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Spatial distribution of cocoon nests and egg clusters of the silkmoth *Anaphe panda* (Lepidoptera: Thaumetopoeidae) and its host plant *Bridelia micrantha* (Euphorbiaceae) in the Kakamega Forest of western Kenya

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Abstract. A study on the spatial distribution of the silkmoth *Anaphe panda* (Boisduval) cocoon nests, egg clusters and the host plant *Bridelia micrantha* (Hochst) Baill. was conducted in two different habitats of the Kakamega Forest of western Kenya: Ikuywa (indigenous forest) and Isecheno (mixed indigenous forest). The mean densities of cocoon nests, egg clusters and *B. micrantha* were significantly different in the two blocks and were not semi-randomly distributed in the two habitats. The host plants were underdispersed in the indigenous forest, whereas they were overdispersed in the mixed indigenous forest. The cocoon nests were overdispersed and the silkmoth egg clusters were underdispersed in the two blocks of forest. This study reveals that *A. panda* tends to distribute its egg clusters uniformly over the lower and middle crown of *B. micrantha* with a preference to eastern localization and confirms the insufficient presence of populations of this silkmoth in a mixed indigenous forest compared with an indigenous forest. Consequently, indigenous forests should be managed in a sustainable way and more indigenous tree species should be used in reforestation campaigns.

Key words: *Anaphe panda*, *Bridelia micrantha*, forest management, sericulture, Kenya, silkmoth

Introduction

Non-mulberry sericulture is universally known as forest or wild sericulture and silkmoths existing in wild conditions are known as wild silkmoths. According to Kioko *et al.* (2000) and Raina (2004), wild silk production is an eco-friendly, agro-based venture with a great potential for environmental amelioration, employment generation, artisans' development and export earnings. Furthermore, the world trend in silk production and consumption is also favourable with an increasing demand and at the same time diminishing production in major silk-producing countries due to factors such as diversification, affluence and high cost of labour (Raje, 1999). According to Jolly *et al.* (1979), the high quality of the wild silk has drawn the attention of silk users, providing excellent opportunities for African producer countries to diversify and optimize any source of production. However, the

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insight on spatial distribution of wild silkmoths in indigenous forests (i.e. forest with only indigenous plant species) and mixed indigenous forests (i.e. forest with a mixture of indigenous and exotic plant species) is one of the several challenges faced by wild silk production in many African producer countries. Furthermore, more precise information is required on the spatial distribution of wild silkmoth species to assist in developing management plans for conservation and their sustainable utilization for income generation. The use of new technologies like geographical information systems (GIS) becomes necessary to analyse environmental changes with the aim to develop recommendations for a sustainable biodiversity management.

This study aims at providing new insights on the spatial distribution of *Anaphe panda* (Boisduval) (Lepidoptera: Thaumetopoeidae) silkmoth egg clusters, cocoon nests and its host plant *Bridelia micrantha* (Hochst) Baillon (Euphorbiaceae) using GIS data for visualization purposes. *Bridelia micrantha* is a semi-deciduous to deciduous tree, up to 20 m tall, with a dense rounded crown and tall, bare stem. The study was conducted in two different habitats of the Kakamega Forest, i.e. an indigenous forest habitat (Ikuywa) and a mixed indigenous forest habitat (Isecheno).

Materials and methods

Study area

The natural vegetation of Kakamega Forest is tropical rainforest. Four different types of forest habitats are found in the Kakamega Forest: Forest habitats with only indigenous species (indigenous forest), mixed indigenous forest habitats (forest with indigenous and exotic species), hardwood habitats (forest with exotic hardwood species only) and softwood plantation habitats (forest with exotic softwood species only). Exotic tree species are mainly pines, black wattle and *Eucalyptus* spp. (Myrtaceae). There are about 150 species of woody trees, 90 species of dicotyledonous herbs, 80 species of monocotyledonous herbs, of which about 60 are orchids, and a further 62 species of ferns, totalling to about 380 identified species of vascular plants (KIFCON, 1994).

