Butterflies (Lepidoptera: Papilionoidea) of Mount Kilimanjaro: introduction and family Papilionidae

Steven D. Liseki\textsuperscript{a,b,*} and Richard I. Vane-Wright\textsuperscript{b,c}

\textsuperscript{a}Tanzania Wildlife Research Institute, PO Box 661, Arusha, Tanzania; \textsuperscript{b}Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, CT2 7NR, UK; \textsuperscript{c}Department of Entomology, Natural History Museum, Cromwell Road, London SW7 5BD, UK

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This article marks the beginning of a short series on the butterfly fauna of Mount Kilimanjaro. It commences with a brief overview of the topography, tectonic history, climate, ecological zonation and conservation significance of Africa’s highest mountain. Following an introductory account to the butterfly fauna, the rest of this paper presents an annotated checklist of the swallowtails (Papilionidae). Eight papilionid species are currently believed to occur within the main forest zone, from 1800 to 2800 m (in places this zone extends down to \textasciitilde 1600 m). Another 10 have been recorded from the lower slopes, which include some disturbed forest and forest relics, from 700–1800 m. The need for better data is discussed in light of the suggestion that the butterflies of Mount Kilimanjaro could become a focal group for monitoring effects of climate change. An identification key to families, together with a key to the swallowtail species and colour illustrations of adults, are included as online Supplementary Information.

Keywords: Africa; Tanzania; keys; checklist; inventory; distribution; conservation; climate change monitoring; altitudinal zonation; size

Introduction

Newmark (1991a: 113) called for “a complete inventory of the fauna and flora of Mount Kilimanjaro”. Perhaps more realistically, Bjørndalen (1991: 100) stated that checklists of mammals, birds, reptiles, amphibians and selected invertebrate groups would be “useful for . . . monitoring . . . rainforests serving as catchment forests”.

Butterflies are widely acknowledged to be sensitive to environmental gradients, and good indicators of environmental changes and habitat quality (e.g. Kremen 1992). To be useful for this purpose on Kilimanjaro it is essential that action be taken to establish reliable baseline data – most notably to obtain far more extensive and accurate knowledge about the distribution and abundance of butterfly species on the mountain, including altitudinal flight and breeding ranges.

The immediate objective of this series of papers is to present a checklist of the butterflies currently known to occur on Kilimanjaro, including those believed to or likely to occur on its lower slopes. By the addition of keys and photographs as online Supplementary Information (SI), a practical means for identification of adult...
butterflies is also provided. The ultimate goal is to facilitate monitoring the butterfly fauna of this exceptional mountain, including the potential to use these conspicuous day-flying Lepidoptera as a focal group to document possible impacts of climate change in eastern Africa.

Mount Kilimanjaro: Africa’s highest mountain

Kilimanjaro, the highest mountain on the African continent, is located at the northeastern boundary of Tanzania with Kenya, 330 km south of the equator, on the eastern margin of the Great Rift Valley. The mountain comprises three volcanoes, Kibo, Mawenzi and Shira, which peak respectively at 5891 m, c.5150 m and c.3960 m above sea level. The precise height of Kibo, the youngest of the three, has recently been re-assessed by Fernandes et al. (2009). According to Downie and Wilkinson (1972) there has been no eruptive activity for over 200 years, and these volcanoes are often referred to as extinct (although Kibo may, in fact, only be “sleeping”).

One of the world’s highest freestanding mountains, Kilimanjaro rises over 4800 m above the surrounding undulating plain, which averages about 900 m above sea level, and 5000 m above the important town of Moshi at its southern base. The long axis of the mountain runs in a northwest to southeast line for up to 90 km and, at its widest part, Kilimanjaro is about 60 km across (Agrawala et al. 2003). The core conservation area of the mountain (see below) lies between 2°45′ to 3°25′ S and 37°00′ to 37°43′ E (UNEP-WCMC 2005).

Africa’s Great Rift Valley system developed over the past 30 million years. The present Kilimanjaro massif was created by a series of volcanic eruptions that commenced about 1 million years ago, when an intersection of the Natron-Manyara trough and the Pangani rift occurred to form the Kilimanjaro Depression (Downie and Wilkinson 1972; Griffiths 1993). The major uplift that resulted only ended about 450 000 years ago. Since then the mountain has been affected by further volcanic events, crater collapses, landslips, glaciation, erosion and, up to a height of about 3000–3500 m, it became densely forested.

Kilimanjaro is therefore very recent (the oldest lavas have been dated at 1.0 million years: Downie and Wilkinson 1972), with a very different origin to the crystalline formations of the “Eastern Arc” system that runs roughly north–south so nearby to the east, from the Taita Hills to the Udzungwas (Figure 1; Wasser and Lovett 1993). These mountains, although far lower than Kilimanjaro, at least partly because of their far greater age (c.30 million years), are more diverse biologically with much greater endemism (Wasser and Lovett 1993; Myers et al. 2000).

Climate and climate change

Climatic zones on Mount Kilimanjaro range from equatorial to subarctic. At the mountain’s base are warm and dry plains with average temperatures of 30°C. With increasing elevation, precipitation initially increases and reaches a maximum at mid-elevations of the forest belt. The current upper forest boundary coincides with a region experiencing regular frost at night. Above the forest zone lie extensive moorlands, with generally decreasing temperatures and rainfall up to the summit – where there is permanent ice and temperatures are constantly below 0°C.
Given its proximity to the equator, the climate of Kilimanjaro is surprisingly seasonal. The main rainy season occurs between March and July, and a second, shorter rainy season generally occurs between October and December. During the long rains, when snow accumulates on the peaks, temperatures on the mountain are relatively warm. The dry season, depending on location starting from late June through July, tends to be very cold at night because of the clear skies. August and September also tend to be cool, because of an encircling cloud belt that forms over the moorland and releases a drizzling rain onto the forest. During the short rains, thunderstorms often occur, but the nights and mornings are usually clear. January and February are normally dry and warm months with brief showers.
The name Kilimanjaro has been said to derive from the Swahili Kilima Njaro, literally “shining mountain” (Agrawala et al. 2003: 29; but see also Hutchinson 1965). However, Kilimanjaro’s glaciers have been in rapid retreat for well over 100 years (Sampson 1965; Kaser et al. 2004; UNEP-WCMC 2005; Mote and Kaser 2007). Declining rainfall coupled with local warming observed during the latter part of the twentieth century has led to predictions that this famous ice-cap is likely to disappear, perhaps as early as 2015–2020 (e.g. Thompson et al. 2002). While there seems little doubt that the glaciers have shrunk by over 80% since about 1880 (Cullen et al. 2006), the reasons for this appear to be complex, and predictions of total loss within one or two decades from now are probably premature (Mölg et al. 2008).

