The Inaugural Conference on African Lepidoptera
Nairobi – Kenya – 1-8 May 1997
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Editorial

It was about four years ago, at the annual conference of the then Lepidopterists’ Society of Southern Africa, that a small group of people gathered under the shade of an umbrella thorn, having lunch. We were discussing matters concerning the development of the society and in particular the value of these annual gatherings. Everyone agreed that these events were an invaluable part of the society and that all who attended them were enriched by this interaction of like-minded people. Steve Collins lamented the fact that these conferences were attended mostly by South African lepidopterists, and expressed the view that we should think bigger and organise a truly international conference on African Lepidoptera. He said it was a great pity that there was so little communication between us and the many other lepidopterists, he knew, with an interest in Afrotropical Lepidoptera. We uhm’d and ah’d over this suggestion and basically decided that we were not up to such a big task just yet. At the time of the conference the political situation in South Africa was changing dramatically. We had come out of a long period of isolation and suddenly realised that there was indeed, life north of the Zambezi river. The movement within the society wanting to expand the geographical base to include all of the Afrotropical region grew and grew resulting in a definitive proposal to change the society to become a truly African one.

One evening at the Curle’s home, Alf, Steve Collins and myself had a meeting discussing various publications in which the society and the newly formed African Butterfly Research Institute (ABRI) were jointly involved. Steve informed us that he intended to host an international conference on Afrotropical Lepidoptera in order to launch ABRI, and that he strongly supported our bid to upgrade the society to continental proportions. He suggested that we should join forces in hosting such a conference. We decided that if this event were to take place it should be held in April/May as this was a time of the year that very little else was going on. Alf and I were enthused by these prospects and decided to call a special council meeting of the society. At the meeting the members concurred and gave their support to the bid to change the status of the society and to be actively involved in the proposed conference. These decisions and the necessary changes to the society’s constitution were later ratified by the membership at the annual general meeting held in August 1996.

What ultimately transpired from these humble beginnings, was that The National Museums of Kenya, ABRI and The Lepidopterists’ Society of Africa joined forces to host the Inaugural Conference On African Lepidoptera from 1-8 May 1997 in Nairobi Kenya.

Steve and Jackie Collins did a truly remarkable job in organising everything, including conference proceedings, travel arrangements, accommodation, car hire, registration, field trips, programmes, “T” shirts etc. etc. Jackie had an open house for weeks with all sorts of hungry “weird bug types “ trotting in and out of their beautiful Karen residence. ABRI did a sterling job in organising sponsorship and free accommodation to those that needed it. Ivan Bampton and Colin Congdon were veritable shuttle busses, constantly transporting people to and fro between the Airport, ABRI, hotels, the Museum, field trips etc.. Nairobi’s National Museums of Kenya, where the conference was held, was a more than adequate venue. The staff at the museum did a great job. Our sincere thanks for the catering (we all ate very well!) and for allowing the delegates access to their well preserved collection.

From the Lepidopterists’ Society, it was Alf Curle who took the bull by the horns and ran with it: From the beginning he compiled lists of all those interested in attending the
conference, he co-ordinated all the arrangements of the South African delegates, he compiled the abstracts of the members participating, he sent out instructions regarding health and visa requirements and the list goes on. As I see it, these players are the pillars on which the making or the breaking of the conference rested. There are of course many other people that made the conference the success that it was, the conference facilitators, the speakers, not to mention the delegates themselves. Suffice to say that all stood together and together we made this the historic event it turned out to be.

The conference itself was a bustle of activity. The papers were well presented and the fact that the questions after each paper always ran over time is an indication of the interest shown. During the breaks in the proceedings there was frenzied networking. In between renewing old acquaintances, the delegates were trying to meet others whose work they know so well but whom they had not actually met in the flesh. All this between trying to satisfy the grumbling in their stomachs. The evenings were spent in a more leisurely manner either at the hotels or at ABRI, discussing the day’s happenings and cementing new friendships. And then there were the strange things happening in the ABRI bunkhouse, in the middle of the night, but I shall not elaborate on those. The conference ended much too soon, but with a bang. We were all invited to a grand lunch at the Collins’ residence, and grand it was. I was amazed at the magnificent cuisine that we were presented with in the middle of Africa. Jackie really excelled herself and I am sure that all who attended will never forget that particular “Lunch”.

But all was not over. The following day the delegates broke up into small groups and were off in different directions to get a smell of the African bush. Some of us unfortunately had to leave for home on that day because of business commitments. From what I hear the field trips were a continuation of what earned much from each other as far as field work was concerned and a number of newly cemented friendships got the glass-stone coating. There is already talk of when and where the next international conference should be held. The Cape lepidopterists are keen to put in a bid for it, perhaps a conference at the southern tip of the continent would be nice.

Probably the most important thing that emanated from this inaugural conference was the increase in communication between the relatively small world-wide community of Lepidopterists interested in Afrotropical Lepidoptera. I visited the Natural History Museum, London, a week or so ago. As I was being led to my workbench by Mark Parsons, the collections manager, I stumbled onto a familiar face, Anders Bjornstad from Norway. The previous occupant of my bench was Kuhn Maes from Kenya. Dick Vane-Wright, from nhm London spotted me and tried, in jest, to escape me because he owed me a manuscript. Later that afternoon I heard a familiar voice, Bernard and Lucilla D’Abrera were coming down the corridor towards me, just arrived from Australia. All of them people that I had got to know at the Kenya conference. I felt that I belonged to this world community of lepidopterists. It was about four years ago, that day under the umbrella thorn, when I had first heard of Steve’s dream of bringing a community together. I did not fully understand what he meant that day, I do now. All I can say is: Steve Collins, well done young man.

This supplement is not a normal 'proceedings of a conference' , but rather a compilation of papers that derive their origin from The Inaugural Conference On African Lepidoptera, held in Nairobi Kenya, 1-8 May 1997. The papers have gone through the normal mill of peer-review and editing. Some papers are only short abstracts of the work that people are doing, some papers are interim reports and others are full papers. This supplement is meant to be a monument to a truly historic event.

Hermann S. Staude.
BIODIVERSITY AND OROPHILY ON THE CAMEROON HIGHLANDS

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Abstract: Orophily is defined, and several examples are given of the difficulty of asserting the orophilic character of a given species. Data published in 1991 on the butterfly fauna of the Cameroon Highlands is updated and confirms both a relatively low diversity and a surprisingly low proportion of orophilic species. The very low degree of differentiation of at least 75% of these species indicates a recent isolation; the term “Cameroonian oro-endemic” is defined and shown to apply to only about 13% of orophilic species. A comparison between these two groups suggests that the hypothesis of a continuous montane forest belt across the continent is not necessary to explain the present disjunctions in the distribution of orophilic butterflies.

The first comprehensive study on the Cameroon Highlands recorded 170 species over 1800 m (Libert 1991). Correction of a few omissions brought this number to 183. Since 1991, three new places have been visited: Mt Bana, on the southern edge of the Bamileke Plateau; Mt Koupe, near Mt Manengouba. Mt Tchabal Mbabo (Hosseré Ziver, in the Mandara Mts, has also been visited, but this place is lower - only 1300 m - and cannot be included at this stage).

