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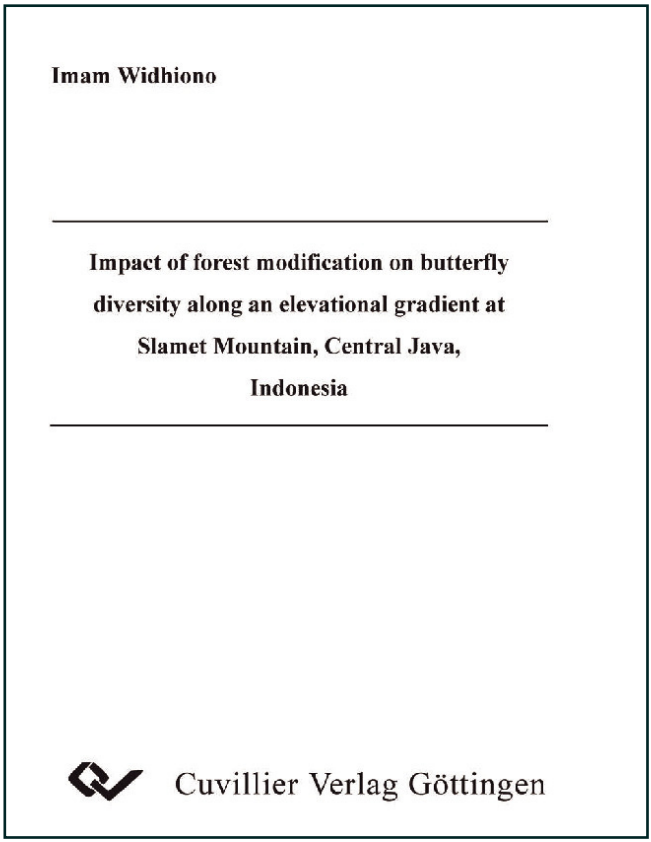
Impact of forest modification on butterfly diversity along an elevational gradient at Slamet Mountain, Central Java, Indonesia



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1. INTRODUCTION

Tropical forest ecosystems are under threat across the world as anthropogenic pressures increase. Squatting, shifting cultivation, hunting, enhanced levels of timber extraction and other types of forest use are some of the most frequently encountered causes of this increased pressure. Many forest areas in the tropics may only persist as production areas (Gomez-Pompa *et al.*, 1991; Brown, 1997; Rice *et al.*, 1997; Hunter, 1999), and pressure on unprotected forest is very likely to escalate (WIR, 1985; Terborgh, 1999; Lewis, 2000). Despite the generally recognised importance for global diversity (e.g. Sutton and Collins, 1991; ICBP, 1992; World Conservation Monitoring Centre, 1992), not more than 4% of all tropical rainforest are situated within the boundaries of reserves or national parks (Whitmore and Sayer, 1992). Even the best protected areas might not be adequate to maintain the original ecosystem because of their small size and difficult political and social circumstances (Terbrogh, 1999).

Twenty years ago, Indonesia used the principles of conservation biology to plan a national protected area system based on representativeness, irreplaceablility, complementarity and connectivity of natural habitats. Large areas of many natural habitat types were proposed as conservation areas within each biogeographic region. Subsequently, all of the country's forests (more than 70% of the total land area) were alocated either for production, watershed protection or conservation, and Indonesia endorsed the principles of sustainable forest management. Unfortunately, these scientific principles were never fully reconciled with national policy and practice (Jepson *et al.*, 2002). Today, forest in Indonesia, like in other Southeast Asian countries, are rapidly being logged. Of the estimated 1.2 mio km^2 of remaining closed canopy moist forest, 55% were reserved in 1986 as production forest and subjected to selective logging which, in theory, is repeatable on a 35 year cycle (Collins *et al.*, 1991). Currently, 3% of the world forest are plantations, comprised of 60 million hectare in developed nations and 55 million hectare in developing nations (WRI, 1998; FAO, 1999). Though tropical forest cover is declining throughout the world, tropical plantations forest area has increased dramatically, from about 10 million hectare in 1980 to about 44 million hectare in 1990 (Lugo, 1997).

In Indonesia, regular plantations started in 1873, in Java mostly with teak wood (*Tectona grandis*). In 1916 mainly pine (*Pinus merkusii*) was introduced. Other species planted by

the State Forestry Corporation (Perhutani) are *Pinus merkusii, Agathis spp., Swietenia macrophylla, Dalbergia latifolia, Paraserianthes falcataria* and *Sorea spp.* (FORIS, 2002). In 1980, the total area of plantation forest was 2,669,000 ha with the major proportion in Java (1,949,515 ha). In Central Java, plantation forests covered about 579,186 ha (State Forestry Corporation, 1990). Compared to naturally regenerated forest, plantations forest are often viewed unfavourably, because they usually include exotic species, non-local native species, or native species not typically forming extensive, pure stands (Hartley, 2002).