While the loss of ice per se might have little other than symbolic impact (the glaciers do not supply significant run-off, but their disappearance might be bad for tourism: Mölg et al. 2008), the climatic trends of lower rainfall and increasing fires, together with human influence, could lead to a rapid decline of the remaining sub-alpine Erica forests. This in turn is likely to result in a considerable reduction of upper montane and alpine rainfall, with potentially serious consequences for water supplies and agricultural production on the lower slopes. Hence, the likelihood of continuing climate change in Tanzania, and on Kilimanjaro in particular, has become a cause for considerable economic as well as environmental concern (Agrawala et al. 2003).

Ecological zonation on Mount Kilimanjaro

The slopes of Mount Kilimanjaro can be divided into five major altitudinal zones: lower slopes (now extensively cultivated), montane forest, heath and moorland, highland desert and summit (see e.g. Salt 1954; Mwasaga 1991; Pócs 1991). The last two major zones have little significance for butterflies, so only the first three are described in more detail here. A system of 11 altitudinal zones and vegetation units, based on the work of Andreas Hemp and presented by Agrawala et al. (2003), can be used to characterize these major divisions more precisely (Table 1).

Each of the three lower main zones occupies a belt of approximately 1000 m altitude. In general, temperature falls approximately a little over 1°C for every 200 m increase in height, and rainfall also decreases steadily with altitude from the main forest zone upward. Plant life is abundant in areas of high temperature and high rainfall and decreases with colder and drier conditions. Very few resident butterflies occur higher than the Lower Subalpine zone (Table 1), with temperatures becoming too low above 3000 m. This low diversity and abundance may have been exacerbated by the quite extensive destruction of the Erica forests by fires and for fuelwood (UNEP-WCMC 2005), and consequent reduction of understorey flora and shelter (Jan Axmacher, personal communication). Salt (1954) listed only two butterfly species, a skipper and a lycaenid, from what he termed the upper moorland zone, above 3500 m. According to Kielland (1990), neither of these typically occurs above 3000 m. Mani (1968: 153) stated that the nymphalid Vanessa cardui, the pierid Colias electo and the swallowtail Papilio demodocus occur “above the timberline”.

Lower Slopes Zone

The lower slopes cover elevations between 700 and about 1800 m, encompassing the first four altitudinal zones shown in Table 1: the “Colline” (a region of savanna, crop and pasture land: Agrawala et al. 2003), Submontane, and the lowest parts of the
Table 1. Altitudinal zones and main vegetation units for Mount Kilimanjaro according to Agrawala et al. (2003: table 5), based on Hemp (2001: table 3).

| Altitude (metres) | Main vegetation type                                          | Altitude zone |
|-------------------|----------------------------------------------------------------|---------------|
| 4400              | *Helichrysum* cushion                                          | 11 lower Alpine |
|                   | *Erica* shrubland, *Helichrysum* cushion                       | 10 upper Subalpine |
|                   | *Erica* shrubland, *Erica excelsa* forest, *Hagenia-Rapanea* forest | 9 middle |
| 2800              | *Erica excelsa* forest, *Podocarpus* forest, moorland          | 8 lower |
| 2700              | *Podocarpus-Ocotea* forest, *Erica excelsa* forest             | 7 upper Montane |
|                   | *Ocotea-Podocarpus* forest                                     | 6 middle |
|                   | *Agauria-Ocotea* forest, *Cassipourea* forest                  | 5 lower |
| 1600              | *Agauria-Ocotea* forest, coffee-banana plantations, *Bulbostylis* meadows | 4 |
| 1500              | Coffee-banana plantations, *Croton-Olea* forest, *Hyparrhenia* meadows | 3 upper Submontane |
|                   | Coffee-banana plantations, savanna bushland and grassland, agriculture, pasture | 2 lower |
| 900               | Savanna bushland and grassland, agriculture, pasture           | 1 Colline |
| 800               |                                                             |               |
| 700               |                                                             |               |

Note that this zonation pattern does vary around the mountain (see text). Few butterflies normally occur above zone 8, and none appears to breed above zone 9.

Lower Montane zones. The lowland agricultural zone occurs below the lower slopes, at 500–700 m (O’Kting’ati and Kessy 1991). Rainfall varies from 500 mm/year on the plains to 1800 mm/year at the forest boundary.

Over most of the lower slopes there is extensive evidence of anthropogenic alterations of habitat conditions, particularly by grazing and cultivation. This has had a
radical impact on the natural vegetation, and most of what once must have been lowland or riverine forest is now grassland or cropland. An idea of how the southern slopes above Old Moshi (altitude 990 m) looked 130 years ago can be appreciated from the engraving made by Johnston (1886: 153). On the northern, eastern and western slopes, which are largely too dry for easy cultivation, remnants of the former lowland vegetation and (in the north only) macrofauna (O’Kting’ati and Kessy 1991: 80) still persist.

*Olea africana* forest occurs on the southwestern slopes at 1300–1500 m near Sanya Juu, and some relict submontane gallery forest can be found on the southern slopes (Hemp and Hemp 2003). The southern slopes have a seasonal rainfall pattern, and are used extensively for cultivation of maize, coffee, bananas and a wide variety of vegetables. These slopes also receive water that falls as rain in the Forest Zone, and then percolates through underground channels. This, together with the fertile volcanic soil, sustains the densely populated settlements (Moshi Rural and Moshi Urban districts have a combined population of c.600,000). The total human population of the Kilimanjaro District has increased dramatically over the last 110 years, from a figure possibly as low as 50,000 in 1899 (Odner 1971), to an estimated 267,700 in 1948 (Gamassa 1991), and to over 1.5 million today (Shangali 2007).

**Forest Zone**

A wide band of montane forest originally encircled the entire mountain. During WWII timber mills were operated on the mid slopes, leading to the current widespread occurrence of secondary forest at lower elevations (Jan Axmacher, personal communication). Moreover, since 1958, the circumferential continuity has been all but broken by two conifer plantation forests, one on the western, the other on the northeastern side of the mountain (Lamprey et al. 1991; Hemp 2006b: fig. 2).

