Butterflies (Lepidoptera: Papilionoidea) of Mount Kilimanjaro: family Pieridae, subfamily Coliadinae

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This paper forms part of a series on the butterfly fauna of Mount Kilimanjaro. Three genera (Catopsilia, Colias and Eurema) with eight species of Coliadinae are believed to occur within the main forest zone. However, of these, one or two may prove to be no more than variants of a third species, Eurema desjardinsii. A fourth conventionally recognized member of the complex may occur on the lower slopes below 1800 m. The widespread species Eurema hecabe occurs on the lower slopes, but records are sparse, and no records of its close relative Eurema floricola, with which it has often been confused, have been found. The need for original field and laboratory research on the taxonomy of African Eurema species is stressed. Keys to adult Coliadinae found in Tanzania, with colour illustrations, are included as online supplementary material.

Keywords: Lepidoptera; Pieridae; Coliadinae; Africa; Tanzania; taxonomy; keys; checklist; inventory; monitoring; climate change; distribution; variation

Introduction

This paper, which offers a synopsis of the sulphur butterflies of Mount Kilimanjaro, is the second in a series intended to present a checklist for all butterflies currently known or likely to occur on the mountain and its lower slopes. As indicated by Liseki and Vane-Wright (2011), the ultimate goal of this inventory programme is to facilitate monitoring the butterfly fauna of this exceptional mountain, including the potential to use these conspicuous day-flying insects as a focal group to document possible impacts of climate change in eastern Africa. Keys and photographs, provided as online Supplementary Information (SI), offer a practical means for identification of the adult butterflies. However, there are several taxonomic difficulties affecting the status and recognition of some of the conventionally recognized species of grass yellows (Eurema Hübner) thought to occur in Tanzania. These problems, which require resolution, are addressed in the Discussion.

Pieridae of Kilimanjaro

Of the four subfamilies of Pieridae recognized worldwide (Pseudopontiinae, Dismorphiinae, Coliadinae, Pierinae), only the last two are represented in East Africa.

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Table 1. The 16 genera of Pieridae known from Tanzania, and their current classification according to the scheme proposed by Braby et al. (2006: fig. 6).

| Subfamily    | Tribe/group       | Subtribe/group    | Genus                      |
|--------------|-------------------|-------------------|---------------------------|
| Coliadinae   |                   |                   | Eurema Hübner, 1819        |
|              |                   |                   | Catopsilia Hübner, 1819    |
|              |                   |                   | Colias Fabricius, 1807     |
| Pierinae     | Colotis group     |                   | Teracolus Swainson, 1833   |
|              |                   |                   | Colotis Hübner, 1819       |
|              |                   |                   | Nepalheronia Butler, 1870  |
|              |                   |                   | Pinacopteryx Wallengren, 1857|
|              |                   |                   | Eronia Hübner, 1823        |
|              |                   |                   | Afrodryas Stoneham, 1957   |
|              | Leptosia group    |                   | Leptosia Hübner, 1818      |
| Pierini      | Appiadinia        |                   | Appias Hübner, 1819        |
|              |                   |                   | Pontia Fabricius, 1807     |
|              |                   |                   | Pieris Schrank, 1801       |
| Belenois group|                   |                   | Belenois Hübner, 1819      |
|              | Aporiina          |                   | Dixeia Talbot, 1932        |
|              |                   |                   | Mylothris Hübner, 1819     |
|              |                   |                   | (=Pseudomylothris Neustetter, 1929) |

Pseudomylothris, sometimes regarded as a separate genus, is undoubtedly a synonym of Mylothris (Vane-Wright and Liseki 2011). Fitzherbert et al. (2006) incorrectly listed Nepalheronia and Eronia within the Coliadinae. Nazari et al. (2011) have recently segregated Teracolus and Afrodryas from previous concepts of Colotis and Eronia, respectively.

For Tanzania, Kielland (1990) recorded 14 genera and 95 species of Pieridae. The 16 currently recognized genera, the separation of which still owes much to the classic study of Klots (1933), are listed in Table 1, in order of the most recent higher classification (Braby et al. 2006).

In this paper, and the subsequent paper on Pierinae (Liseki and Vane-Wright in preparation), the genera are dealt with in the order of Table 1. All three coliadidine genera known from Tanzania (Catopsilia Hübner, Colias Fabricius and Eurema) are represented on Mt Kilimanjaro. Within each genus or subgenus the species are presented alphabetically. Those species known or believed to occur within Mt Kilimanjaro’s montane forest reserve areas (above 1800 m: Liseki and Vane-Wright 2011) are given in bold type-face, while additional species that occur or possibly occur on the lower slopes are listed in non-bold.