More than half of global diversity in terms of numbers of species is represented by insects (Stork, 1991), especially those species inhabiting tropical rainforests (Wilson, 1988), but few data are available about the effects of forest disturbance upon insect faunas (Holloway, 1987; Holloway *et al.,* 1992; Eggleton *et al.*, 1995). The response of some insect groups to severe large scale forest disturbance (clear cutting and subsequent conversion to plantation) has been documented in several studies (but see: Holloway *et al.*, 1992; Daily and Erlich, 1995). Butterflies have been suggested as potentially excellent environmental indicators in both temperate and tropical regions (Gilbert, 1984; Brown, 1991; Kremen, 1992). The dependence of the larval stage on a specific host plant, combined with the adult potential role as pollinator for plant species, link butterflies closely to the diversity and health of their habitats (Erlich, 1984). Butterflies are also very sensitive to changes in temperature, humidity and light levels, parameters that are typically affected by habitat disturbance. Furthermore, unlike most insects in tropical forests, butterflies are taxonomically well-known and many species can reliably be identified in the field. They occur at moderate levels of species richness, and are easy to sample (Gilbert, 1984; Brown, 1991; New, 1991; Sparrow *et al.*, 1994). These characteristics have made tropical butterflies a popular group for investigations on the effects of forest disturbance (e.g. Bowman *et al.*, 1990; Spitzer *et al.*, 1997) and forest fragmentation (e.g. Daily and Erlich, 1995). In Southeast Asia, butterfly species composition has been relatively well investigated in disturbed and undisturbed forests (e.g. Spitzer *et al.*, 1993; 1997, Hill *et al.*, 1995; 2001; Beck and Schulze, 2000; Hamer *et al.* 1997; Hill, 1999, Ghazoul, 2002; Hamer *et al.*,2003).

Some studies have shown that moderate disturbance results in a negligible change of insect diversity (e.g. Wolda, 1987), or even an increase in butterfly diversity (e.g. Hill *et al.*,

1995; Hamer *et al.*, 1997; Spitzer *et al.*, 1997). These result are in accordance with the intermediate disturbance theory (Connel, 1978). The greater diversity of butterfly species in moderately disturbed or modified forests supports the view that the mosaic of microhabitats and vegetation structure is likely to support more species than undisturbed forest (Janzen, 1987; Raguso and Llorente-Bousquets, 1990; Spitzer *et al.*, 1993). However, an increase in species richness can often be explained by the invasion of generalist and widely distributed species in disturbed habitats, resulting in the homogenisation of biological communities. This is an important threat to global biodiversity conservation. Many studies also reflect the influence of sampling scale and nearby natural habitats on diversity estimates found in modified system (see Hamer *et al.*, 2003, Fermon *et.al.*, 2003a).

Many studies also indicate adverse effects of disturbance on tropical butterfly communities (Bowman *et al.*, 1995; Thomas, 1991; Spitzer *et al.*, 1993; 1997; Kremen, 1994; Hamer and Hill, 2000; Hill, *et al.*, 1995; 2001; Hill and Hamer, 1998; Brown, 1997; Willot, *et al.*, 2000; Lewis, *et al.*, 1998, Fermon, *et al.*, 2000; 2001; 2003b). The understorey of closed tropical rainforest is characterized by the presence of highly specialized biota. Many butterflies of the rainforest understorey are highly stenotopic, habitat-specific, and their geographic range of distribution can be relatively small, often nearly endemic in a particular biogeographic forest type (Leps and Spitzer, 1990; Spitzer *et al.*, 1993). Opening forest canopy due to clear cutting and forest conversion to other land use systems brings dramatic changes to several environmental conditions typical of tropical rainforests understorey such as buffered temperature, sunlight, wind and others related to the butterfly community. In Southeast Asia, the majority of butterfly species are hostplant specialists (Fiedler, 1998). Species within the subfamilies Morphinae and Satyrinae, for example, exclusively depend on monocotyledone plant species as larvae and these are mainly restricted to lower forest strata (Beck and Schulze, 2000).