The study was conducted in two different habitats of the Kakamega Forest, Isecheno and Ikuywa, at Lunyu and Ikuywa sub-locations, Ileho Division, in the Kakamega Forest, western Kenya. The Kakamega Forest is located between latitudes 0° 10′ and 0° 21′ north and longitudes 34° 47′ and 34° 58′ east (Fig. 1). The Kakamega Forest covers a total area of approximately 265 km^2. It comprises several separate blocks of forest of which Isecheno (415 ha) belongs to the Lunyu sub-location and Ikuywa (380 ha) to the Ikuywa sub-location. Continuous plots were chosen randomly in each block and about 8.6% of the total area of each block was sampled. Sixty-five plots of 5000 m^2 each were chosen in Ikuywa (indigenous forest), Musembe village, and 71 of the same dimensions in Isecheno (mixed indigenous forest), Chirobani village (Fig. 1). Sampling was carried out from February to April 2006. This period is characterized by an abundance of *A. panda* egg clusters in the field, each egg cluster containing between 250 and 560 eggs.

Spatial distribution of A. panda *host plant* B. micrantha

In each plot, all *B. micrantha* >0.5 m in height were recorded by GPS. A tape measure was used for measuring the height.

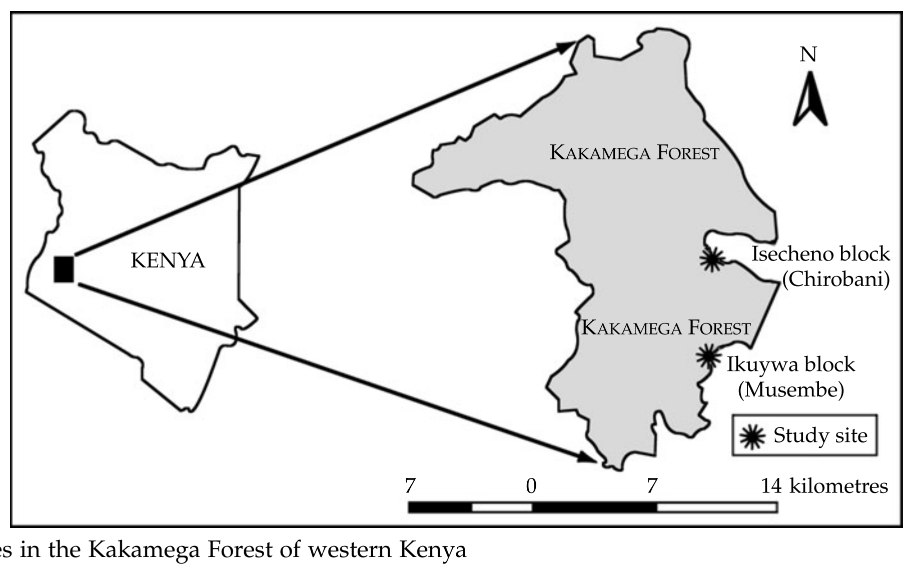

Fig. 1. Study sites in the Kakamega Forest of western Kenya

Table 1. Mean number of *Bridelia micrantha* trees and cocoon nests and egg clusters of *Anaphe panda* found on them in Isecheno and Ikuywa blocks of Kakamega Forest, western Kenya

		B. micrantha trees		*A. panda* cocoon nests		*A. panda* egg clusters	
Blocks ($n = 2$)	Plots n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)	n
Isecheno	71	7.28 ± 2.96*	517	0.99 ± 1.01*	70	1.37 ± 1.07*	97
Ikuywa	65	5.89 ± 2.16	383	1.31 ± 1.20	85	1.82 ± 1.27	118

* Significant at $P < 0.05$; n: sample size.