In most, but not all, cases male and female forewing lengths are given for each species. The ranges are estimates. The means and standard deviations (SD) have been calculated from direct measurement of small samples from the Natural History Museum London (BMNH) collections, using STANDARD DEVIATION CALCULATOR (http://www.easycalculation.com/statistics/standarddeviation.Php). Wherever possible these size estimates are based on material entirely from northeastern Tanzania. Where necessary, however, additional material from elsewhere in Tanzania, Kenya or East Africa has been employed. Sizes are indicative only. For certain Eurema some additional data on size are added from Yata (1989, 1991, 1994, 1995) and Larsen (2005).
Annotated checklist of Pieridae: Coliadinae of Mt Kilimanjaro

“Most members of Eurema show considerable seasonal and/or geographical variation, and thus it is often very difficult to identify them with external features alone. In contrast, the male and female genitalia, however, show little variation within each species. Given this reliable basis for recognizing species, external key characters which correlate with the genitalic characters have now been found, making it possible to distinguish almost every species from close allies by external features alone.”

Osamu Yata (1989: 3)

Kielland (1990) and Ackery et al. (1995) recognized nine species of Eurema from mainland Africa, potentially all of which could occur on Mt Kilimanjaro if its lower slopes are included. However, there are considerable uncertainties concerning the status and identification of several of these taxa. In general, individual specimens can be difficult to identify (Larsen 1996). Moreover, although these butterflies are often considered to be common, we have had access to very little authentic Eurema material from the Kilimanjaro massif. We therefore give brief accounts below of all nine conventionally recognized African Eurema species – but these should be read in conjunction with the Discussion where, and despite the view expressed by Yata (1989: 3) quoted above, the continuing need for further taxonomic research is addressed.

Eurema (Eurema) brigitta brigitta (Stoll, 1780)

Pennington 1978: pl 142 figs 593 i–vi. Larsen 1996: pl. 5 figs 37 i,ii. d’Abrera 1997: 65 (4 figs). SI: Figures 2a–d, 8, 14.

Forewing length: male 14–23 mm [mean (n = 6) 18.72 mm, SD = 2.883]; female 17–23 mm [mean (n = 5) 19.54 mm, SD = 1.560]. For the collective species, Yata (1989: 63) gives forewing length ranges of 14.0–25.0 mm (males), and 13.5–22.0 mm (females). Larsen (2005) gives “18 mm”.

Said to be common in all parts of the country, from sea level to 2400 m (Kielland 1990: 51 [who gave author and date of publication as Cramer, 1770, in error]). Kielland does not give specific records, but Liseki (2009) recorded this butterfly as common in disturbed areas at 2000 m during March and May (two male specimens deposited in BMNH). A female in BMNH labelled Kilimanjaro, collected at “5000 ft” (1500 m), was registered in 1885 (Godman 1885, tentatively identified this specimen as Terias candace Felder and Felder, 1865, a synonym of brigitta). Aurivillius (1910a: 12) recorded a single female from Kilimanjaro, found in April at c.1000 m. The nominate subspecies is found in open habitat throughout sub-Saharan Africa; other subspecies occur in Madagascar and elsewhere in the Old World tropics (Yata 1989: 61–77; Ackery et al. 1995: 173).

Eurema (Eurema) desjardinsii marshalli (Butler, 1898)

Pennington 1978: pl 142 figs 595 i–x. Kielland, 1990: 266 (3 figs). Larsen 1996: pl. 5 fig. 34i (as “desjardinsi oberthuri”). SI: Figures 5a,b, 9, 15.

Forewing length: male 16–23 mm [mean (n = 10) 20.45 mm, SD = 1.514]; female 18–23 mm [mean (n = 5) 20.5 mm, SD = 1.565]. For the collective species, Yata (1989:
98) gives forewing length ranges of 17.0–22.0 mm (males), and 18.0–22.5 mm (females). Larsen (2005) gives “20 mm” for “E. desjardinsii regularis”.

Found commonly in woods, forests and more open montane habitats throughout most of the country, at 400–2500 m (Kielland 1990: 52 [who gave year of original publication as 1897, in error]). Kielland does not give a specific record for Kilimanjaro, and it was not reported by Liseki (2009). However, Aurivillius (1910a: 12) recorded 13 individuals of this species from Kilimanjaro, collected in January, August, September and October. Although apparently unrepresented in the BMNH from Kilimanjaro, this widespread species occurs throughout sub-Saharan Africa (Ackery et al. 1995: 174), and seems almost certain to occur on both the high mountain and its lower slopes. Moreover, one or more of the next three species listed here may ultimately prove to be conspecific (see Discussion).