The remaining Montane Forest Zone occurs between about 1800 and 2800 m, comprising altitudinal zones 5–7, equivalent to all but the lowest part of the Montane region (Table 1). Rainfall varies from about 2000 or even as much as 3000 mm/year on the southern slopes, to less than 1000 mm/year on the eastern and northern flanks. This aspect difference has an influence on the altitude and composition of the Forest Zone, which is more diverse and extensive to the south and west, and altitudinally more restricted and less diverse to the north and east (Salt 1954; Pócs 1991: fig. 4.1; Hemp 2006a: fig. 4). Hemp (2006b: fig. 2) provides an outstanding vegetation map, which makes these differences very clear.

About 96% of the water on Kilimanjaro originates in this zone, with much of the rain being absorbed by the thick carpet of leaves, and the mosses and liverworts covering tree trunks and much of the ground. After percolating through the soil and porous volcanic rock, water emerges as springs lower down the mountain. This zone is very humid, and a wide band of drizzling clouds frequently envelop it, especially at 2500–3000 m. When the sky clears, the nights can be cold, but daytime temperatures are typically in the range 15–20°C.

**Heath and Moorland Zone**

This zone extends from 2800 to 4300 m, encompassing the Subalpine and Alpine areas, or zones 8–11 (Table 1). Rainfall varies from about 1300 mm/year at the upper edge
of the forest to c.530 mm/year at the upper zonal limit. This alpine region is divisible into two major communities: the lower moorland and shrubland zones (2800–3600 m), with only tuft trees (*Dendrosenecio*) and cushion vegetation above 3800 m, and a transition zone at 3600–3800 m (Table 1). Again, however, it should be noted that there are differences in the height and composition of these zones and subzones on different sides of the mountain (Salt 1954; Pócs 1991; Hemp 2006a,b).

The climate is usually cool and clear except for mist and fog at the forest boundary. Above 3000 m frost becomes regular and sunshine can be intense. Mani (1968: 144–157) gives an extensive discussion of conditions affecting insect life on upper Kilimanjaro. Altitudinal zone 8, which encompasses the upper limit of the *Podocarpus* forest (Table 1), occurs at about 2800–3100 m, and this represents the upper limit for most butterflies. No butterflies breed above c.3500 m, but windblown individuals are occasionally found higher still. As noted by Axmacher et al. (2004), even the diversity of geometrid moths drops to very low levels above the forest zone, where only a few specialists are able to live in face of the harsh environmental conditions.

At c.4300 m the alpine vegetation gives way to almost barren rock, snow and ice, running up to the Kibo and Mawenzi peaks. This is the “Alpine Desert” of Salt (1954) and Pócs (1991). However, small, discontinuous patches of vegetation occur right up to 5700 m, less than 200 m below the Kibo summit (Körner 2003: 11).

Figure 2. Mount Kilimanjaro: contour map showing boundaries of the National Park and Forest Reserve, climbing routes, and villages. (H. Kijja, TAWIRI.)
Importance of Kilimanjaro as a protected area

The upper levels of Mount Kilimanjaro are now designated Kilimanjaro National Park and Kilimanjaro Forest Reserve (Figure 2). Kilimanjaro National Park has an area of 756 km², and comprises all the land above 2700 m. The Park therefore includes the entire heath, moorland and highland zones, Shira Plateau, and the Kibo and Mawenzi peaks. In addition, the National Park has six corridors or rights of way through the Forest Reserve. The National Park was established in 1973 and officially opened in 1977 (UNEP-WCMC 2005). The Forest Reserve, which is also a Game Reserve, was established in 1921 – its upper limit is the Park boundary, while its lower limit lies at c.1800 m.

The National Park exists to preserve Mount Kilimanjaro’s outstanding scenic and geological features, as well as its flora and fauna. Staff of the two agencies, the National Park and the Forest and Game Reserve, cooperate in efforts to conserve all the mountain’s resources. In 1989 Kilimanjaro was declared a UNESCO World Heritage site. An extensive survey of key issues relevant to the conservation of Kilimanjaro was presented by Newmark (1991b).

The Forest Zone, and the lower part of the Heath and Moorland Zone (or Subalpine zone) offer significant habitat for approximately 200 species of butterflies (de Jong and Congdon 1993), including many montane specialists and a small number of montane endemics. Above about 3000 m, as already noted, there are few resident butterflies – but this could change under a global warming scenario that also delivers sufficient water to this region to permit upwards extension of the two main vegetation zones. However, current models point to a likely decrease in rainfall. The lower slopes fall outside the protected areas and are, for the most part, either heavily degraded by human use and agriculture, or rather dry. However, the pockets of semi-natural vegetation that still exist could, under a global warming scenario, potentially provide many source populations for lowland species to move into the lower margins of the protected area. For example, among the Papilionidae this potentially includes one or more kite swallowtails (Graphium), none of which is currently believed to breed within the main forest zone.

The butterflies of Mount Kilimanjaro

To make use of a taxonomic group for environmental purposes it is generally necessary to know which species occur in a given area, their correct scientific names, and have some practical means for their accurate identification. This presupposes that we already have good taxonomic knowledge of the group as a whole (ideally in the form of systematic revisions or illustrated catalogues), and a set of accurate scientific names – to give reliable access to the literature and databases, and for effective communication. As discussed by Nielsen and West (1994) in the context of setting priorities for conservation, even though they typically offer minimal information (e.g. current binominal name, author and year of original publication), checklists are very cost-effective and useful contributions for information access and information transfer.

In the case of African Lepidoptera, founded on the monumental work of Aurivillius (1898–99), including his major contribution to Seitz (1908–25), the “Carcasson” catalogue of Ackery et al. (1995) and the online encyclopaedia of Williams (2010) provide a baseline annotated checklist for the butterflies of the entire
Afrotropical Region – now known to have just over 4000 species. For Tanzania, the outstanding work of the late Jan Kielland (1990), and its supplement by Congdon and Collins (1998), provide a very sound baseline for studies anywhere within the country’s borders, listing in total almost 1400 species. Supplemented by the illustrated Afrotropical atlases of d’Abrera (1997, 2004, 2009), and the Kenyan field-guide of Larsen (1996), we also have a means of identification for most of these species.

However, what is lacking for more practical conservation and monitoring work is a series of up-to-date checklists for specific local regions, coupled with keys and illustrations. Historically important works for Kilimanjaro include Johnston (1886) and Aurivillius (1910). A tabulated list of Kilimanjaro’s montane butterflies is given by de Jong and Congdon (1993), but they do not deal with the fauna of the lower slopes or provide any means of identification. Kielland (1990) frequently mentions Kilimanjaro within his brief accounts of species ranges, but not consistently or comprehensively, and his work cannot readily be used for identification purposes. A key to families, and a key to the species of Papilionidae known from Kilimanjaro together with illustrations of the adults, are included here as online SI.