Mt Bana is the richest of all visited places, with 169 species (Amiet & Libert, 1995); 67 of these species had not been collected on the Cameroon Highlands before, and the total number jumped to 250, an increase of 42%. Only 36 and 32 species were recorded on Mt Kupé and Tchabal Mbabo respectively, but 14 were not on the previous list and the number of species observed at over 1800 m reaches 264.

This number may seem important, but it must be compared to what occurs in other places in Cameroon. For comparison, I chose Mt Fébé, a hill near Yaoundé, about 1000 m high. I thoroughly studied its fauna (Libert,1994) and observed 700 species there, almost three times the number found in the Cameroon Highlands.

The important gap between the two figures -264 and 700- cannot be explained by a difference in areas, since only about 8 ha have been visited on Mt Fébé (which makes the 700 figure all the more impressive), which is several orders of magnitude smaller than the area visited in the Highlands.

However, it took about 1200 hours to record the 700 species of Mt Fébé, whereas only about 120 hours have been spent in the Cameroon Highlands, which could perhaps explain the difference between the numbers of species. The evolution of the number of species observed as a function of the observation time has been studied on Mt Fébé; many curves have been drawn, and an average curve shows that it would only take about 35 hours to observe 265 species on Mt Fébé or that, in
120 hours on Mt Fébé, one could observe about 360 species, roughly one hundred more than in the Cameroon Highlands.

One may also compare the numbers of species recorded during a given lapse of time, ie 35 hours, in various places: 260-270 on Mt Fébé, about half this number, ie 130 species, on Mt Bana (the richest spot), and only 40 species in Bafut Ngemba.

So the difference in the duration of observation does not account either for the difference in the number of species observed, and it can be concluded that specific diversity on the Cameroon Highlands is significantly lower than on Mt Fébé and in other lowland places in Cameroon.

Diversity is not the main interest of the butterfly fauna of the Cameroon Highlands: this interest lies rather in its specificity, ie in the fact that some of the species found there can not be found in other, lowland, places.

Such species, found only above a given altitude are termed orophilic; we may also call them orobionts, a term forged by Amiet (1963), to designate any living organism found only on “mountains”. A species will be considered as orophilic if it is not found below 1000 m. This limit is an average altitude, based on botanical considerations, which is valid for Cameroon, although it may vary between 800 and 1200 m, according to various factors.

Practically, it can be difficult to assert the orophilic character of a given species. There may be many reasons for that, some of which are reviewed below.

This applies firstly to species known from a single high place: if no further observations are available, the species can not be considered as an orobiont. This case is exemplified by lolaphilus schultzei (Mts Alantika), Pseudathyma legeri (Obudu) and Eicochrysops sanyere (Mbam massif). But new observations have confirmed the orophilic character of Pseudacraea anneckae, also described from Obudu, and found later in the Gotel, Mbam, Lefo and Tabenken Mts, and of Liptena boei, described from Mt Tabenken and since collected on Mt Kupe (and probably in Obudu, as priscilla).

This also demonstrates that our appreciation of the orophilic character of a species can change: in 1-locality, Bibundi, at the foot of Mt Cameroon, was not considered as an orobiont. It has since been recorded on Mt Bana, Rumpi Hills and Obudu and can be considered as an orobiont since it is known that the name “Bibundi” was also used for specimens collected on the slopes of the mountain. The case of Mylothris yulei bansoana, described from ~ 1000 m, and then collected on Tchabal Mbabo and Obudu, is similar.

Another problem is that of species often found at higher altitude, but which also occur at low levels: Papilio plagiatus, sometimes considered as a “montane species”, has also been collected at about 600 m, in eastern Cameroon, far from any mountain; the cases of Tirumela formosa or Neptis ochracea are similar, and these species are not orophilic. However, some true orobionts, such as Papilio charopus or Belenois zochalia sometimes venture to low levels, but always at the foot of a mountain.

Similarly, Acraea karschi, which can be very common in most localities in the Highlands, is also found, in smaller numbers, in several forest galleries on the Adamaoua Plateau, sometimes lower than 1000 m. Since the Adamaoua Plateau itself forms part of the Cameroon Highlands, A. karschi is considered as an orobiont.
The problem is similar for *Ypthima albida*, *Bicyclus saussurei* and *Eicochrysops unigemmata*.

The situation is hardly different for another two species (*Ariadne pagenstecheri* and *Eagris lucetia*), which have been found both in the Cameroon Highlands and on various hills in the Massif of Yaoundé, (Mts Fébé, Messa & Kala). A true orobiont (*Bicyclus anisops*) has also been collected on Mt Kala, which shows that orobionts may live in this massif, and these two species are also considered as orophilic.

Systematics is also a major cause of uncertainty: the first thing one must do is to separate one’s material in to various species, identify these specialist.

Among the *Mylothris* I collected, for instance, *M. hilara* has only been identified recently, with the help of T.B. Larsen: it was previously considered as an unidentified true orobiont, since it had been collected in almost every high place, and never in lowland places; its relation with at least two close species remains uncertain. The same problem occurs with two other orophilic Pierids, which are not clearly identified.

Another aspect is that orophily can only be appreciated through a good knowledge of the lowland fauna: to say that a taxon is “not found under 1000m” implies collecting in places where it could have been found. Although collections in 200 different places in Cameroon did give me a certain knowledge of the lowland fauna, this is not always sufficient, as exemplified by *Bicyclus graueri choveti*, found on Mt Kupe; it is obviously close to *B. g. graueri*, which has only been observed in Cameroon near Foumban and Goyoum. Is *choveti* an orophilic subspecies of *graueri*, or only a western subspecies? More data is needed to answer this question, and *choveti* is not considered here as an orobiont.

The situation is different for *Euphaedra imperialis*, the distribution of which in Cameroon is better known. Three subspecies can be found in the country: the nominal subspecies, *I. imperialis*, which flies on the central Plateau, *I. gabunica*, which occurs only in the littoral plain, and *I. hecqui*, described from Mt Manengouba and then observed on Obudu Plateau and Mt Kupe, and which is most probably an orobiont.

As a result of all these difficulties, the number of orobionts can only be approximated. One can say that the orophilic character is unquestionable for 46 species, and 8 others, perhaps a few more, are probably orophilic, ie about 54 orobionts on the Cameroon Highlands. As two of them have not been found above 1800m, only about 52 orobionts have been observed in range of the Cameroon Highlands, **diversity is mainly due to non-orophilic species**: this is an interesting, and rather unexpected, result.

It is furthermore different from observations for batrachians, where almost all species found over 1800m are orophilic. This seems to be the same for birds, and butterflies could be an exception, which still awaits explanation.