**Eurema (Eurema) mandarinula** (Holland, 1892)

Pennington 1978: pl 142 figs 595 ix,x (as form of E. desjardinsii but said to be a misidentification: Larsen, 1996: 123). Kielland 1990: 266 (3 figs). Larsen 1996: pl. 5 fig. 35i. d’Abrera 1997: 67 (holotype female of Terias punctinotata Butler, 1895, considered to be a synonym). SI: Figure 5c,d.

Forewing length: no data, but probably the same or very similar to E. desjardinsii (see Discussion regarding this taxon, which may ultimately prove to be conspecific with desjardinsii).

According to Kielland (1990: 52), *E. mandarinula* is only found above 1400 m, with records from the Uluguru, Nguru and Ukaguru mountains, the Udzungwa range and Southern Highlands, Tukuyu, Ufipa plateau, Mt Mahale, Mt Meru, Kilimanjaro, the Oldeani-Ngorongoro highlands and Mbulu forests. Recorded for Kilimanjaro by Liseki (2009) in an open area at 2000 m during January and November. Outside Tanzania this butterfly has been recorded from Malawi, Democratic Republic of Congo (Ituri, Kivu, Shaba, Haut-Lomani, Sankuru), Rwanda, Burundi, Uganda and Kenya.

**Eurema (Eurema) regularis** (Butler, 1876)

Pennington 1978: pl 142 figs 595 v,vi (as form of E. desjardinsii, but probably a misidentification: Larsen, 1996: 123). Kielland 1990: 266 (4 figs). Larsen 1996: pl. 5 figs 36 i,ii. d’Abrera 1997: 65 (5 figs). SI: Figure 5e,f.

Forewing length: no data, but probably the same or very similar to E. desjardinsii (see Discussion regarding this taxon, which may ultimately prove to be conspecific with desjardinsii). Larsen (2005) gives “20 mm” for “E. desjardinsii regularis”.

Woodland and forest edges from 300–1800 m, and found in most wooded areas of Tanzania (Kielland 1990: 53), this butterfly probably occurred in the past on the lower slopes of Kilimanjaro, and might continue to do so. Widespread throughout much of the rest of mainland Africa.
**Eurema (Eurema) upembana** (Berger, 1981)

Berger 1981: 83, pl. 50, figs 15, 16. Kielland 1990: 266 (3 figs). d’Abrera 1997: 67 (2 figs). SI: Figures 4e–h.

Forewing length: 22.2 mm (female paratype).

According to Kielland (1990: 53), in Tanzania this is an upland species found from 1100 to 2600 m in the Uluguru (Berger 1981: 83), Nguru, Ukaguru and Rubeho mountains (apparently very common on Mangalisa), the Udzungwa range to Mufindi, Livingstone Mts (Berger 1981: 83) and Njombe highlands, Ufipa plateau (Bizi forest, Mbuzi Mt and Chala Mt), Mpanda District (Kampisa-Sitebi-Wanzizi), Kigoma District (Mahale Mts), and Ngara District. Kielland did not list this butterfly for Mount Kilimanjaro, but it was recorded there by SDL in November 2001, from an open area at 2000 m (Liseki 2009).

Beyond Tanzania this species is only known from the region of the type locality, in the Democratic Republic of the Congo (Berger 1981; d’Abrera 1997). However, we are not entirely certain about the status of this taxon, which appears to be another member of the intimately related *E. desjardinsii* complex, and may ultimately prove to be conspecific with *desjardinsii* (see Discussion). There is no material of this butterfly in the BMNH, other than one female(?) that may be this insect, collected by SDL on the Marangu route at 2000 m on 9 September 2000 (SI: Figure 5g,h).

There is also some uncertainty about to which subgenus this butterfly belongs; it is included on the Tree of Life website in *Terias* (http://tolweb.org/Terias/76388), the genus in which it was originally described. In the absence of any available information on the male genitalia, we only have the underside wing pattern as a guide. In our view the underside of the paratype female figured at http://www.metafro.be/lepidoptera/butterflies/RMCA-0116/taxon (see also SI) is in many ways comparable to that of *E. desjardinsii*. Berger (1981) compared his new species with the very closely related *E. mandarinula*. On this basis we include *upembana* within *Eurema* s.s, as a member of the *desjardinsii* complex.