Although plantation forests and other types of forest modification are very widespread in Java, little is known about the effects of the changes in forest structure resulting from human disturbance on the butterfly diversity. Butterfly communities in Java are diverse with 46 endemic species, most or all of which depend to some extent on canopy-closed forests (Whitten *et al.*, 1997). The present study documents patterns in abundance, species richness and diversity of the understorey butterfly community in the presently most

common forest habitat types at the southern slope of Slamet Mountain, Central Java. The study was conducted in different habitats representing different types of forest modification (plantation, wood extraction and logging, clear-cutting, agroforestry and tourism). Butterfly sampling was done at different elevations (600 to 1,700 m asl.), in different seasons (dry and wet) and in different years (2000 and 2001).

2. BACKGROUND AND OBJECTIVES

Indonesia was once clothed with tropical rainforest, except for the southern islands of eastern Java, Madura, Bali and the Lesser Sunda Islands (Nusa Tenggara) which have tropical monsoon forest (Collins and Morris, 1985). Forest loss in Indonesia is increasing tremendously. Between 1976 and 1980, FAO estimated that 550.000 ha of natural forest was being cleared annually (Hurst, 1990). In contrast, current estimates, including the conversion of primary forest to other forest uses, ammount to 1.6 Mio ha per annum in average (Ministry of Forestry, 2000). Barber (2000) calculated that the average annual deforestation rate in Indonesia between 1986 and 1997 was about 1.7 Mio ha. Although this recent deforestation primarily occurred in production forests, the operations can still imply serious threats to the remaining biodiversity in the country. Undisturbed forest has become rare in Java and therefore production forests necessarily play a significant role in the buffering and conservation of the country's remaining biodiversity resources (Hartley, 2002).

Java, one of the most densely populated islands in the world, has lost more than 90% of it's natural vegetation. Primary forest remains only in mountainous regions at elevation above 1,400 m (Collins and Morris, 1985). Whereas natural forest cover is declining throughout the island, the area covered by plantation forest has increased. Indonesia started regular plantations in 1873, in Java mainly with *Tectona grandis,* and since 1916 with *Pinus merkusii*. Later on, some fast growing species like *Agathis spp, Swietenia macrophylla, Dalbergia latifolia, Paraserianthes falcataria,* and *Shorea spp* were planted by the Perhutani, a stated owned enterprise. There is a common belief that forest management negatively affect biodiversity (Wagner *et al.*, 1998), since increasing fibre yield decreases biodiversity. However, for most forest use types, there is only a

limited understanding of the functioning relationship between biodiversity and fibre production. Compared to naturally regenerated forest, plantations are often viewed unfavourably both by the public and conservation biologist, because they lack biodiversity relative to natural forests (Friend, 1982).

High social pressure, particularly in Java, has resulted in illegal felling, cattle grazing beyond capacity, fire and encroachments into plantations. Such damage hampers long-term planning and efficiency, and in response Perhutani began to initiate a large number of programmes in 1973 to involve local people in forest management and to increase their prosperity. Multiple use of plantation forest is encouraged in order to share benefits with local people and to reduce the pressure on protection areas. Such programmes include fuel wood production, silk production, bee keeping, agroforestry and forest recreation (Whitten *et al.*, 1997), and were also introduced on the study area at Slamet Mountain.

Java holds a diverse butterfly fauna with many endemic species, most or all of which depend to some extent upon closed forest (Collins and Moris, 1985). From a conservationist's viewpoint, patterns in the richness of geographical restricted or endemic butterflies will be of very particular interest (Thomas and Mallorie, 1985). As mentioned above, several studies have shown that both the diversity and species richness of butterfly communities were higher in disturbed forest and in large clearings on edge forest than in closed forest (Leps and Spitzer, 1990; Hammer, *et al.*, 1997; Hill, *et al.*, 1995; Spitzer, *et al.*, 1997; Fermon, *et al.*, 2000; 2001). However, each single species differs in it's conservation value. In several of the above mentioned studies, species occur most abundantly in disturbed forest habitats were generally widely distributed, generalist species for which conservation priority is less. Species characteristic of undisturbed forest habitats, mostly understorey species sensitive to changes in the buffered microclimatic conditions at forest floor level, often had restricted ranges of distribution, and were mostly hostplant specialists. These species with restricted area of distribution (endemic taxa) are of highest conservation priority (Collins and Morris, 1985; New, 1991; Spitzer and Leps, 1992; Spitzer, *et al.*, 1993). Their habitats are usually becoming more rare and endangered, and disturbance on a local scale reducing their local population density more rapidly results in the species's global extinction, due to their limited distribution and specific habitat needs.