Annotated checklist of Papilionidae of Mount Kilimanjaro

Species are listed alphabetically, by genus. Those butterflies known or believed to occur within the montane forest reserve areas of Mount Kilimanjaro (above 1800 m) are listed in bold. Other swallowtails that occur, or are believed to have occurred on the lower slopes that conceivably could become established within the conservation areas, are listed in non-bold.

For the lists developed here, we have relied heavily on the literature, notably Kielland (1990), Ackery et al. (1995) and Congdon and Collins (1998), together with extensive reference to the collections of the Natural History Museum (BMNH), London. Fieldwork was carried out on Kilimanjaro by S.D.L., who observed and sampled butterflies at three sites on the Marangu Route (southern slopes), at 2000, 2500 and 3000 m. Visits, lasting 5–7 days at a time, were made during January, March, May, July, September and November 2001 (Liseki, 2009). R.I.V-W. accompanied S.D.L. during the May sampling period.

De Jong and Congdon (1993) list Papilio jacksoni jacksoni (illustrated by Larsen, 1996, and d’Abrera, 1997) from Kilimanjaro. We have been unable to confirm this from the BMNH collection. This species was not recorded from Tanzania by Carcasson (1975), or from the Northern Highlands by Kielland (1990) or Ackery et al. (1995), and we have not included it here.

Male and female forewing lengths are given for each species. The ranges are estimates. The means and standard deviations (s) have been calculated from direct measurement of small samples from the BMNH collections, using STANDARD DEVIATION CALCULATOR (http://www.easycalculation.com/statistics/standard-deviation.php). Wherever possible these size estimates are based on material entirely from northern Tanzania. Where necessary, however, additional material from elsewhere in Tanzania has been used, and/or from Kenya. No material from outside Tanzania or Kenya has been employed. These sizes are indicative only (see Discussion).
Papilio constantinus constantinus Ward, 1871

Larsen 1996: pl. 1 fig. 4i. d’Abrera 1997: 19. SI: Figure 5f.

Forewing length: male 44–54 mm, mean 50.12 mm \((n = 10)\), \(s 2.26313\); female 49–57 mm, mean 52.50 mm \((n = 4)\), \(s 2.17868\).

This butterfly occurs in dry woodland and gallery forests in eastern Africa, from southern Ethiopia south to Natal as far west as Shaba (DRC), and northeastern Botswana (Ackery et al. 1995; Larsen, 1996). Within Tanzania, Kielland (1990) states that the nominate subspecies occurs from sea-level in coastal areas of Tanga, south to the Rondo Plateau, and at various localities inland up to 1200 m (with an isolated record for Rubeho at 1950 m). Rogers (1913: 127) records it from Taita (southeast Kenya). Not listed by de Jong and Congdon (1993) for the montane forests of the eastern Afrotropics, and not encountered on the mountain by Sjöstedt (Aurivillius 1910) or Liseki (2009). However, Carcasson (1975: 10) records it for Morogoro, and it is included here as a member of the Kilimanjaro lower slope fauna (700–1800 m) on the basis of Carcasson’s (1975: 10) record for Moshi, and a specimen in the BMNH collected in March 1912 by Alluaud and Jeannel, at 1000 m on the Himo river.

Papilio dardanus Yeats in Brown, 1776

Larsen 1996: pl. 1 fig. 2 i–iii. d’Abrera 1997: 12–17. SI: Figures 5c, 7d,e.

Forewing length: male 46–62 mm, mean 53.75 mm \((n = 12)\), \(s 3.88084\); female 41–55 mm, mean 48.81 mm \((n = 7)\), \(s 3.472\). Three males from the Kilimanjaro area included in the sample average 50.0 mm. The reversed size dimorphism in this species, with males on average larger than females, has been confirmed by examination of a halved gynandromorph.

Note: Peter Brown is the authority normally given for this species name. However, as the introduction to Brown (1776) makes very clear, all the new insect names introduced in his work should be attributed to Thomas Pattinson Yeats.

This very well-known butterfly is not listed by de Jong and Congdon (1993) as a member of the montane forest fauna of eastern Africa, nor was it encountered on the mountain by Liseki (2009). However, it occurs on the slopes of Mount Meru (S.D.L., R.I.V-W., personal observation, May 2001) and, according to Kielland (1990), subspecies Papilio dardanus tibullus occurs within Tanzania from sea level to 2100 m, from Pemba and coastal areas inland to the Northern Highlands, Rubeho Mountains, and Southern Highlands. Carcasson (1975: 9) records it specifically from Kilimanjaro and it is included here as an element of the lower slope fauna (700–1800 m). The BMNH has a male from Meru, and two males from Old Moshi. In addition, the BMNH has a male that appears close to the typical \(P. d. dardanus\) phenotype apparently collected on the northern slopes of Mount Kilimanjaro during June 1905 (SI: Figure 5c); Aurivillius (1910: 12) also records \(dardanus\) from the “Nordseite”. The BMNH specimen could be a “stray” from the west or northwest of Tanzania (where the nominate race occurs), a mislabelled specimen, a “reversion” from the normally much more darkly marked subsp. \(tibullus\) (a female from Loitokitok, just over the border into Kenya, and collected at almost exactly the same date, appears to belong to \(tibullus\) – SI: Figure 7e...
left), or even reflect a genuine “outpost” of the western race. Another distinct possibility is that the populations on and around Meru and Kilimanjaro are transitional between the two races. These matters need to be addressed by collection of fresh material from Kilimanjaro and Meru for DNA analysis (a great deal of molecular work has been done on *P. dardanus* in the past decade), and morphological investigations based on the work of Turner (1963).

Females in the Kilimanjaro area are likely to be of the forms “hippocoonides” (black and white), “cenea” (black, buff and white) and “trophonissa” or “trophonius” (black, orange, white, sometimes with a little yellow: “lamborni”) – see also accounts in Gifford (1965: 21) and Larsen (1996).

*Papilio demodocus demodocus* Esper, 1798

Larsen 1996: pl. 3 fig. 14i. d’Abrera 1997: 37. SI: Figure 7a,b.

Forewing length: male 37–57 mm, mean 52.075 mm ($n = 8$), $s = 6.04666$; female 51–62 mm, mean 56.82 mm ($n = 6$), $s = 2.85196$.