Table 2. Variance to mean ratios of *Bridelia micrantha* trees and cocoon nests and egg clusters of *Anaphe panda* found on them in Isecheno and Ikuywa blocks of Kakamega Forest, western Kenya

	B. micrantha trees			*A. panda* cocoon nests			*A. panda* egg clusters		
Blocks ($n = 2$)	Variance (σ^2)	Mean (μ)	σ^2/μ^+	Variance (σ^2)	Mean (μ)	σ^2/μ	Variance (σ^2)	Mean (μ)	σ^2/μ
Isecheno	8.75	7.28	1.2	1.01	0.99	1.02	1.15	1.37	0.84
Ikuywa	4.66	5.89	0.79	1.44	1.31	1.10	1.62	1.82	0.89

$^+ \sigma^2/\mu$: Ratio of the variance to the mean.

Spatial distribution of A. panda *cocoon nests*

Cocoon nests were checked, counted and recorded by GPS not only on *B. micrantha* but also in several other places, such as stones, cavities, holes or dead trees in each plot.

Spatial distribution of A. panda *egg clusters*

In each plot, egg clusters were checked in the crown of living *B. micrantha* trees using a Binocular spectron 7 × 50 multi-coated optics 123 M/1000 M (Metler PJ 360 Delta®, Yokohama, Japan) for the trees >2.5 m height. For the tallest *B. micrantha*, the part of the crown level above 6 m height could not be monitored for egg clusters. Crowns were divided into three equal levels designated as lower (L), middle (M) and upper (U), respectively. Egg clusters were checked, counted and recorded by GPS in the four intercardinal directions at the three crown levels of the canopy.

Data analysis

A *t*-test (SAS Institute, 2003) was carried out to determine whether significant differences exist between the mean number of *B. micrantha* trees, cocoon nests and egg clusters per plot recorded in the different indigenous and mixed indigenous forest habitats. The ratio of the variance (σ^2) over the mean (μ) was used to determine if *B. micrantha* trees, cocoon nests and egg clusters are semi-randomly distributed over the space containing this host plant of *A. panda* in the indigenous and mixed indigenous forests. A distribution in which μ equals σ^2 is considered an equidispersion (random) population and $\sigma^2/\mu = 1$, if $\sigma^2 > \mu$ there is

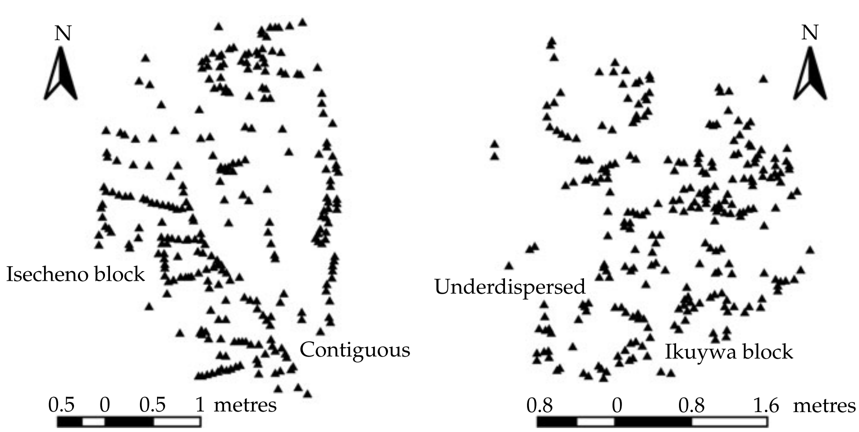

Fig. 2. Geographical distribution of *Bridelia micrantha* tress in the mixed indigenous (Isecheno) and indigenous (Ikuywa) forests of the Kakamega Forest of western Kenya

Fig. 3. Brown silk nest of *Anaphe panda* in the Kakamega Forest of western Kenya

overdispersion and $\sigma^2/\mu > 1$ and if $\sigma^2 < \mu$ there is underdispersion and $\sigma^2/\mu < 1$ (Zar, 2005). ArcView GIS 3.2 software (Garmin® Ltd, 2002) was used to map the geo-reference data.