As for the two orobionts which have only been observed below 1800m, they represent only 4% of the orobionts, whereas 33% of orophilic batrachians are found only in the submontane range (1000-1700m).
One is *Mylothris yulei bansoana*; the other is *Papilio rex schultzei*, known only from Mts Mandara, which are somewhat special: they are lower (~1400 m) than the rest of the Highlands, from which they are slightly isolated by the valley of Benoue river; besides, they belong to a different climatic region (Sudanian), which makes comparison more difficult. Nevertheless, *P. rex schultzei*, which fits our definition, is considered an orobiont.

The proportion of orophilic species in the fauna is variable from one place to another, ranging between 16% and 40%. The lowest value (16%) is for Mt Bana, which is the richest (169 species), whereas the highest value (40%) is for Mt Oku where fewer species have been recorded (40). This suggests that the proportion of orobionts decreases when prospecting is more intensive.

This was verified on Mt Oku: during a short visit there (less than 2 hours) the total number of species was increased from 28 to 40, while the number of orobionts only increased from 13 to 16: as a result the proportion of orobionts decreased from 46% to 40%.

This is also true for the Highlands as a whole: as explained, further collecting increased the number of species by 44%. But, during the same period, only four new orophilic species could be observed (+8%), and the proportion of orobionts decreased from 26% to 20%. Besides, three of these four new orobionts were also new to Science, which suggests that the number of orobionts will not increase much, if any, in future. As a matter of fact, during our last trip on Tchabal Mbabo, we did not add a single name to the list (though we were three people, and spent five days). This indicates that the proportion of orobionts in the fauna, even if it is low, is still overestimated.

An attempt is made below to define the relationship between Cameroonian orobionts and other African species by separation of 52 of the 54 orobionts into three groups (table 1).

**Group A** Includes 8 species found both on the Cameroon Highlands and in other parts of Africa.

**Group B** Consists of the 37 orobionts which have at least one African vicariant; this vicariant is usually a subspecies (B1: 31 taxa), which is often, but not always, found on other African mountains; it can also be a different species, which is mentioned (B2: 6 taxa).

**Group C** Comprises 7 taxa found only on the Cameroon Highlands and which have no known vicariant: for these two reasons, they are called **Cameroonian oro-endemics**. Five are close to lowland taxa found in Cameroon, which is quoted, but two are not closely related to any other species.

The limits between the groups are not always obvious: I must confess that I had to ask J. Pierre whether *Acraea karschi* was closer to *A. cabira* or to *A. viviana* (with
which it is sympatric); the answer led me to include *karschi* in group B2 (rather than in group C). Similarly, *C. tectonis* may either belong to group B1, if considered as a subspecies of *druceanus*, or to group B2, if considered as a distinct species. Arrows indicate other doubtful cases.

The following comments can be made about this table.

1) The degree of differentiation is weak or nil for most of the Cameroonian orobionts: all those from groups A (occurring elsewhere in Africa) and B1 (which can only be separated at the subspecific level), and probably several from group B2, ie at least 39 taxa, representing 75% of the orobionts. This low degree of differentiation indicates a recent isolation of these taxa.

2) The proportion of Cameroonian oro-endemics, about 13%, is low, especially when compared with other zoological groups: one third of montane forest birds and all orophilic batrachians are oro-endemics.

The influence of altitude on diversity and on the proportion of orobionts has been studied by collecting at altitudes below 1800 m in several places (the shift upwards of range limits when going north has not been taken into account).

On Mt Kupe for instance, 93 species were observed at the 1500/1600 m level, 36 at the summit; the same 14 orobionts occurred at both levels, but they represent 40% of the summit fauna, and only 15% of the 1500 m fauna.

This can be compared with Obudu (although altitude is not specified in data kindly provided by T.B. Larsen, 1500 m is the altitude of Obudu cattle ranch), where the 29 orobionts represent 16% of the 180 recorded species.

Most of the collecting on Tchabal Mbabo took place at 1700-1750m, as access to the summit was too difficult. The same three people recorded only 83 species, 18 of which are orophilic (22%).

The Kounden Plateau (which belongs to the Mt. Nkogam massif), the altitude of which is about 1300 m, was regularly visited: 70 to 75 hours of observation led to the discovery of 210 species. Although this is still much less than on Mt Fébé during the same time (~320 species), this is significantly more than in any other higher place. Not surprisingly, only 12 orobionts, about 6% were recorded in Kounden.

As expected, these results show that a decrease in altitude results both in a decrease in the number of orobionts and an increase in the number of non-orophilic species, ie a sharp decrease in the proportion of orobionts.

This conclusion is confirmed for the whole Cameroon Highlands by the cumulative number of species observed at various levels: 264 species above 1800m, 284 above 1700m, 315 above 1500m (357 including Obudu), and 377 above 1300m (410 including Obudu, 423 including Hosséré Ziver in the Mandara Mts).

One must stress that this relatively large number results from collecting over a vast area, stretching over 900 kilometres and covering extremely different climatic
zones; in spite of this, it is only about half the number of species found in the comparatively tiny massif of Yaoundé.

As a conclusion, we can say that the butterfly fauna of the Cameroon Highlands presents some similarities to the fauna of other mountains, such as an impoverishment with increasing altitude, and a parallel enrichment in orobionts. But it also presents, when compared with other zoological groups, some unique characteristics: a surprisingly low proportion of orobionts, a very low proportion of species living exclusively at medium altitudes and a low proportion of oro-endemics.

Besides, even if the ecological requirements of all orobionts are not known, one can note that most of the species of group B are open-habitat taxa and that the few species living exclusively in forest, such as B. amieti or C. alticola, are oro-endemics. This clearly supports the hypothesis that there is no need for a continuous montane forest belt across the continent to explain the present distribution of orophilic species of butterflies.

References
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<th>A tentative classification of the orobionts of Cameroon Highlands</th>
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<td><strong>Group A : 8 species found in Cameroon and in other parts of Africa</strong></td>
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<tr>
<td>Acraea oreas</td>
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<td>Ariadne pagenstecheri</td>
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<td>Anthene definita kersteini</td>
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<td>Uranothauma nubifer</td>
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<td>Eagris lucetia Nitrobalane canopus</td>
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<td>Belenois zochalia connexiva</td>
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<tr>
<td>Tuxentius margaritaceus --?--&gt;</td>
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| **Group C : 7 cameroonian oro-endemics** | **Charaxes (acum.) obudoensis --?-->** |
| **Close to a lowland species** | (druceanus) tectonis --?--> |
| Bicyclus amieti (B. analis, feae) | Neptis occidentialium batesi |
| Cymothoe alticola (C. caenis) | Antanartia dimorphica mortoni |
| Charaxes musakensis (C. eudoxus) | Issoria baumannii excelsior |
| Chondrolepis nero (C. niveicornis) | Uranothauma antoniria bamend. |
| **Close to a lowland subspecies** | Eicochrysops unigemmata sagba |
| Euphaedra imperialis hecqui | Epamera bansana bansana |
| (E. i. imperialis, i. gabunica) | Capys disjunctus bamendanus |

| **No known close species** | **Abisara neavei latifasciata rogersi ssp ?** |
| Bicyclus anisops | Metisella orientalis gamma |
| Liptena boei | medea obscura |
| cf midas malda |