**Eurema (Terias) floricola leonis** (Butler, 1886)

Kielland, 1990: 266 [1 fig.; as subsp. near *floricola floricola* (Boisduval, 1833)]. Larsen 1996: pl. 5 fig. 32 i,ii [as “subsp. orientis” (Butler, 1888)]. SI: Figures 3g,h, 12, 18.

Forewing length: no data. For the species as a whole, Yata (1994: 99) gave the forewing length range in both sexes as 15.0–22.0 mm. Larsen (2005) does not give data on size. See Discussion.

Common in lowland forests in eastern Tanzania, including East Usambara, to about 700 m, then more rarely up to 1200 m (Kielland 1990: 52), there is a possibility that this butterfly might occur or have occurred on the very lowest slopes of Kilimanjaro – but we have not located any material from the massif in the BMNH, or found any records in the literature.
**Eurema (Terias) hapale** (Mabille, 1882)

Pennington 1978: pl. 142 figs 594 i–iv. Larsen 1996: pl. 5 fig. 33 i. d’Abrera 1997: 65 (3 figs). SI: Figures 2e–h, 11, 16.

Forewing length: male 17–21 mm [mean ($n = 5$) 18.86 mm, SD = 0.853]; female 15–20 mm [mean ($n = 5$) 17.82 mm, SD = 1.195]. Yata (1991: 8) gave the forewing length range for both sexes as 17.5–19.5 mm. Larsen (2005) gives “18 mm”.

Found in all parts of Tanzania except very dry areas, this species typically occurs in marshy forests, grasslands and riversides up to 2000 m (Kielland 1990: 52). Kielland did not give a specific record for Kilimanjaro but this butterfly was recorded from the mountain by Aaurvillius (1910a: 12), based on five specimens collected in August and September. SDL found it to be common in an open area at 2000 m during March 2001 (Liseki 2009). There is no material from Kilimanjaro in the BMNH, but a single male from the east side of Mt Meru was obtained by B. Cooper in 1937, at 5000 ft (1500 m). Beyond Tanzania this species occurs in marshy grassland throughout many parts of tropical Africa (as far south as northern Mozambique: van Son 1949), and in Madagascar (Ackery et al. 1995: 174).

**Eurema (Terias) hecabe solifera** (Butler, 1875)

Pennington 1978: pl 142 figs 592 i–xii (as subsp. ‘senegalensis’, misidentification). Larsen 1996: pl. 5 figs 30 i–iii. d’Abrera 1997: 65 (3 figs). SI: Figure 3a–f, 10 (*hecabe hecabe*), 17.

Forewing length: male 18–25 mm [mean ($n = 5$) 22.04 mm, SD = 2.644]; female 19–25.5 mm [mean ($n = 5$) 22.34 mm, SD = 1.806]. For *E. h. solifera*, Yata (1995: 47) gave the forewing length ranges as 19.0–22.5 mm (males), and 19.0–22.0 mm (females). Larsen (2005) gives “19 mm”.

Records: All parts of Tanzania in a variety of habitats, from sea-level to 2200 m (Kielland 1990: 52). Kielland offered no specific records, and the species was not encountered at 2000–3000 m on Kilimanjaro by Liseki (2009). We have located three specimens in the BMNH said to be from Kilimanjaro: one male in the Rothschild Collection with a typewriter-generated label “Kilimanjaro” (however, such Rothschild labels usually signify an uncertain or doubtful provenance – RVW, personal observation), one very worn female labelled “Kilimanjaro [18]85-60” that might be *hecabe*, and one male labelled “Kilima-njaro [18]87-140” with an unusual phenotype but very similar to a specimen illustrated by Yata (1995: pl. 33, figs 7, 8) as a dry season form of *hecabe* from Eritrea. On this basis, and the opinion of Torben Larsen (in litt. 27 April 2012) we conclude that this very common butterfly occurs on the lower slopes of Kilimanjaro and, perhaps, within the lowest levels of the forest. Distributed widely in savannahs and woodland throughout sub-Saharan Africa (Ackery et al. 1995: 175), including Cape Verde (Mendes and Bivar de Sousa 2010), numerous subspecies have been described from the Indo-Pacific region – but *solifera* is the only race currently recognized from the African mainland.

