinellidae		
Hippodamia parenthesis	0	1
Olla sp.	4	1
Mordellidae		
Mordella marginata	1	4
Mordella sp.	1	5
Brentidae		
Arrhenodes minutus	0	1
Dytiscidae		
Agabus sp.	0	2
Chrysomelidae		
Colaspis brunnea	2	1
Colaspis sp.	3	5
Systena blanta	1	1
Scaphididae		
Scaphidium sp.	0	1
Pyrochroidae		
Dendroides cyanipennis	1	0
Tenebrionidae		
Tenebrio sp.	1	0
Alobates pennsylvanica	0	2
Alobates pennsylvanicus	0	1

Phalacridae		
Phalacrus simplex	3	2
Stilbus sp.	0	1
Meloidae		
Meloe sp.	2	0
Anthicidae		
Notoxus sp.	1	0
Anthribidae		
Acanthoscelides sp.	1	0
Ptinidae		
Ptinus sp	1	0
Homoptera		
Cercopidae		
Lepyronia quadrangularis	11	2
Locris arithmetica	1	0
Lepyronia sp.	7	3
Aphrophora permutta	1	0
Cicadellidae		
Endria sp.	1	0
Aceratagallia sanguinolenta	7	2
Endria inimica	3	0
Acanaloniidae		
Acandonia bivittata	2	2
Psyllidae		
Psylla pyricola	0	5
Psylla floccosa	0	1
Membracidae		
Enchenopa binotata	3	0
Delphacidae		
Stobaera sp.	3	0
Fulgoridae		
Crypoptus belfragei	1	0
Flatidae		
Metcalfa pruinosa	2	0
Dictyopharidae		
Scolops sulcipes	1	0
Aleyrodidae		
Dialeurodis sp.	0	2
Dictyoptera		
Blattidae		

Blatella sp.	0	1
Supella longipalpa	0	1
Pseudocalolampra pardalina	2	0
Derocalymma sp.	1	0
Periplanata americana	3	3
Periplanata sp.	1	1
Periplaneta fuliginosa	1	0
Blatta orientalis	1	0
Mantidae		
Litaneutra minor	1	1
Blattellidae		
Parcoblatta pennsylvanicus	1	0
Hemiptera		
Reduviidae		
Repipta taurus	0	2
Tinatoma sp.	1	0
Miridae		
Lygus sp.	0	1
Coreidae		
Anasa sp.	4	0
Cydnidae		
Pangaeus bilineatus	0	1
Pentatomidae		
Thyanta accerra	1	0
Lygaeidae		
Oncopeltus fasciatus	4	1
Tingidae		
Melanorhopala clavata	0	1
Collembola		
Poduridae		
Podura aquatica	0	2
Isotomidae		
Isotomis viridis	7	20
Isotomis sp.	0	5
Odonata	1	0
Phasmida		
Phasmatidae		
Diapheromera femorata	1	0

Trichoptera		
Hydropsychidae		
Macrostemum sp.	3	0
Psychomyia flavida	0	2
Thysanura		
Lepismatidae		
Lepisma sp.	4	0
Thysanoptera		
Thripidae		
Heliothrips sp.	3	0
Taeniothrips simplex	0	1
Frankliniella sp.	0	1
Taeniothrips sp.	0	1
Isoptera		
Termitidae		
Amitermes wheeleri	1	0
Dermaptera	0	3
Siphonaptera		
Leptopsyllidae		
Peromyscopsylla sp.	0	1
Protura		
Acerentomidae	0	1
Odonata		
Aeshnidae		
Anax junius	0	1
Lepidoptera		
Noctuidae		
Agrotis orthogonia	65	50
Spodoptera ornithogali	0	4
Notodontidae		
Ichthyura inclusa	0	1
Lymantriidae		
Orgyia leucostigma	0	1
Arctiidae		
Euchaetias egle	30	7