Kilimanjaro, West Usambaras, and throughout the entire Afrotropical Region. This “ubiquitous” species (Rogers, 1913: 127) was encountered on Kilimanjaro during January and March by Liseki (2009), but not above 2000 m. Kielland (1990) gives its altitudinal range as sea level to 2600 m. However, Aurivillius (1910: 14) recorded this species from Kilimanjaro at 3000–4000 m, as well as on the lower slopes and elsewhere, consistent with Mani’s (1968: 153) comment that *demodocus* can occur above the timberline.

This common butterfly is very variable in size. A recurrent aberration or rare recombinant, ‘cariei’ Le Cerf, could cause confusion (SI: Figure 7b). This phenotype has the three marks in the distal part of the forewing discal cell fused into a single large mark, while the upperside submarginal marks of both wings are largely obsolete (Smith and Vane-Wright 2008: A28). So far as we are aware, the “cariei” phenotype has not been recorded from Kilimanjaro, but it seems possible it could occur anywhere in the species’ range. Intermediates between ‘cariei’ and ‘typical’ also occur.

*Papilio desmondi magdae* Gifford, 1961

Kielland 1990: pl. 2. *P. d. teita* – Larsen 1996: pl. 2 fig. 10i. SI: Figure 6a.

Forewing length: male 43–51 mm, mean 47.175 mm ($n = 8$), $s = 1.53134$; female 49.9 mm (1 ex.).

Recorded from highland forest at 1600–2600 m (Kielland 1990), and found on Kilimanjaro quite commonly at 2000 m during January and March (Liseki 2009). However, two old males in the BMNH, one labelled “Old Moshi”, the other “6 miles N.W. of Moshi”, together with specimens from Ngare-Nairobi (1200–1500 m) suggest that, in the past at least, this butterfly may have occurred as low as 1000 m. This taxon is based on material collected from Kilimanjaro by H.H. Johnston, “in forest country at 5000 ft [1530 m]” (Godman 1885, as *Papilio brontes*, preoccupied). Aurivillius (1910: 14) recorded *P. bromius* var. *brontes* from Kibongoto (1300 m) “up to 1900 m”. According to Kielland (1990: 39), subspecies *magdae* is probably confined to Mount Meru, Mount Kilimanjaro and the North Pare Mountains, but Ackery et al. (1995:
also recorded Arusha and Ngorongoro. Arusha, elevation 1400 m, the locality represented by a pair in BMNH collected by Arthur Rydon, is very close to Mount Meru (Arusha National Park covers much of the mountain). However, we now suspect that “Ngorongoro” probably represents a misinterpretation of a BMNH specimen from “Kilossa” [recte Kilosa], which lies to the south, near Morogoro, where the race *P. d. australis* occurs. The latter extends from the Usambaras south into Malawi and Zambia, and is not easy to separate from *P. d. magdae*. Two further, very similar named races occur in parts of southeast Kenya (Larsen, 1996: 113).

**Papilio echerioides wertheri** Karsch, 1898

*P. e. rectofasciata*—Kielland 1990: pls 3,4. *P. echerioides* ssp. – Larsen 1996: pl. 3 fig. 15i,ii. SI: Figure 6c.

Forewing length: male 37–45 mm, mean 41.56 mm (*n* = 9), *s* 2.00756; female 39–50 mm, mean 42.09 mm (*n* = 8), *s* 2.62757.

This subspecies occurs in submontane forests throughout eastern and northern Tanzania and eastern Kenya (Ackery et al. 1995: 148). Recorded from Kilimanjaro by Aurivillius (1910: 12) at 1300–2000 m, Kielland (1990) indicates that its altitudinal range is 1400–2200 m, but notes a female at 2400 m on Oldeani, while Carcasson (1975: 20) gives a record for Moshi (c.800–900 m). Specimens in the BMNH collected by B. Cooper at Ngare-Nairobi were found at 4000–5000 ft (1200–1500 m). Under the synonym *P. echerioides rectofasciata* Kielland, Kielland (1990: 39) records this butterfly from the Oldeani-Ngorongoro range, Mount Meru, Mount Kilimanjaro, Mbulu forests, Mount Kwaraha, Mount Longido, Meto Hills, Mount Lossoganeu, Mount Lolkiisale, and the Pare and Usambara Mountains. The continuing presence of *P. e. wertheri* on Mount Kilimanjaro was confirmed by Liseki (2009), who found it in March at 2000–2500 m. However, it should also be looked for in remnant forests on the lower slopes. Elsewhere, *P. echerioides* occurs as a series of up to a dozen or more subspecies, mainly in eastern Africa (Ackery et al. 1995). According to Kielland (1990: 46), the more westerly subspecies should be separated as a distinct species, *Papilio zoroastres* Druce, 1878.

**Papilio hornimani mbulu** Kielland, 1987

Kielland 1990: pl. 3. Larsen 1996: pl. 2 fig. 7i. d’Abrera 1997: 25. SI: Figure 5b.

Forewing length: male 47–61 mm, mean 54.675 mm (*n* = 8), *s* 3.47758; female 56–65 mm, mean 60.40 mm (*n* = 3), *s* 2.68514.

Vane-Wright and Liseki (2008) give records for Chyulu Hills (Kenya), Gelai, Kitumbene, Oldeani Crater, Karatu Ngorongoro, Mamasara (Mbulu), Marang Forest (Mbulu), Babati (Kwaraha), Momella Forest (Meru), Ngare-Nairobi (West Kilimanjaro), Simba Forest (West Kilimanjaro), Marangu route (South Kilimanjaro), and Ol Molog (Kilimanjaro). *Papilio hornimani* was recorded from Kilimanjaro by Aurivillius (1910: 14), apparently from the cultivated lower slopes (“Obstgartensteppe”). Kielland (1990: 40) notes this subspecies from forests at 1400–2400 m, but Liseki (2009) found this butterfly on the Marangu route at 2500 m.
Elsewhere, the nominate subspecies sometimes occurs as low as 250 m in riverine forests (Vane-Wright and Liseki 2008). Apart from the Chyulu Hills population, the species is confined to highland areas in the eastern half of Tanzania.

*Papilio nireus lyaeus* Doubleday, 1845

Kielland 1990: pl. 6. Larsen 1996: pl. 2 fig. 11i. SI: Figure 6b.