**Eurema (Terias) senegalensis** (Boisduval, 1836)

Larsen 1996: pl. 5 fig. 31 i. d’Abrera 1997: 65 (3 figs). SI: Figures 4a–d, 13, 19.
Forewing length: male 21–24 mm [mean (n = 5) 22.32 mm, SD = 0.554]; female 19.5–26 mm [mean (n = 5) 22.4 mm, SD = 1.880]. For *E. senegalensis*, Yata (1994: 95) gives the forewing length ranges as 22.0–26.0 mm (males), and 22.0–25.0 (females). Larsen (2005) gives “22 mm”.

According to Kielland (1990: 53 [who gave year of original publication as 1833, in error]), this relatively large species is found in all parts of the country with evergreen forest (sometimes heavy woodland) from sea-level to 2000 m, but appears to be absent in the drier, central parts of Tanzania. Kielland did not give specific records for Kilimanjaro, but it was found in both open and forested areas at 2500 m during January (Liseki 2009). However, there does not appear to be material in BMNH from Kilimanjaro, and it would be desirable to confirm this record – especially given the altitude at which the observations were made. Outside Tanzania this species occurs from western Uganda, Zimbabwe to Democratic Republic of Congo, Congo, Equatorial Guinea, Cameroon, Nigeria, Liberia, Sierra Leone and Senegal (Ackery et al. 1995: 175).

*Catopsilia florella* (Fabricius, 1775)

Larsen 1996: pl. 4 figs 28 i–iii. d’Abrera 1997: 63 (5 figs). SI: Figure 6a–f.

Forewing length: male 27–37 mm [mean (n = 10) 33.13 mm, SD = 2.957]; female 28–36 mm [mean (n = 13) 33.04 mm, SD = 2.205]. In Botswana, Larsen (1992: table 2) recorded mean values of 31.6 mm (non-migratory males; n = 45), 34.8 mm (migratory males; n = 34), 31.0 mm (non-migratory, whitish females; n = 13), and 35.9 mm (migratory, yellow females; n = 17). Larsen (2005) gives “33 mm”.

Occurs throughout Tanzania “from sea-level to the summits of high mountains” (Kielland 1990: 51). Kielland does not give specific records, but *Catopsilia florella* was encountered on Kilimanjaro by Liseki (2009), where it was common during January and March at 2000–3000 m, in both open and forested areas. BMNH records indicate that, as would be expected, this species also occurs on the lower slopes. Outside Tanzania this migratory butterfly is found in more open habitats throughout the whole Afrotropical region, including Bioko, Madagascar, Réunion, Mauritius, the Comoro Islands and Aldabra; also the Canary Islands, Arabia, India and Sri Lanka (Ackery et al. 1995: 170), and Cape Verde (Mendes and Bivar de Sousa 2010). The females are polymorphic, and Larsen (1992) reported a number of significant differences between migratory and non-migratory individuals, including morph frequency and size (see Discussion).

*Colias electo pseudohecate* Berger, 1940

Larsen 1996: pl. 4 figs 29 i–iii. d’Abrera 1997: 65 (4 figs). SI: Figure 7a–f.

Forewing length: male 21–27 mm [mean (n = 6) 24.2 mm, SD = 2.191]; female 22–34 mm [mean (n = 10) 25.17 mm, SD = 3.119].

Note: Jarvis (1953) proposed that *pseudohecate* should best be regarded as a separate species from *Colias electo*. In stark contrast, Grieshuber et al. (2012) suggest that differentiation of any subspecies within *electo* is open to doubt, maintaining currently recognized subspecies, including *pseudohecate*, only provisionally. Available
barcode data (BOLD AAC0416; see also SI, Appendix) can be interpreted as supportive of the latter view, with the possible exception of the West African *Colias electo manengoubensis* Darge, 1968, which (based on a sample of one) might be distinct.

Found in the uplands of Ufipa, Mpanda and Kigoma, Mbeya district, Njombe and Livingstone Mts, Udzungwas, Usambaras and Northern Highlands (Kielland 1990: 51). Kielland did not give specific records within the Northern Highlands, but the presence of this butterfly on Kilimanjaro is well known, where it is said usually to occur above the timberline (Mani 1968: 153), typically flying in the montane grassland (de Jong and Congdon 1993). According to Kielland (1990) subspecies *pseudohecate* generally flies at 1300–2700 m, but Liseki (2009) encountered it in all seasons among montane grassland at 3000 m just above the tree-line, never below this level. However, there is an old specimen collected by F.J. Jackson from Loitokitok on the northern slopes that was apparently obtained considerably lower on the mountain. Beyond Tanzania this subspecies occurs in numerous African countries, including Malawi, Uganda, Kenya, eastern Democratic Republic of Congo, Rwanda, Burundi, southern Sudan, southern Ethiopia and northern Somalia. Represented by six subspecies, the butterfly occurs widely throughout much of tropical Africa, but is not found in Madagascar (Ackery et al. 1995).