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<tr>
<th><strong>B 2 : 6 orobionts with a vicariant species</strong></th>
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<tr>
<td>Acraea karschi (A. cabira)</td>
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<tr>
<td>Pseudacraea anneckae (P. acholica)</td>
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<td>Uranoth. frederikkae (U. poggei)</td>
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<tr>
<td>Argiolaus manasei (A. crawshayi)</td>
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| | **Metisella kumbona (M. tsadicus?)** |
|--------------------------------------------------|
| <-?-- Eurema cf upembana |

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<tr>
<th><strong>B B1 : 31 orobionts with a vicariant subspecies</strong></th>
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<tr>
<td>Papilio rex schultzei *</td>
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<tr>
<td>charopus charopus</td>
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<td>zoroastres zoroastres</td>
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Orobinonts not included: Belenois cf rubrosignata - Dixiea pigna ssp.
AFRICAN LEPIDOPTEROLOGY AT THE MILLENNIUM

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Abstract: Following a brief discussion of the importance of Lepidoptera in relation to human welfare and the so-called 'biodiversity crisis', an overview of our limited understanding of their diversity in the Afrotropics is presented. After 250 years, how far have we got with the task of knowing Africa's butterflies and moths? How many families and species of Lepidoptera exist within the limits of the Afrotropical Region? Given the urgent need for effective conservation planning and management, it is evident that we should make a concerted effort to assess the Lepidoptera of Africa through the catalogue-revision cycle, and make this knowledge available through new and improved field and laboratory guides. Some ways in which information technology can help with these tasks are outlined. With appropriate systems and good leadership, vital data on the distribution and biology of Africa's many thousands of butterflies and moths can be gathered and analysed on a large scale. Such a programme is fundamental to any serious attempt to ensure survival of the full diversity of African Lepidoptera, through the 21st century and beyond.

Introduction
With the world population rising by 100,000,000 each year, and estimated to reach 10 billion by 2050, it is evident that the scale of human economy has grown to a point where natural resources and the biosphere's carrying capacity are limiting factors for human welfare (Ehrlich, 1995). The global economy must move from unlimited growth to environmental sustainability (Goodland, 1995). To do this successfully will involve addressing the issue of poverty as well as over consumption, pollution and biodiversity loss (DFID, 1997).

The Convention on Biological Diversity (see Glowka et al., 1994) has three primary objectives: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the utilisation of genetic resources. For such an enterprise, the importance of a major animal group like the Lepidoptera mainly relates to the first of these goals, and in their aesthetic and educational value—even though, given our almost total ignorance of lepidopteran genetic diversity, we almost certainly underestimate their potential as a source of direct material or other economic benefit (their 'option value'). In this paper, after brief overviews of known global and Afrotropical diversity within the Lepidoptera, I go on to consider how this knowledge needs to be improved, particularly to help assess priorities for the conservation of Lepidoptera, and biodiversity in generally well-known groups, like the butterflies and moths, is probably the only effective indicator we have...
for a much wider, but much less well-known range of invertebrates, the opportunities and responsibilities of lepidopterists, both amateur and professional alike, are almost unparalleled.

Global Perspectives on The Afrotropical Lepidoptera
About 150,000 species of Lepidoptera have been named worldwide (Heppner, 1991), and it is estimated that about 50-100,000 await discovery, suggesting that as many as a quarter million species of butterflies and moths may eventually be recognised. I have accepted these round figures for discussion, even though there are many uncertainties (notably with how Heppner derived his basic figures in the first place; see comments in Scoble et al., 1995). Lepidoptera will probably end up as the fourth largest order of insects, after the Coleoptera, Hymenoptera and Diptera.

What major works on Afrotropical Lepidoptera are available?
The bibliography to the Carcasson butterfly catalogue (Ackery et al., 1995) includes over 2000 references, so one might imagine that our knowledge of the African Lepidoptera would be vast and comprehensive. On the contrary, despite nearly 250 years of work since Linnaeus' 10th Systema Naturae, information about the Lepidoptera of Africa, like so many parts of the Earth, remains fragmentary and incomplete. There is no comprehensive account. Henning (1985) gives a useful introduction for southern Africa, and other details can be found in the excellent general works of Scoble (1992), Holloway et al. (1987) and Kristensen (in press), and the outstanding regional review for Australia by Nielsen & Common (1991).

Most of the revisional works that do exist are incomplete, or have just a South African or southern African focus. Both of these limitations apply to the remarkable series by

Janse (1932-1964) on The Moths of South Africa, and to

Vári's (1961) South African Lepidoptera (of which only the first volume, on Gracilariidae, is a major work). The later index work by Vári & Kroon (1986) is alle. For moths,

Pinhey (1975) gives a good overview which includes numerous references. For butterflies, Ackery et al. (1995) provide a comprehensive way into the basic literature. For particular families, Carcasson (1967) is a good start for the Sphingidae, especially if coupled with the illustrations in d' Abrera (1986), and the new world checklist expected from Kitching & Cadiou (ms). Watson (1965) revised the African Drepanidae, Whalley (1971) the Theridiidae, and Scoble (1983) the Nepticulidae. Amongst the butterflies, Henning (1989) gives a recent and comprehensive account of the Afrotropical Charaxinae. Despite these and various other Herculean efforts, it is not possible to enumerate the known fauna from any comprehensive source. Instead, even to assess the extent of the Afrotropical Lepidoptera, we must turn to secondary sources and armchair statistics.
Total number of Afrotropical Lepidoptera

About 15% of the world's Lepidoptera are thought to occur in the Afrotropics (which I take here to include the Malagasy subregion)\(^\frac{3}{4}\) giving a total of 37,500 species if we accept the quarter-million limit suggested above, or about 22,500 based on the estimate of known species (Table 2). If we assume that most of the butterflies are now known\(^3\) or at least, when revisionary work is carried out carefully, new species are about equal in number to new synonyms, as Lees (1997) found with the Madagascan Mycalesina\(^3\) then, with a total now approaching 3700 species (based on Ackery et al., 1995), it is evident that 10% of Afrotropical Lepidoptera will prove to be butterflies, the rest moths. This percentage seems quite plausible for some other tropical faunas (J.D. Holloway, pers. comm.), but not for temperate regions: in Britain butterflies make up less than 3%, and in New Zealand the figure falls below 2%, emphasising the degree to which butterflies must be seen as a tropical group. Even in Australia, butterflies account for less than 4% of the known Lepidoptera fauna. Thus, although in terms of recognised species, butterflies comprise about 15-16% of the known Afrotropical Lepidoptera, this percentage is sure to diminish as the relatively poorly-known African moths are more fully sampled and described.