Results

Mean numbers of B. micrantha, A. panda *cocoon nests and egg clusters by two blocks*

The mean numbers of *B. micrantha* trees, *A. panda* cocoon nests and egg clusters from the Isecheno and Ikuywa blocks are summarized in Table 1. Differences were highly significant between the numbers of *B. micrantha* and egg clusters by block, and also there were significant differences between the numbers of cocoon nests between the two blocks.

Spatial distribution of B. micrantha *by two blocks*

The average number of *B. micrantha* per plot was significantly lower ($P < 0.001$) in the indigenous than in the mixed indigenous forest habitats (Table 1). The ratios of variance to the mean were computed for the Isecheno and Ikuywa blocks, respectively, indicating a non-semi-random distribution of *B. micrantha* trees throughout the indigenous and the mixed indigenous forests (Table 2). Consequently, the spatial distribution of *B. micrantha* at mean densities of 4.32–10.24 and 3.73–8.05 trees per 5000 m^2 at the Isecheno and Ikuywa blocks, respectively, is non-random but overdispersed (clustered) at the Isecheno (mixed indigenous forest) and underdispersed at the Ikuywa block (indigenous forest) (Fig. 2).

Spatial distribution of cocoon nests by two blocks

The average number of cocoon nests per plot was significantly higher ($P < 0.05$) in the indigenous than in the mixed indigenous forest (Table 1 and Fig. 3). The variance to the mean ratios show that *A. panda* cocoon nests are not semi-randomly distributed throughout the indigenous and the mixed indigenous forest habitats (Table 2). Hence, the spatial distribution of cocoon nests, at mean densities of 0–2 and 0.11–2.51 cocoon nests, respectively, per 5000 m^2 in the mixed indigenous and the indigenous forest habitats is not random but overdispersed (contiguous) (Fig. 4).

Spatial distribution of egg clusters by two blocks

The average number of *A. panda* egg clusters per 5000 m^2 plot was significantly lower ($P < 0.05$) in the mixed indigenous than in the indigenous forest

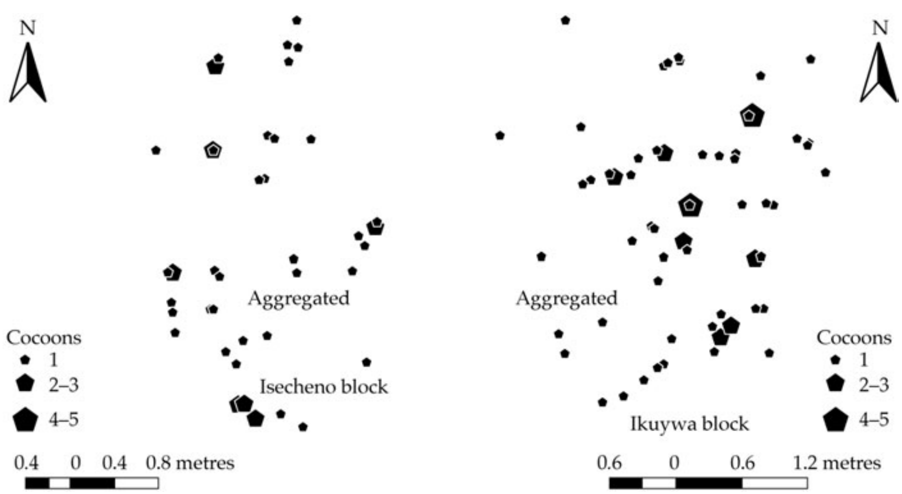

Fig. 4. Geographical distribution of *Anaphe panda* cocoon nests in the mixed indigenous (Isecheno) and indigenous (Ikuywa) forests of the Kakamega Forest of western Kenya

Fig. 5. Egg cluster of *Anaphe panda* hanging on a host plant *Bridelia micrantha* in the Kakamega Forest of western Kenya

habitats (Fig. 5 and Table 1). The variance to mean ratios show that *A. panda* egg clusters are not semi-randomly distributed throughout the mixed indigenous and the indigenous forest habitats (Table 2). This indicates that the spatial distribution of *A. panda* egg clusters, at mean densities of 0.3–2.44 and 0.55–3.09 eggs per 5000 m^2 in the mixed indigenous and the indigenous forest habitats, respectively, is not random but underdispersed (Fig. 6).