**Discussion**

**Polymorphism, sexual dimorphism, polyphenism and adult size and shape**

The small Old World tropical genus *Catopsilia* has only one representative in mainland Africa, and the cosmopolitan genus *Colias* (which includes over 80 species: Grieshuber and Lamas 2007) has only one species in Africa south of Ethiopia. According to Grieshuber et al. (2012), *Colias electo mukana* Berger, 1981, sometimes recognized as a separate species, should be retained as a subspecies of *Colias electo* (Linnaeus, 1763), and barcode data appear to confirm this (BOLD AAC0416; see also SI, Appendix), or even suggest (assuming correct identifications) that *mukana* is not separable from the mass of other *Colias electo*.

As with so many Pieridae, female-limited polymorphism is striking in both *Colias* and *Catopsilia*. In *Colias electo*, females occur either as a male-like, orange morph, or as whitish or creamy “alba” morphs. *Catopsilia florella* females are either whitish (f. “pyrene” – similar to the greenish-white males), a rarer but more strongly marked whitish morph (f. “hyblaea”), or a yellow form (sometimes referred to as f. “rhadia”). However, Larsen (1992) noted significant differences between migratory and non-migratory *Catopsilia florella* in Botswana, with migratory individuals of both sexes larger, the underside colour pattern more strongly marked, and purplish rather than blackish antennae. Most strikingly, and confirming earlier observations of this species in Africa, Larsen found that the vast majority of all migratory females were of the yellow morph (see also Pringle et al. 1994).

With respect to the grass yellows, their wing patterns and sizes are also variable, with both traits variously subject to seasonal polyphenism (see e.g. Jones 1992, on Australian *Eurema*; and Yata 1989, 1991, 1992, 1994, 1995), and they also exhibit sexual dimorphism. However, unlike *Catopsilia* and *Colias*, discrete female-limited polymorphism is not well marked among the African *Eurema*. Even so, considerable individual variation and underlying sexual dimorphism coupled with seasonal
variation in both pattern and size makes reliable identification of some *Eurema* species a particular challenge.

A further issue here, yet to be systematically investigated, concerns wing shape – often used to differentiate taxa within the *E. desjardinsii* complex. Wing shape is said to vary seasonally in *E. brigitta* (Larsen 1996) and, if so, this might affect other *Eurema* taxa as well. Seasonal variations in size and wing shape, as well as dramatic colour pattern shifts, are well-known in various nymphalid butterflies.

In consequence of all this, we have yet to reach a point where there is agreement even among specialists on the limits and identification of several of the African *Eurema* species.

Problems with the taxonomy of African *Eurema* species

*Eurema* comprises a large pantropical group of well over 60 sulphurs, many of them divided into subspecies. The genus is represented in Africa, including Tanzania, by up to nine species (Ackery et al. 1995; Kielland 1990) divided among two subgenera: *Eurema* s.s. and *Terias* (for separation, see SI). All nine species recognized by Kielland (1990) were recorded from Udzungwa National Park (Congdon and Bampton 2001) and it is conceivable, although unlikely, that all the same taxa occur on Kilimanjaro and its lower slopes.

However, this apparently straightforward situation hides a series of problems that become evident on comparing different accounts based on the external phenotype of these little butterflies, all of which, as noted above, are more or less variable. It is unfortunate that the outstanding revisional work of Yata (1989, 1991, 1992, 1994, 1995), founded largely on examination of male and female genitalia, came too late to be taken into account in preparation of what remains the standard work on Tanzanian butterflies (Kielland 1990). By the same token, it is regrettable that Yata did not have access to Kielland’s book and, moreover, seemed to have largely overlooked two earlier key works by Berger (1980, 1981).