Major features of Afrotropical Lepidoptera diversity

The higher classification of the Lepidoptera at all levels, including superfamilies, remains in flux. In the near future we will receive a new benchmark, in the form of the two Handbook of Zoology volumes (Kristensen, in press), but for the purpose of this brief survey I have adopted the classification of Scoble (1992) for superfamilies, who recognised 41 (within about 12 major lineages), and Heppner (1991) for families, who recognised 121. Table 1 lists the superfamilies, of which the 31 known from the Afrotropical Region are indicated in bold. Among these, nine large family or superfamily groups for which fairly reliable data are to hand (Hepialoidea, Tineidae, Tortricidae, Pyraloidea, Geometridae, Hesperioidea, Papilionoidea, Bombycoidea, Noctuidae) make up approximately 69% of the known species of African Lepidoptera. Globally, the same nine groups account for 65% of known world species (Table 2).

Given the uncertainties, the discrepancy between 65% and 69% cannot be regarded as significant (especially as these data reflect the figures used to estimate, in round terms, that 15% of the world's known Lepidoptera occur in the Afrotropical Region). Some large groups come very close to this overall proportion (e.g., for Geometridae, Scoble et al., 1995, estimate 3106 Afrotropical species out of a world total of 21,144, or 14.7%; see also Gaston et al., 1995). However, certain groups found in Africa show significant departures from 15%, notably the Tortricidae, with only 6% representation in the Afrotropics, and the Papilionoidea, Noctuidae and Tineidae, which may be particularly rich in the African realm (Table 2). The low number of Tortricidae seems to be real, and due to relative poverty of such groups as the Archipini. Kevin Tuck (pers. comm.) estimates a final world total of 10-12,000 tortricids, with perhaps 1000 eventually known from the Afrotropics\(^\frac{3}{4}\) a modest rise to about 8-10% representation. This picture could change, however, if Africa turns out to have a large and unknown series
of species complexes in, for example, the Grapholitini, as could prove to be the case if legume seeds and pods were to be examined systematically for this potentially large and obscure tribe.

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<th>'HOMONEURA'</th>
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<th>Immoidea</th>
<th>higher DITRYSIA</th>
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<td>Micropterigoidea</td>
<td>Tischerioidea</td>
<td>Copromorphoidea</td>
<td>*Geometrioidea</td>
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<td>Agathiphagoidea</td>
<td>lower DITRYSIA</td>
<td>Schrenkensteinioidea</td>
<td>Uranioida</td>
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<td>Epermenioidea</td>
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<td>Cossoidea</td>
<td>Hyblaeoida</td>
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<td>*Tortricoida</td>
<td>Thyridoidea</td>
<td>*Papilionoidea</td>
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<td>lower HETERONEURA</td>
<td>Castnioidea</td>
<td>Pyraloidea</td>
<td>*Bombycoidea</td>
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<td>Incurvarioidea</td>
<td>Sesioidea</td>
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<td>*Noctuoidea</td>
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<td>Nepticuloidea</td>
<td>Zygaenoidea</td>
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Table 1. The 41 superfamilies of Lepidoptera, according to Scoble (1992: 187), grouped in four major grades: 8 primitive groups ('Homoneura'), 4 lower Heteroneura, 19 lower Ditrysia, and the possibly natural group of 10 superfamilies making up the 'Macrolepidoptera' or higher Ditrysia. Thirty-one superfamilies (emboldened) are recorded from the Afrotropical Region. The poverty of primitive lepidopterous groups found in the Afrotropics is striking¾even more so when it is realised that micropterigids were only recently discovered in Madagascar by David Lees (Kristensen, 1997). Nine species groups, marked by an asterisk, are dealt with in more detail in Table 2.

Of the 121 families listed by Heppner (1991), 79 (65%) are recorded from the Afrotropics. Heppner also provides some data on endemism. According to his figures, subfamily endemism is higher in the Afrotropical Region than in any of the other five Sclater-Wallace biogeographical realms (Nearctic 0.6%, Oriental 2.0%, Palaeartic 2.6%, Australian 4%, Neotropical 4.9%, Afrotropical 6.6%). These figures are questionable, however, simply because of the uncertainty surrounding the validity of many lepidopterous taxa at subfamily level (even, for example, the Pseudopontiinae, long thought to be an exceptionally distinct subfamily, may yet prove to be deeply internal to the Pieridae: de Jong et al., 1996). Ackery et al. (1995) gave a figure of 97.8% for the endemism of Afrotropical butterfly species, but found much lower endemism at higher taxonomic levels. The value drops to 8.3% at subfamily rank (2 out of 24) if the Lipteninae are accepted, or 4.2% if not (Eliot, 1990, no longer accords the Lipteninae subfamily rank, treating this major African element of the Lycaenidae as a tribe of the Old World Poritiinae), or even zero if the Pseudopontiinae were also to be downgraded.
Table 2. Representation of nine major family-groups of the Lepidoptera in the Afrotropical Region for which reasonably reliable species numbers are available. Between them these nine groups account for approximately 69% of the estimated 22,500 known species of African Lepidoptera. On a global scale these nine groups make up 65% of the estimated 150,000 known world Lepidoptera. It seems notable that the Tortricidae have only 6% global representation in the Afrotropics, whereas the Tineidae, with 27% of all known species included, may be particularly rich in the African realm. (Note: none of these figures has been adjusted to take account of land area or available habitat area, or regional taxonomic revisions; the numbers are based on Heppner (1991), Poole (1989), Scoble et al. (1995), and personal communications from Gaden Robinson, Kevin Tuck, Michael Shaffer, Malcolm Scoble, Ian Kitching, Martin Honey and Phillip Ackery.)

Despite these doubts, the Afrotropical Region does appear to be relatively rich in endemic higher taxa conventionally given family or subfamily rank, including (according to Heppner) the Prototheoridae, Apoprogonidae and Thyretidae, and one or more subfamilies within the Tineidae, Chrysopolomidae, Theridiidae, Zygaenidae, Pterothyssianidae, Drepanidae, Eupterotidae, Lasiocampidae, Lemonidae and Saturniidae, in addition to the Pseudopontiinae (and the Whalleyanidae from Madagascar: Minet, 1991). According to Heppner (1991: table 6), only the Neotropical and Australian regions approach this richness of endemic higher groupings. If this difference is real, then it could well reflect the high diversity of Afrotropical Lepidoptera coupled with a degree of isolation only exceeded by the slightly less species-rich Australian Region. However, it must be emphasised again that several of the groups listed by Heppner are doubtful; for example, the Apoprogonidae (based on the single genus Apoprogones) have been synonymised with the otherwise Neotropical Sematuridae by Minet (1986), and were evidently treated as such by Janse (1932) and others many years before.
THE STUDY OF LEPIDOPTERA: PAST, PRESENT AND FUTURE

The catalogue-revision cycle
The most important process in building up taxonomic knowledge can be characterised as the catalogue-revision cycle. After a more or less extensive period of ad hoc description of new species and the publication of regional works, this information has to be drawn together by means of an annotated checklist or catalogue (published or unpublished). Following this, a rational overview, detailing those previously described taxa as valid or invalid based on acquaintance with more material than available to earlier authors, and often describing yet further taxa, in the form of a comprehensive revision, can be undertaken. Once published, a good revision (including keys, comparative data, and comprehensive descriptions and illustrations) makes it possible to identify new or previously under worked material far more readily than before, typically leading to a second phase of ad hoc alpha taxonomic description, as further new taxa come to light. In time this leads to the need for a revised catalogue, and this paves the way for another revision, and so on. Of course, in practice these affairs rarely proceed in so orderly a fashion, but nonetheless I think this fairly describes the general way. For example, Goodger & Watson (1995) recently catalogued the Afrotropical Arctiinae, a foundation for a classic modern revision of the Afrotropical species of one of the major included genera (Häuser & Boppré, 1997, on Amerila).