Forewing length: male 45–54 mm, mean 48.82 mm \( (n = 5) \), \( s \) 2.28954; female 48–55 mm, mean 51.70 mm \( (n = 6) \), \( s \) 1.88786.

Described by Carcasson (1975: 16) as “ubiquitous in eastern and southern Africa”, Kielland (1990) indicates the altitudinal range of this subspecies in Tanzania as c. 780–1500 m. Ackery et al. (1995) give the geographical range as Kenya, southern Sudan and Uganda and Tanzania south to Cape Province. Not recorded from Kilimanjaro by Aurivillius (1910) or Liseki (2009), but included here as part of the lower slope (700–1800 m) fauna based on a pair in the BMNH from New Moshi, “800 m”, collected by Alluaud and Jeannel in April 1912. Larsen (1996: 113) notes that this butterfly seems able to adapt to “non-forest environments”.

*Papilio nobilis nobilis* Rogenhofer, 1891

Kielland 1990: pl. 7. Larsen 1996: pl. 1 fig. 5i. d’Abrera 1997: 21. SI: Figure 5d.

Forewing length: male 45–54 mm, mean 50.52 mm \( (n = 13) \), \( s \) 2.13976; female 45–57 mm, mean 51.40 mm \( (n = 7) \), \( s \) 2.49867.

Carcasson (1975: 11) notes this butterfly from “Highland forest [up to 8000 ft, or 2400 m] in Kenya and N. Tanganyika”, but gives no specific records for Tanzania. Kielland (1990) gives a record at 2100 m, with “Usambara Mts., Kahe Forest south of Moshi [Rydon], Mt. Lossoganeu south of Arusha” as localities. Ackery et al. (1995) state that the altitudinal range of *P. nobilis* is 1300–2500 m, and that the nominate subspecies occurs from Kenya highlands, Uganda, northern and western shores of Lake Victoria, south to Bukoba, Tanzania. However, material from the Bukoba region (and parts of Uganda) should be referable to *P. n. crippsianus* Stoneham (Kielland, 1990: 43). Not encountered on Kilimanjaro by Aurivillius (1910) or Liseki (2009), but included here as a member of the lower slope fauna on the basis of two old males in BMNH labelled Moshi. However, if this taxon is still present on the lower slopes, given its ability to occur as high as 2100 m or more, it should also be searched for in the main Forest Zone.

*Papilio ophidicephalus ophidicephalus* Oberthür, 1878

Larsen 1996: pl. 3 fig. 13i. d’Abrera 1997: 37. SI: Figure 5e.

Forewing length: male 54–65 mm, mean 59.97 mm \( (n = 9) \), \( s \) 2.40324; female 61–75 mm, mean 66.23 mm \( (n = 8) \), \( s \) 4.79486.

Found “practically everywhere in Tanzania where forests occur, except in the Tukuyu basin (where a different subspecies occurs) and on Pemba Island” (Kielland 1990: 2387).
Outside Tanzania, this subspecies occurs in eastern Kenya, northern Zambia and Democratic Republic of Congo; the species ranges throughout much of East Africa, from Kenya south to Cape Province. Although Kielland (1990: 43) states that it can occur up to 2000 m, like Carcasson (1975: 18), he does not specifically record it from Kilimanjaro, and it was not encountered by Liseki (2009). However, this impressive insect is listed here, based on Aurivillius (1910: 14), who recorded *P. menestheus* var. *ophidicephalus* from mixed forest along the Sanya river, a specimen in the BMNH from West Kilimanjaro, Ngare-Nairobi, collected by B. Cooper at 4000–5000 ft (1200–1500 m) in early 1937, and several specimens from the Moshi area. A specimen supposedly collected from Marangu (1384 m) in January 2009 was recently illustrated at http://www.bidders.co.jp/item/137213754 (accessed 5 January 2011), and various other specimens from “Kilimanjaro” are currently offered for sale on the worldwide web. We are therefore unable to demonstrate that this species does occur above 1800 m on Kilimanjaro but, given Kielland’s statement that it can occur as high as 2000 m, we nonetheless list it as part of the protected area fauna.

**Papilio phorcas tenuifasciatus** Kielland, 1990

Kielland 1990: pl. 8. Larsen 1996: pl. 1 fig. 3i. SI: Figure 5a.

Forewing length: male 42–48 mm, mean 45.40 mm (n = 6), s 1.21655; female 45–55 mm, mean 50.08 mm (n = 5), s 2.6565.

Recorded from Kilimanjaro as *P. phorcas* v. *nyikanus* (Aurivillius, 1910: 14) from Kibongoto (1300 m) and in primary forest at 1900–2000 m, this recently described subspecies occurs elsewhere in the Northern Highlands at Oldeani-Ngorongoro, Mbulu forests, Mount Kwaraha, Mount Meru, Mount Longido, Meto Hills, North Pare Mountains, Mount Lolkisale and Mount Lossoganeu (Kielland 1990: 44). Although said to occur by Kielland at 1700–2400 m, it was commonly encountered on the Marangu route by Liseki (2009) from 2000 up to 2500 m. Accepting the Aurivillius record for Kibongoto, then the range on the mountain appears to be, or to have been, 1300–2500 m. The species as a whole occurs widely in tropical Africa, from Sierra Leone to Sudan and south to Angola and Malawi, in a series of six or more races (Ackery et al. 1995). According to Larsen (1996), the population of *P. phorcas* in the Chyulu Hills, southeast Kenya, is similar to *P. p. tenuifasciatus*. In various parts of Africa *P. phorcas* occasionally crosses with *P. dardanus* to produce male hybrids of the “nandina” phenotype (Vane-Wright and Smith, 1992), but this has not been reported for Tanzania.

**Papilio rex rex** Oberthür, 1886

Larsen 1996: pl. 1 fig. 1i. d’Abrera 1997: 11. SI: Figure 7f.