As there are over 200 barcode sequences for *Eurema* already publicly available on the Internet (e.g. http://www.boldsystems.org/index.php/Public_SearchTerms; search on *Eurema*), it has been suggested to us that it may already be possible to draw additional conclusions with respect to the taxa dealt with here. While this may be so – and there is no doubt that molecular data can be effective in resolving grass yellow species (e.g. Tiple et al. 2010) and even sibling species of *Eurema* (Narita et al. 2007) – data from mitochondrial DNA can pose problems of interpretation if samples are not extensive (Funk and Omland 2003). Moreover, barcode data in insects can be affected by *Wolbachia* infections (e.g. Whitworth et al. 2007), and *Eurema* are known to be infected by these bacteria (e.g. Hiroki et al. 2004; Narita et al. 2007). Given that there are no available barcode data for three of the most uncertain nominal taxa dealt with here (*E. upembana*, *E. mandarinula* and *E. regularis*), and the likelihood that a proportion of the existing records will be based on (phenotypic) misidentifications or may be affected by other technical problems, in our view attempting to make use of these data now is premature. We consider that there is an urgent need for a new synthesis on the African species, based on both morphology and extensive molecular systematics. Below we point first to the species on which there is general consensus, and then discuss the more problematic taxa.
Eurema brigitta, E. hapale and E. senegalensis

Of the nine African Eurema species catalogued by Ackery et al. (1995) and listed above, only three seem wholly unproblematic: E. (Eurema) brigitta (although very variable, most individuals have a characteristic 'jizz', including the often ‘grainy’ underside colour pattern, by which it differs from all other African Eurema), E. (Terias) hapale (characteristically shaped dark forewing apex in both sexes), and E. (T.) senegalensis – although the name of this last, relatively large species has sometimes been confounded with E. (T.) hecabe (e.g. van Son 1949; Gifford 1965; Pennington 1978; Kielland 1980). As demonstrated by Yata (1989, 1991, 1994, 1995), all three of these species as well as hecabe have distinct male genitalia (see his figures reproduced in SI).

Eurema desjardinsii, E. mandarinula and E. regularis – one, two or three species?

Aurivillius (1910b), van Son (1949), Gifford (1965), Pennington (1978), D’Abrera (1980), Carcasson (1981) and Larsen (1984) all treated both mandarinula and regularis as (seasonal) forms of E. desjardinsii. Berger (1980: 879), in contrast, based on a study of Eurema from the Uluguru Mountains, argued that all three represented valid species. He was emphatic that the three forms were present in all seasons, throughout all months of the year, and that the differences could not be explained by polyphenism. This view has since been followed in many publications on the African fauna (e.g. Kielland 1990; Pringle et al. 1994; Ackery et al. 1995; Larsen 1996; d’Abrera 1997; Heath et al. 2002).

Yata (1989), however, in his revision of all Old World species of Eurema, based on examination and comparison of numerous dissections of both male and female genitalia, continued to regard all three as forms of a single, very variable species (employing, in the process, regularis as the senior name for the sub-Saharan subspecies listed here as E. desjardinsii marshalli). However, Yata did not cite Berger’s (1980) paper, and offered no discussion of the colour pattern differences adduced by Berger to make his separations. Berger did not report any information on the genitalia, apparently making his separations solely on colour and shape. Yata’s work was completed before the appearance of the first major work by another entomologist (Kielland 1990) that accepted the separations made by Berger. More recently, Larsen (2005), pointing to numerous intermediates present in West Africa, treated regularis as a subspecies of desjardinsii, but not mandarinula, and this was followed by Williams (2010 – although in the current online version of his catalogue, he reverts to citing regularis as a full species, arguing that Larsen failed to change its status formally). So we now have a situation where the desjardinsii “complex” (Berger 1980) is variously regarded as one, two or three species.

Currently these taxa have not been reliably separated in the BMNH collection (reflected in a comment by d’Abrera 1997: 66). Without a major revision, which could not be undertaken for the purpose of this checklist, we are unable to offer any useful conclusion on this problem. The implication of Yata’s work is that the genitalia of all three taxa are the same (see also Larsen 2005) – but, if so, this ought to be confirmed by more extensive sampling. A new investigation involving both morphological and molecular systematics is clearly needed. The SI key reflects how the division into three species is currently made, but without achieving convincing clarity.
Separation of Eurema floricola from E. hecabe, and its subspecies