A. panda *preferential site for egg laying by two blocks*

Highly significant differences ($P < 0.001$) in the numbers of egg clusters between the different crown levels were detected in both blocks. More egg clusters were laid at the lower and middle than at the upper crown levels on the canopy (Table 3). Fewer number of egg clusters were recorded at the upper level in both the mixed indigenous and indigenous forests, whereas more egg clusters were found at the lower crown level in the Isecheno and Ikuywa blocks with significant differences between the lower and middle ($P = 0.032$) and the lower and upper ($P = 0.017$) crown levels (Table 3). In general, more egg clusters were distributed in the north-eastern and south-eastern directions of the crown levels when compared with the north-western and south-western directions for both the mixed indigenous and the indigenous forest habitats (Table 3), and no significant differences ($P = 0.0541$) in the distribution of the egg clusters by the four intercardinal directions were found between the indigenous (Ikuywa block) and mixed indigenous forest habitats (Isecheno block).

Discussion

This study investigated the spatial distribution of cocoon nests and egg clusters of *A. panda* on its host plant *B. micrantha* in two different habitats of the Kakamega Forest in western Kenya. The variance to mean ratio and the geo-reference data revealed that *B. micrantha* trees and *A. panda* cocoon nests and egg clusters on the trees are not uniformly distributed in the two mixed indigenous and indigenous forest habitats of the Kakamega Forest. A pattern of non-randomness shown by insects can be ascribed to active aggregation or some heterogeneity of the environment (Southwood, 1968). Clumping observed in the spatial distribution of egg clusters and cocoon nests in both indigenous and mixed indigenous forest habitats appears to be due to some environmental effects or other factors like behavioural causes under certain conditions. The mean densities of 1–3 and 0–2 cocoon nests in 5000 m^2 of the indigenous and mixed indigenous

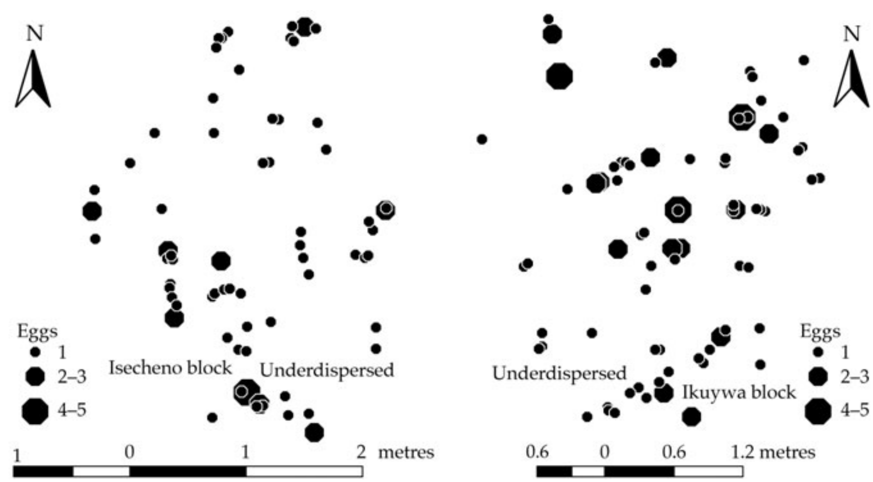

Fig. 6. Geographical distribution of *Anaphe panda* egg clusters in the mixed indigenous (Isecheno) and indigenous (Ikuywa) forests of the Kakamega Forest of western Kenya