Forewing length: male 60–76 mm, mean 68.35 mm (n = 6), s 5.11654; female 55–63 mm, mean 58.975 mm (n = 4), s 2.06135. This is one of the few swallowtails in which the male, as measured by forewing length, is significantly larger than the female. Kielland (1990) notes that the males carry the females when flying in *copula*. Male *P. rex* is the largest swallowtail found on Kilimanjaro, although females of *P. ophidicephalus* are on average larger than *rex* females.
Recorded from the “Obstgartensteppe” (cultivated zone) on Kilimanjaro by Aurivillius (1910: 12), Ackery et al. (1995) indicate that *P. rex rex* is confined to highland forests in Tanzania. According to Kielland (1990: 45) it occurs at altitudes of 1400–2600 m, and is found on the Oldeani-Ngorongoro highlands, Mount Meru, Mount Kilimanjaro, Mount Longido, Mbulu, Mount Kvaraha, probably “several other mountains in the Northern Highlands”, and the Uluguru Mountains and Nguru Mountains. Not encountered on Kilimanjaro by Liseki (2009). The species comprises six or more subspecies, found in East Africa, Nigeria and Cameroon (Ackery et al. 1995). Larsen (1996) and Carcasson (1975) evidently treated the segregate *P. r. regulana* Vane-Wright, 1995 (replacement name for *rex regulus* Le Cerf, 1919, preoccupied, from the Kenyan highlands east of the Rift Valley), as part of the nominate subspecies; this requires re-examination. Larsen (1996: 109) also suggests the existence of a further subspecies at Maralal, in central Kenya.

*Papilio sjoestedti atavus* Le Cerf, 1912

d’Abrera 1997: 47 (as *P. fuelleborni atavus*). SI: Figure 6d.

Forewing length: male 44–54 mm, mean 48.34 mm \((n = 10)\), \(s = 1.73922\); female (subspecies uncertain) 50–57 mm, mean 53.31 mm \((n = 11)\), \(s = 1.33451\).

Endemic subspecies to Mount Kilimanjaro. *Papilio sjoestedti* comprises two subspecies, both endemic to the Northern Highlands, the nominate race occurring on Mount Meru, Oldeani-Ngorongoro highlands, Mbulu forests and Mount Kvaraha (Kielland 1990: 45). This butterfly (the “Kilimanjaro Swallowtail”) was commonly encountered on the Marangu route by Liseki (2009) in January and March at 2000–2500 m. Carcasson (1975) gives the altitudinal range as 7000–9000 ft (2100–2750 m); Kielland (1990: 45) states that this species is “common from 2200 to 2600 m”, with one record (on Mount Meru) at 1700 m. However, old records from Marangu (c.1400 m) in BMNH suggest that the Kilimanjaro Swallowtail might have occurred down to and even below the lower limit of the main Forest Zone, at 1800 m. Doubts about the status of these taxa have recently been debated by Smith et al. (2008), including the vexed issue of the spelling of the specific name.

*Graphium angolanus angolanus* (Goeze, 1779)

Kielland 1990: pl. 9. Larsen 1996: pl. 3 fig. 18i. d’Abrera 1997: 49. SI: Figure 6e.

Forewing length: male 37–44 mm, mean 40.82 mm \((n = 16)\), \(s = 1.22944\); female 39–49 mm, mean 43.45 mm \((n = 6)\), \(s = 2.39896\).

Carcasson (1975: 24) and Kielland (1990: 46) indicate that this savannah and woodland butterfly occurs throughout Tanzania. Not encountered in the mountain forests by Liseki (2009), and no *Graphium* species is included in the list by de Jong and Congdon (1993) of montane butterflies. However, *G. a. angolanus* was recorded from Kilimanjaro by Smith and Vane-Wright (2002), based on material collected by B. Cooper at Marangu, 1200–1500 m, in January 1937, and several other specimens from Moshi and Himo River. According to Gifford (1965: 19), this species rarely flies above 1500 m, although Kielland (1990) apparently did observe it in Tanzania as high as 2200 m. Outside Tanzania, the nominate subspecies occurs very widely in the
southern half of Africa (other than the southwest) with, according to Smith and Vane-Wright (2001: 694), the suggestion of some overlap in southern Kenya with the almost equally widespread northern race, *G. a. baronis* (Ungemach). *Graphium a. angolanus* is included here as an element of the lower slopes fauna.

*Graphium antheus* (Cramer, 1779)

Larsen 1996: pl. 4 fig. 26i. d’Abrera 1997: 59. SI: Figure 4d.

Forewing length: male 38–49 mm, mean 45.77 mm (n = 7), s 3.0723; female 43–52 mm, mean 48.19 mm (n = 7), s 1.87566.

This common species, found in wooded areas below 1500 m (Carcasson, 1975), occurs throughout Tanzania (Kielland 1990: 47). No subspecies of this very widespread tropical African butterfly are currently recognized (Smith and Vane-Wright 2001: 537). Not encountered in the forests by Liseki (2009), but recorded from Kilimanjaro by Smith and Vane-Wright (2002), based on old material obtained on the lower slopes (e.g. a specimen in BMNH from New Moshi).

*Graphium colonna* (Ward, 1873)

Larsen 1996: pl. 4 fig. 23i. d’Abrera 1997: 57. SI: Figure 4b.

Forewing length: male 35–43 mm, mean 39.56 mm (n = 9), s 2.09709; female 40–45 mm, mean 42.62 mm (n = 5), s 1.08028.

*Graphium colonna* is an east African butterfly known from Somalia south to Zululand (Smith and Vane-Wright, 2001). Kielland (1990) indicates that this monotypic, essentially coastal species occurs inland to the Usambaras, but gives no suggestion that it can be found on or around Kilimanjaro – not least because he indicates its maximum altitude to be 600 m. However, Smith and Vane-Wright (2002) list museum records from the massif, including material from Old Moshi (990 m) collected in April 1916 by F.C. Selous, and the Hills of Terta [Kilimanjaro]. Included here as a likely extinct element of the lower slopes fauna.

*Graphium leonidas leonidas* (Fabricius, 1793)

Larsen 1996: pl. 3 fig. 21i. d’Abrera 1997: 55. SI: Figure 6f.

Forewing length: male 34–50 mm, mean 44.30 mm (n = 9), s 4.17702; female 46–54 mm, mean 49.04 mm (n = 5), s 1.98947.

Very common throughout continental Africa south of the Sahara, excluding very dry areas (Ackery et al. 1995: 164) and dense forests (Smith and Vane-Wright, 2001). According to Kielland (1990), occurs from sea level to 2200 m. The only recognized subspecies occur on offshore islands (Smith and Vane-Wright 2001: 696). Not encountered in the forests by Liseki (2009), but recorded from Kilimanjaro by Smith and Vane-Wright (2002), based on several museum records for Moshi (at 800 m) and its environs. This species can be expected to occur on the lower slopes, and might occasionally be found in the lower margins of the Forest Zone.
Graphium philonoe philonoe (Ward, 1873)

Larsen 1996: pl. 3 fig. 20i. d’Abrera 1997: 53. SI: Figure 7c.