Higher classifications and field guides
Nielsen & West (1994) have commented on a number of taxonomic products, including the merits of relatively cheap checklists versus expensive revisions. However, we are close to the point where, through the use of computer and Internet technology, the basic functions of the catalogue-revision cycle can be combined in one interactive, on-line system (more of this below). Two other essential parts of the study process, which currently progress, it seems to me, in a less orderly manner than the catalogue-revision cycle, involve the production and revision of higher classifications, and of field guides or other ready means for identification. Work on higher classification (e.g. Minet, 1991; de Jong et al., 1996; Heath, 1997), essentially a part of the revision cycle and often combined with it (at least at generic level), must progress if our classifications are to be natural, and therefore predictive (Nielsen & West, 1994; Vane-Wright, 1996). Equally, it is vitally important that well designed and easily used field guides (e.g. Larsen, 1991) and comprehensive laboratory guides (e.g. Holloway et al., 1987) are made available for use by specialists and non-specialists alike. Only if all these tools for the development and dissemination of taxonomic knowledge are created can we expect significant improvement on our current very limited ability to identify African Lepidoptera in a fast, precise and predictive way. Accurate identification, within the limits of current taxonomic knowledge, is fundamental for progress in all areas of our science.
Figure 1 (a-d) Stages in construction of an image of the genital valve of *Graphium ridleyanus* (White). For explanation, see text. The system employed to make this image has been developed by Synoptics Ltd, an image-analysis software company based in Cambridge, UK [see http://www.synoptics.co.uk].

Figure 2  Separate digital images of the upperside and underside of *Graphium ridleyanus*, and the male genital valve (taken from Fig. 1d), manipulated and presented together using Adobe® Photoshop.
The future is digital
One of the greatest limitations in the production of revisions and other taxonomic works, including field guides, has been the cost (both in terms of effort and monetary expense) of making and distributing a sufficient number of high-quality illustrations of genitalia, whole butterflies or moths, caterpillars, and so on. Advances in digital technology are having a profound effect on this process. Even 'conventional' revisions are being enhanced by such means (for example, the beautiful digitally-manipulated illustrations in Häuser & Boppré, 1997). But beyond this, it is now entirely feasible to capture hundreds or even thousands of high-quality images using a digital camera or scanner, enhance and manipulate these images with a desk-top computer, and then print them, still at the desk-top, to paper, to CD, or make them available on-line via the Internet. With the development of 'virtual collections' technology, within a decade it is quite likely that we will be able to access, via the world-wide-web, all 2000+ references and original descriptions listed in Ackery et al. (1995), together with everything published on African butterflies since, a continually up-dated checklist, many thousands of colour pictures illustrating type specimens, subspecies, forms, aberrations and, where known or available, living habitus, host-plant and habitat photographs, early stages, genitalia and other anatomical features, distribution maps, with a fully interactive multiple-entry key, and have the ability to post new discoveries as we make them to a responsive central 'editor' or 'curator'.

This digital vision amounts to no less than a veritable virtual library, collection and scientific society all rolled into one, with the catalogue-revision cycle compressed into a single, seamless process! To make this practical, software developments still need to be made, but these advances will come rapidly. Far more limiting will be the taxonomic capacity to locate and make the relevant images and analyses in the first place: such new technology will not speed up the laborious process of making good quality genitalia preparations, for example, or gathering the very large data matrices needed for meaningful cladistic or biogeographical analyses. Nor will it replace the experience needed to make sound taxonomic judgements. Even so, the development of virtual collections should reduce the excuse for 'unscientific naming', so lamented by Heath (1997).

Here I would like to describe in a little more detail one way in which electronic data processing can already help: producing high quality anatomical images. Even a skilled artist may have difficulty in making effective line-drawings of genitalia dissections, for example. Moreover, if many drawings are required, this can be prohibitively time-consuming and expensive. As a result, many lepidopterists have resorted to micro-photography but with only limited success because of poor depth-of-field. Digital transformation, coupled with software designed to integrate multiple images, can overcome these limitations. Figure 1 shows stages in the construction of an image of the genital valve of a male kite swallowtail, Graphium ridleyanus (White). A base image of the valve (1a) is first captured via a video camera and associated software. The microscope is then re-focused at the focal plane of various sub-organs, and at each step (1b-d) the in-focus area is selected, captured and integrated
with the original image. This is repeated until a focused image of the whole valve is built. Up to 25 layers may be used, the whole process taking less than half an hour.

Figure 3  Distribution map for Graphium ridleyanus based on data downloaded directly from the BMNH insect specimen register (solid spots), together with grid-cell records interpreted from the G. ridleyanus distribution map in Mathot, 1990 (open spots). Records from the BMNH register that located in southern and eastern Tanzania have been deleted, as has a record for Sierra Leone presented in Mathot, as these are considered to fall outside the known range (Ackery et al., 1995). If ridleyanus specimens from many of the museums holding significant collections of Afrotropical butterflies, together with a wide range of literature records, were added to a database and assessed in this way, the complete range of this insect would be far better known and interpolated data could be added on a secure basis.
In more recent versions, the software itself measures what is in focus, and what therefore to record, and stepper motors may be added to the focusing controls to automate the process further. A dedicated system, based on a good microscope, is not cheap in terms of initial investment, but in terms of quantity, quality and speed, it is very cost-effective if a large library of such illustrations is to be prepared. In Figure 2 the final image has been electronically cleaned up and presented together with two digitally scanned and manipulated images of adult *G. ridleyanus*, in a style that might be suitable for inclusion in a field guide or laboratory identification manual or to be made available on CD, or via the Internet.

**Linked databases**

More generally, various types of electronic databases need to be created as building blocks for the on-line virtual collection. These include electronic picture libraries based, in part, on the type of technology just described (for adults, eggs, larvae and pupae, male and female genitalia, androconia, setal maps, host-plants, including feeding damage and mine patterns, habitat photographs, etc.), host-plant databases (with special attention paid to source and reliability), bibliographic databases (including original descriptions and other key literature), specimen databases (referring to authenticated museum specimens, each with unique voucher numbers), and distribution databases (in which records of different types, such as range-filled, interpolated, literature-based and voucher-based data points are distinguishable, so that record sources, from geo-referenced to grid and polygon, can be clearly identified). To draw on this information for analytical and identification purposes, appropriate software is required to create and store taxonomic data matrices (taxon x character) for phylogenetic analyses and identification systems, and distributional matrices (taxon x area) for biogeographical and biodiversity analyses. For full access to all such information, it must also be admitted that the thorny issues of intellectual property rights and data ownership will have to be addressed and solved - but further consideration of these problems is beyond my task here.