Table 3. Repartition of *Anaphe panda* preferential site for egg cluster laying as influenced by the four intercardinal directions and three different tree crown levels (lower, middle and upper) of *Bridelia micrantha* in Isecheno and Ikuywa blocks of Kakamega Forest, western Kenya

Localization of egg clusters and crown levels	Isecheno (mixed indigenous forest)					Ikuywa (indigenous forest)				
	North-eastern	South-eastern	North-western	South-western	Total+	North-eastern	South-eastern	North-western	South-western	Total+
Upper	3	2	2	1	8	2	1	1	0	4
Middle	15	11	5	6	37	15	11	9	10	45
Lower	21	11	12	8	52	39	10	12	8	69
Total	39	24	19	15	97	56	22	22	18	118

+Number of egg clusters found at each tree crown level.

forest habitats is an indication of weak density. We were expecting a ratio of at least 1:1 between cocoon nest and *B. micrantha*, and the observed density of cocoon nests seems to be insufficient for use in income-generating activities. The other expectation was to have a ratio of 1:1 between egg clusters and cocoon nests, which was also not the case. Both human disturbance and environmental factors are probably responsible for the observed significant differences between indigenous and mixed indigenous forest habitats. These results corroborate earlier studies, which found that the decline in populations of wild silkmoths in Africa is due to both deforestation and over-consumption of the larvae by humans as food source (Ashiru, 1988; Munthali and Mughogho, 1992; Oberprieler, 1994; Kioko *et al.*, 1999). According to Oliveira *et al.* (1976), 100 g of caterpillars provide 76% of the individual's daily protein requirement and more than 100% of the daily requirements of many vitamins and minerals. Our results underline the importance of reforestation with indigenous species that are well adapted to the local environmental conditions rather than the use of exotic tree species to stem the decline of wild silkmoth populations, stressing the role of indigenous forests for the conservation of indigenous biodiversity.

Bridelia micrantha trees, and *A. panda* cocoon nests and egg clusters on them, were recorded at different densities in the indigenous and the mixed indigenous forest habitats. Similarly, Kioko *et al.* (1999) observed in their survey in western Kenya that *B. micrantha* is abundantly distributed with 84% of the community members reporting these trees in varying numbers on their land. Respondents also confirmed to have seen caterpillars and cocoon nests of *A. panda*, and 16% had noted even the egg clusters. Hence, the introduction of wild silk production in the Kakamega Forest may offer important economic incentives to farmers in western Kenya. In the Kakamega Forest, more than 12,400 ha are suitable for a possible silkworm food plant plantation. This land can be utilized for the cultivation of *B. micrantha*. According to Gowdey (1953), *B. micrantha* grows fast from cuttings and is ready for silkworm feeding within a 1-year period.

According to the results of this study, trees of *B. micrantha* and the cocoon nests and egg clusters of *A. panda* found on them are not randomly distributed in the Kakamega Forest, but are overdispersed or underdispersed in indigenous or mixed indigenous forest habitats, respectively.

Knowledge of the egg distribution patterns allows greater precision in the location of eggs (Pottinger and LeRoux, 1971). Fewer egg clusters were laid at the upper crown level of *B. micrantha* trees. However, more egg clusters were found on the lower and middle crown levels, possibly because of the larger amount of foliage being available there for oviposition and larval feeding. Geertsema (1975) made similar observations in plantations around Cape Town, South Africa. It appears from this study that *A. panda* tends to distribute its egg clusters uniformly over the lower and middle crown of *B. micrantha* with a preference to eastern location of the trees.

Results of this study indicate that (i) indigenous forests should be managed in a sustainable way, (ii) left alone or with a small amount of assistance through seeding and/or the introduction of primary indigenous species, even degraded indigenous forests will regenerate and sustain themselves and (iii) GIS data can be of tremendous importance for conservation, management and long-term monitoring of biodiversity.

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