Euchaetias sp.	8	2
Halisidota caryae	3	0
Hyphantria cunea	0	1
Satyridae		
Hallelesis halyma (MF)	4	0
Mycalesis sp.?	13	22
Bicyclus dorothea (ALF)	50	16
Bicyclus safitza (GUI)	12	2
Gnophodes chelys (ALF)	8	5
Gnophodes betsimena (ALF)	6	0
Melanitis leda (UBQ)	3	1
Nymphalidae		
Aterica galena (ALF)	11	3
Aterica sp.?	11	0
Catuna crithea (ALF)	25	2
Catuna angustatum (MF)	31	10
Euphaedra janetta (ALF)	11	1
Euphaedra xypete (MF)	9	3
Euphaedra sarcoptera (DRF)	21	21
Euphaedra harpalyce (ALF)	11	23
Euphaedra medon (ALF)	5	0
Cymothoe mabillei (MF)	12	0
Cymothoe egesta (MF)	16	0
Cymothoe fumana (MF)	11	0
Euriphene simplex (WF)	10	0
Euriphene barombina (ALF)	11	1
Neptis nemetes (ALF)	2	0
Neptis melicerta (ALF)	8	10
Neptis metella (ALF)	8	4

Pseudacraea boisduvali (DRF)	4	0
Pseudacraea lucretia (ALF)	7	25
Phalanta phalanta (UBQ)	5	0
Hamanumida Daedalus (GUI)	2	0
Euphaedra edwardsii (ALF)	1	0
Ariadne albifasca (ALF)	3	0
Eurytela dryope (DRF)	1	2
Junonia oenone (UBQ)	48	18
Junonia terea (ALF)	24	19
Junonia Sophia (ALF)	10	0
Junonia chorimene (GUI)	3	0
Salamis cacta (ALF)	1	0
Hypolimnas anthedon (ALF)	5	3
Hypolimnas salmacis (ALF)	7	0
Hypolimnas misippus (UBQ)	4	0
Libytheidae		
Libytheana labdaca (ALF)	1	0
Charaxidae		
Charaxes varanes (GUI)	4	1
Charaxes protoclea (ALF)	0	1
Charaxes brutus (DRF)	1	0
Danaidae		
Danaus sp.?	3	0
Danaus chrysippus (UBQ)	15	1
Amauris Hecate (ALF)	14	7
Amauris niavius (UBQ)	1	2

Pieridae		
Leptosia alcesta (ALF)	20	5
Leptosia medusa (MF)	13	3
Leptosia marginea (MF)	10	5
Belonois calypso (ALF)	14	8
Belonois creona (GUI)	1	0
Mylothris chloris (UBQ)	20	15
Mylothris rhodope (MF)	1	0
Mylothris jaopura (GUI)	0	2
Mylothris schumanni (MF)	0	2
Nepheronia pharis (ALF)	10	26
Nepheronia thalassina (ALF)	17	9
Nepheronia argia (ALF)	8	0
Colotis danae (GUI)	4	10
Appias Sylvia (ALF)	3	0
Appias Sabina (MF)	2	0
Pieris sp ?	0	2
Colotis evippe (UBQ)	1	0
Eurema brigitta (GUI)	20	9
Eurema floricola (GUI)	22	12
Eurema senegalensis (MF)	3	1
Eurema hecabe (UBQ)	6	8
Colotis antevippe (GUI)	8	0
Catopsilla florella (UBQ)	6	0
Hesperiidae		
Pyrrhiades lucagus (DRF)	14	17
Anthene liodes (ALF)	15	0

lycaenidae		
Oxylides faunus (MF)	2	0
Euchrysops albistriata (GUI)	7	6
Dapidodigma hymen (DRF)	21	3
Euchrysops reducta (GUI)	0	2
Papilionidae		
Graphium antheus (DRF)	2	0
Graphium policenes (ALF)	4	0
Papilio demodocus(UBQ)	18	14
Papilio phorcas (ALF)	2	0
Papilio bromius (ALF)	1	0
Papilio menestheus (MF)	1	0
Papilio nireus (ALF)	4	4
Papilio horribilis (WF)	1	1
Papilio dardanus (ALF)	5	7
Acraeidae		
Acraea alciope (ALF)	10	6
Acraea zetes (GUI)	13	2
Acraea macaria (MF)	1	0
Acraea epaea (ALF)	0	7

Numbers are abundances of insects recorded in each site; Forest zone categories are from Larsen (2005). Forest zone designations: WF, Wet forest; MF, Moist forest; DRF, Dry forest; ALF, All forest subtypes; GUI, Guinea Savannah; UBQ, Ubiquitous; SPE, Special habitat. Abundance designations: VC, Very common; CO, Common; NR, Not rare; RA, Rare; VR, Very rare.