Forewing length: male 34–41 mm, mean 37.21 mm \( n = 8 \), \( s = 1.27104 \); female 36–43 mm, mean 40.05 mm \( n = 6 \), \( s = 1.79861 \).

The nominate subspecies of this Graphium is largely but not exclusively restricted to coastal regions of Kenya and Tanzania; the only other race occurs in Sudan, Ethiopia and Uganda. Most populations probably occur at up to 500 m, but Smith and Vane-Wright (2002) list old museum records from Kilimanjaro (the BMNH collection includes a specimen collected by Johnston), including New Moshi \( (c.800 \text{ m}) \). Kielland (1990), who reported a specimen taken on the summit of Mount Bondwa \( (2140 \text{ m}) \), indicates that G. philonoe occurs inland in Tanzania to the Usambaras, but gives no suggestion that it can be found on or around Kilimanjaro. Included here as a likely extinct element of the lower slopes fauna.

Graphium policenes policenes (Cramer, 1775)

Larsen 1996: pl. 4 fig. 25i. d’Abrera 1997: 57. SI: Figure 4f.

Forewing length: male 32–47 mm, mean 41.66 mm \( n = 14 \), \( s = 3.82697 \); female 42–47 mm, mean 44.42 mm \( n = 5 \), \( s = 0.71903 \).

Known from Meru (BMNH), with at least one record for Rau River, Kilimanjaro (Smith and Vane-Wright 2002). This widespread African species is recorded from a scattering of localities in Tanzania, including the Usambaras (Smith and Vane-Wright 2001: 693). According to Carcasson (1975), in east Africa this butterfly normally occurs in forested areas up to about 1800 m, while Kielland (1990) states that it can be found rarely up to 2000 m \( (\text{the BMNH has a specimen from Nandi, Kenya, collected at 6500 ft}) \). Not encountered by Liseki (2009), it should be looked for at the lowest level of the montane forest \( (1800–2000 \text{ m}) \), in relict gallery forests of the lower slopes, or perhaps around Sanya Juu.

Discussion

A more extensive discussion will be presented with the concluding paper in this series. Here we make a few points that may stimulate others to send or gather data relevant to some of the more important issues.

The need for better data

Better data are required concerning many aspects of the occurrence of butterflies on Kilimanjaro – even the large and conspicuous swallowtails. This includes far greater knowledge about the pool of species currently breeding on the lower slopes below the main forest zones \( (700–1800 \text{ m}) \), the abundance, vertical range and seasonality of all recorded species, and individual movement. Very little is known about which host plants are used and at what altitudes – many of the butterflies have not been reared anywhere, let alone on the mountain itself – summaries of much of the existing host data can be found in Ackery et al. (1995) and Williams (2010). Regular monitoring
of physical data, notably temperature and rainfall widely over the mountain, is also needed – at present we are unsure of what has been and is being achieved in this respect. Likewise, further vegetation surveys and vegetation monitoring are also vital. However, as Axmacher et al. (2009) have demonstrated, changes in geometrid moth diversity on Kilimanjaro seem more closely correlated with temperature and humidity than with floral diversity – and this might also prove to be the case for butterflies.

**Overlap**

The vegetation zones on Kilimanjaro are, in many parts of the mountain at least, discrete, palpable even to the casual observer. While there is little doubt that many of the butterflies are typically encountered within specifiable altitudes, because of their great vagility they can occur much higher or lower than the altitude at which they developed as larvae. This means that, based on the observation of adults, even if they have specific altitudinal ranges within which they develop as larvae, fundamental zonation patterns are likely to be at least partially obscured. Carcasson (1964: 134) discussed what he called *vertical overlap* in the following way: “The dividing line between the [lowland forest division and highland forest division]... is around 5000 ft [1500 m] at the equator... a wide zone of vertical overlap [occurs] between the two divisions, particularly at the equator, where highland species do not normally descend below 3000 ft. [900 m] and lowland species do not rise above 6000 ft. [1800 m].”

Carcasson’s observations give rise to several questions. If original conditions were restored, could all forest zone butterflies on Kilimanjaro occur down as far as Moshi? Historical records suggest that this may have been the case, for many of them at least. Is the lower limit of natural forest, at around 2000 m, now too high for lowland species to colonize? In which case, if lowland butterflies such as *Graphium* species, *Papilio constantinus* or *Papilio nireus* were to start colonizing the lower forest, would this constitute strong evidence for climate change? In this context the suggestion of Hemp and Hemp (2003) that, with the destruction of their habitats at lower levels, various stennoecious grasshoppers have moved up to occupy the disturbed lower forest borders at 1600–1800 m, is significant. In any future study on butterflies it will be important to try to separate such ecological displacements from upward shifts because of climate change *per se*.

Finally, however, we have to question to what extent Carcasson’s division into simply lowland and highland forest species masks finer levels of subdivision within the Kilimanjaro forest belt – subzonation that might be much clearer if it were known at what height the various forest butterflies normally develop as larvae. Any answers to these questions are, of course, dependent on many aspects of the better data called for above.

**Size**

Forewing length has been given for the males and females of each swallowtail species listed. These data are based on small samples collected at different times under very heterogeneous conditions, and must be considered indicative only. However, the fact that the data consistently indicate that females are larger than males, with the clear and expected exception of *Papilio rex* and the interesting exception of *Papilio dardanus*, suggests that they do reflect some reality.
Butterflies of a given species can vary in mean size with latitude (e.g. Vane-Wright et al. 1975). While differences in average size between species are undoubtedly partly the result of genetics, and this is undoubtedly also the case with intraspecific size variation, it has been demonstrated by rearing experiments that size variation can also be induced by environmental factors such as host plant quality (specific and intraspecific differences), water availability and, notably, temperature – such that, in general, if development takes place at a lower temperature, larger adults are likely to result. As recently noted “The temperature–size rule (TSR), which states that body size increases at lower developmental temperatures, appears to be a near-universal law for ectotherms” (Karl and Fischer 2008: 215).

On a mountain like Kilimanjaro, with different rainfall at different heights, falling temperature with increasing altitude, differences in host availability and quality at different heights, and differential movement of individuals making up the populations, it would be possible to investigate these effects, but only with an extensive and sophisticated sampling and breeding programme. The study by Karl and Fischer (2008) indicates the complex nature of the size-variation phenomenon, including sexual differences. Even so, if robust baseline size data could be established for certain common or tractable species on Kilimanjaro, this might offer a further indicator-variable for assessing effects of climate change.

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