Aurivillius (1910b: 64) included three African species in his "hecabe group": E. senegalensis (under the synonym brenda Doubleday, 1847), E. hecabe (as senegalensis, misidentified), and E. floricola. However, the last of these taxa has sometimes been treated as a form of hecabe (e.g. van Son 1949; Pennington 1978). Yata (1994, 1995) demonstrated small but significant differences between the male genitalia of these two species (see his illustrations reproduced in SI). Kielland (1990: 52), following Berger (1981: 83), stated that the eastern Tanzania populations of E. floricola differ little from the nominate Madagascan subspecies. Ackery et al. (1995) included leonis within the synonymy of E. hecabe solifera (Butler, 1875). However, Yata (1994: 104) had by then selected a lectotype for Terias leonis Butler from Sierra Leone, which name he then applied to the subspecies of E. floricola "widely distributed in Africa mainland". As a result, if we follow Berger (1981) and Kielland (1990) in accepting two subspecies on the African mainland, then the one occurring from Sierra Leone and Nigeria to Kenya and eastern Tanzania should be referred to as E. f. leonis, while the second, from the Democratic Republic of Congo, Burundi (which may be transitional) and western Tanzania, is E. f. nivea (Berger 1981). Hence the correct name for the subspecies found in Tanzania is E. f. leonis (see Williams 2010 – who includes nivea as a synonym). Other subspecies of E. floricola occur in Madagascar (nominate), Aldabra, the Comoros, Mauritius and Réunion.

Although there is no reasonable doubt that two species are involved, superficially E. hecabe and E. floricola are similar, and some individuals apparently identified on the basis of their genitalia are difficult to differentiate based on wing pattern. As Larsen (1996: 122) has commented, they have often been confused. We have been unable to document reliably either species from Kilimanjaro, although one or even both might occur. Of the two, hecabe seems the more likely to be found, and some old records that might be valid are discussed in the annotated checklist (above).

Eurema upembana – a valid species?

Berger (1981) illustrated the upperside of the holotype male of his new taxon, together with that of a female paratype (“allotype”). Both upperside and underside of this paratype female, in Musée royal de l’Afrique centrale (MRAC, Tervuren), are figured at http://www.metafro.be/lepидoptera/butterflies/RMCA-0116/taxon (see also SI). D’Abrera (1997: 67) illustrated the upperside of another authentic male from the MRAC collection, together with the same female paratype, both collected by de Witte. The male illustrated by d’Abrera was obtained at only 700 m but Kielland (1990: 53) gave an altitudinal range of 1100–2600 m for this species in Tanzania. Both the male and female specimens from Tanzania illustrated in Kielland (1990: 266: see SI) have less extensive upperside marginal borders at the forewing tornus compared with the three Democratic Republic of Congo specimens that have been figured.

Is the species illustrated in Kielland (1990) truly the same as E. upembana? It is unfortunate that Yata (1989, 1991, 1992, 1994, 1995) made no reference to E. upembana, and he has yet to examine authentic material (O. Yata personal communication, March 2012). Moreover, Yata’s (1989–1995) published work, based on
his 1988 doctoral thesis, also took no account of Kielland (1990). Veins at the bases of both forewings and hind wings of *upembana* are strongly maculated, a pattern only otherwise matched by darker individuals attributed by Yata (1989) to *E. desjardinsii*. Examination of genitalia from material attributed to *upembana* from both the Democratic Republic of Congo and Tanzania is desirable. It appears to be a fourth member of the *E. desjardinsii* complex, and subject to much the same uncertainties regarding its validity as a full species or not, as is the case with *regularis* and *mandarinula*. However, Berger evidently encountered all of these butterflies in life as well as the insect cabinet, and he was clearly convinced that he was dealing with close but distinct species (Berger 1980, 1981), and the same seems to be true for Kielland (1990).

**Conclusions**

Summarizing, it is clear that fundamental taxonomic research on the African *Eurema*, using morphological and molecular data in addition to characters derived from colour pattern and wing shape, is urgently needed. As discussed by Liseki and Vane-Wright (2011), taxonomic precision is necessary if butterfly species are to be used for assessing shifts in distribution, including altitudinal zonation on Kilimanjaro due to climate change. The work of Kielland (1990) suggests, for example, major differences in altitudinal zonation of the supposed members of the *E. desjardinsii* complex but, if these differences relate to variations within three, two or even only one collective species rather than four discrete species, then the significance of any observed changes in occurrence could be interpreted very differently.

Were new taxonomic research on the African *Eurema* undertaken successfully in the near future, the present somewhat unsatisfactory list for Kilimanjaro could be updated in the final part of this series. To do this it would be important to locate extensive Tanzanian material in existing collections (e.g. MRAC Tervuren, African Butterfly Research Institute Nairobi), as well as collect fresh material from Kilimanjaro and elsewhere in Africa, for molecular and morphological work. Meanwhile it is hoped that this list and discussion, together with the keys and images presented (SI), will provide both the baseline and stimulus for further investigation.

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