Fundamental to all such databases is the creation of appropriate annotated taxonomic checklists. A primary goal for African lepidopterists could therefore be the production of fully-synonymic checklists for all regional taxa. Given an expected faunal size of up to 37,500 species, or ten times the extent of the Carcasson butterfly catalogue, this looks a rather daunting task. Furthermore, these would ideally be created as by-products from global 'life-lists' for all Lepidoptera, not as a series of isolated regional accounts. To do this in one pass would mean cataloguing up to 250,000 species seventy times the extent of the Carcasson catalogue! However, butterflies have an extra burden of names, due to the abundance subspecific and infrasubspecific taxa, so the real extent of the global Lepidoptera list might be 'only' 25-50 times the size of 'Carcasson' (which includes some 14,000 names in total). Moreover, based on the unique resource of the general card-index for Lepidoptera held in the BMNH, it has now been demonstrated that such world lists can be produced in a manageable time.
The **Global taxonomic facility of geometer moths** (Scoble, in press) documents nearly 35,000 available names, as they apply to the 21,100+ species of geometrids currently recognised, and took less than four years for the team of specialists, based around just one full-time research assistant employed for three years, to produce (Scoble, 1997). The world noctuid catalogue (Poole, 1989) is already available, and the revised world sphingid catalogue (Kitching & Cadiou, ms) will be in the near future. Other major projects exist or are in progress, so that not all of the work would have to start from scratch.

With agreement between specialists on different groups, and relatively modest funding for dedicated research assistants, it is clear that it would be practical to create the desired global list for all Lepidoptera, and to do so within a reasonable span of time. By ‘networking’ appropriately, lepidopterists throughout the world could combine their efforts to bring this about. From this could then be derived any regional or national lists, with all the advantages of

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![Figure 4 (a) Smoothed species richness for 318 species of butterflies recorded for Madagascar, based on specimen data and interpolated records collated and prepared by David Lees. The grid cells are $\frac{1}{4}^\circ \times \frac{1}{4}^\circ$, approximately 25 km x 25 km. Species richness values vary from minimum in darkest blue, increasing in sequence with the colours of the spectrum, to maximum values in red. The mid-island peak was unexpected, but seems to be real (for discussion, see Lees, 1996, 1997). 4 (b) A set of grid-cell areas chosen to include all Madagascan species in the data set, based on actual records, and achieved using as few areas as possible. Red areas are irreplacable (they contain one or more species found nowhere else in Madagascar, on the records available); the orange areas are flexible to the extent that they can be replaced, again based on the available records, by one or more other areas chosen in such a way that full representation can still be achieved. Maps and calculations by David Lees, using Williams’ WORLDMAP (http://www.nhm.ac.uk/science/projects/worldmap). Lees’ work, carried out at The Natural History Museum (BMNH) and in collaboration with Claire Kremen, has been supported by BBSRC, Leverhulme Trust, the Wildlife Conservation Society, and the Centre for Conservation Biology (Stanford).](image-url)
global consistency and relationship. To do this effectively, however, it is essential that certain minimal data standards are set and adhered to, for the production of the primary lists. Scoble's geometrid group has already addressed this issue, and it would seem sensible to build directly on their proposals. The data fields they have included as basic for the documentation for each and every name are: current genus, original genus, species name (or subspecies, or infrasubspecific), number of synonyms, name(s) of synonym(s), author, year of description, journal (or book), volume, part, page, indication if original has been checked, type depository, sex of type, type locality, collection voucher reference(s), and biogeographical area (this last field is essential if regional lists are to be derived from global accounts).

Once we have, for a given group, a suitable (ideally world-based), fully synonymic checklist for the Afrotropics, this can be used as a key-word source linking all other types of databases. As the taxonomy changes and develops with the addition of new taxa, and the synonymy or revival of old nominal taxa, this will enable all linked information to be traced. Even so, special care will be needed to deal with misidentifications, the most pernicious of all systematic errors. This means that it will be vital to ensure continuing and improving quality in the basic cataloguing system, by entrusting its maintenance to the active care of designated and widely acknowledged specialists. This will require a degree of co-operation amongst taxonomists and taxonomic institutions rarely seen. While I offer no solutions to this problem here, I believe that this goal will be achieved if there is a wider need and motivation. Botanists seem to be more advanced with such approaches, and we lepidopterists could certainly learn from their experience (but without, it has to be hoped, falling into the trap of creating a closed-shop run by a self-electing junta—a fate hardly better than total anarchy, and one easily blundered into with self-righteous zeal).

The idea of linked databases can be illustrated using the example of Graphium ridleyanus. The taxonomic position of ridleyanus, as a member of the G. angolanus group (from which it differs so strongly in shape and colour because of its mimicry for Acraea), is confirmed by the striking basal lamella of the harpe (Fig. 2), as first pointed out by Berger (1951). The known larval host-plant is Popowia (Annonaceae), as recorded by Fontaine (1985). A 1° x 1° gridded distribution map, made directly from 406 databased G. ridleyanus specimens in the BMNH, together with data points added from Mathot (1990), is presented in Figure 3. Given an enquiry about Papilio ridleyanus njami Röber, one could go to the Carcasson catalogue, confirm this was a synonym of Graphium ridleyanus (White), and then use this name to access the illustrations, host-plant data and distribution map, all from linked databases. All these specialised databases exist: the African Graphium taxonomic database with Campbell Smith, the HOSTS database of Gaden Robinson (see http://www.nhm.ac.uk/hostplants/), and the African Graphium distribution database, prepared by Jack Gilbert and other colleagues, is with the author. Even so, none of them is yet linked to an electronic version of Carcasson, nor centrally accessible, let alone directly available over the Internet. As I have already indicated, however, this is not a matter of if, but when. The apparently simple dot-map presented in Figure 3 was generated using a specialised biodiversity assessment system developed in our
Biogeography and Conservation Laboratory, by Paul Williams.  WORLDMAP is designed to operate on multiple layers like a Geographical Information System, but in this case each and every 'layer' is an identically gridded map (like Fig. 3), one for each taxon.  If a complete and reliable set of such maps were available for all African swallowtail butterflies (Mathot, 1990, offers a useful but limited start), we could then analyse the biodiversity of this 'flagship' butterfly group throughout the Afrotropics, using powerful tools implemented within WORLDMAP (see http://www.nhm.ac.uk/science/projects/worldmap).  This system has already been used to map and assess the combined distributions of all 1900+ African birds (Burgess et al., in press; Williams et al., submitted), and most African mammals (Williams et al., in press).  Lees (1996, 1997) has used this system on a ¼º grid to examine over 1000 species of animals and plants in Madagascar, including all the butterflies (Fig. 4), based on a mixture of empirical and interpolated records.  The results are already very informative.  We look forward to analysing the butterflies of the whole of Africa, together with the geometrids, sphingids and other Lepidoptera, in similar fashion.  Only by doing this will we be able to use our knowledge of the Lepidoptera in a way that appropriately reflects the millions of hours of dedicated work that has already been devoted to their study, and the continuing efforts that are being made.

A way forward
For this fantasy to happen, two vital steps must be made.  First, leadership is required to set about the process of cataloguing the Afrotropical Lepidoptera, major group by major group, to agreed standards.  This is only likely to come about effectively thorough active collaboration between African lepidopterists, amateur and professional alike.  If the ideal of deriving these catalogu to be realised, then this will also involve many other lepidopterists, worldwide.  Organisations such as the Lepidopterists' Society of Africa and ABRI are in a position to play the leading role.  If this can be achieved, then it will be possible to link existing databases, and encourage the compilation of new such databases, to all aspects of our knowledge of African Lepidoptera, through the use of this taxonomic 'spine'.  As Robert May (1990) has put it, "without taxonomy ... the house of biological science is a meaningless jumble."

The second vital step will, in my view, depend of there being an end-user who has a 'business interest' in seeing a virtual collection for Afrotropical Lepidoptera created.  Without such a focus and stimulus, only a fragmentary and slow response is likely.  A key development could be the new biodiversity project within the work plan of ICIPE (The International Centre of Insect Physiology and Ecology, Nairobi).  Entitled the Arthropod Biodiversity, Conservation and Utilisation Programme, this new project has three main research areas: biodiversity conservation, agroecosystem biodiversity, and commercial arthropods (ICIPE, 1996).  Although Lepidoptera undoubtedly have significance in all three areas (one need only think of the threat of cut worms for agriculture, and the value of mopani worms as food), it is the first of these areas, biodiversity conservation, where Lepidoptera could have the most impact, and where this ICIPE programme could have the most impact on
lepidopterists. Indeed, if the wider goals of biodiversity conservation and an ability to plan and manage our relationship to nature are to be realised, we must earnestly hope for an active collaboration between the members of the African Lepidopterists' Society, museum, field and other specialist workers beyond as well as within Africa, and the team responsible for putting this plan into action. The fact that this new ICIPE programme is to be headed for the next two years by a leading lepidopterist, Dr Scott Miller, must give us an outstanding opportunity to respond to this unique challenge for the study of African Lepidoptera now, and into the new millennium.

Acknowledgements
This paper is based on the keynote address, delivered to the Inaugural Conference on African Lepidoptera (Nairobi, 1-3 May 1997). I am grateful to Richard Bagine, Steve Collins (ABRI) and the Lepidopterists' Society of Africa for their gracious invitation. The generous support of British Airways made my participation at the meeting possible. For help with preparation of the original address and subsequent discussion Ackery, David Goodger, Kim Goodger, Jeremy Holloway, Martin Honey, Ian Kitching, Helen de Klerk, Torben Larsen, David Lees, Julia Pope, Gaden Robinson, Malcolm Scoble, Michael Shaffer, Campbell Smith, Kevin Tuck, David Vaughan and Paul Williams. From my colleagues John Lambshead and Gordon Paterson I learned something of 'virtual collections'. Figures 1 and 2 were prepared by Campbell Smith; Figure 3 was based on work by Jack Gilbert; David Lees gave permission for inclusion of Figure 4. Malcolm Scoble, David Lees and Campbell Smith kindly read a draft version of the final text, and made many valuable suggestions for improvement. To all of them I offer my heartfelt thanks.

References


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SYSTEMATIC RESEARCH ON AFROTROPICAL HETEROCERA: PAST AND PRESENT

By Martin Krüger,
Lepidoptera Department, Transvaal Museum,
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The purpose of this communication is first and foremost of a practical nature, in that it aims to provide an overview over current systematic research being conducted on the moths of the Afrotropical Region. As such the paper was intended to serve as something of a counterpoint at the launch of an institute primarily dedicated to butterfly research. At any rate I was heartened to see that several of the other delegates present had an interest in moths.

In addition, I will take a brief look at who practices taxonomy and systematics nowadays and in the past, and at the value accorded these disciplines in European and African cultures, as well as the resulting implications for conservation in an African context.

To put things into perspective, we may do well to remember at the outset that the institute whose coming into being we are marking is really concerned with three superfamilies of specialized diurnal moths out of a total of some 41 currently recognized (e.g., Scoble, 1992). These are, of course, the Neotropical Hedyloidea, the Hesperioida or Skippers and the true butterflies of the superfamily Papilionoidea.

One level above that of the superfamily, we find that systematists recognize about eight suborders (according to Vári & Kroon (1986)), these are the

1. Zeugloptera (Micropterigoidea)
2. Aglossata (Agathiphagoidea)
3. Heterobathmiina (Heterobathmioidea)
4. Dacnonypha (Eriocranioidea)
5. Neopseustina (Neopseustoidea)
6. Exoporia (Mnesarchaeoidea + Hepialoidea)
7. Heteroneura (Incurvarioidea, Nepticuloidea, Palaephatoidea, Tischerioidea)
and
8. Ditrysia.

Thirty of these 41 superfamilies fall into the eighth and largest suborder, the Ditrysia, and it is this suborder that accounts for some 98,5% of lepidopterans known. In turn, there are several major lineages within Ditrysia, and most species are contained in the Obtectomera, a group in which the pupa has lost the mobility of the first four abdominal segments. Within this clade, we find the butterflies placed somewhat tentatively on the one side between Calliduloidea and Axioidea, both groups that are absent from sub-saharan Africa, and the Geometroidea and Drepanoidea on the other side. The strong bias in the number of amateur entomologists working on
butterflies on the one hand, and moths on the other hand is, of course, a well-known fact.

Given the occasion, then, I think it is only fitting for me to begin the overview in Africa. It is biassed insofar as it is mostly comprised of entomologists who have had dealings with the Lepidoptera Department at the Transvaal Museum. Omissions are, at any rate, unintentional. Numbers in superscript refer to the addresses listed at the end of the article.

SOUTH AFRICA

H. Geertsema, University of Stellenbosch¹: Hepialidae, Zygaenidae, Megalopygidae
M. Krüger, TM, Pretoria²: Geometridae: Ennominae; Arctiidae: Lithosiinae
R. Oberprieler, PPRI, Pretoria³: Bombycoidea

KENYA

K. Maes, NMKE, Nairobi⁴: Crambidae (excl. Crambinae)

GERMANY

R. Gaedike, DEI, Eberswalde⁵: Epermeniidae
C.L. Häuser, Staatliches Museum für Naturkunde, Stuttgart⁶: Taxonomy of Amerila (Arctiidae: Arctiinae)
A. Hausmann, ZSM, München⁷: Taxonomy of the Scopula nigrinotata-complex (Geometridae: Sterrhinae)
C.M. Naumann, ZFMAK, Bonn⁸: Zygaenoidea
M. Nuß, c/o ZMHB, Berlin⁹: Systematics of Pyralidae: Scopariinae

AUSTRIA

M. Lödl, NHMW, Vienna¹⁰: Noctuidae: Hypeninae

POLAND

J. Razowski, Polish Academy of Sciences, Kraków¹¹: Tortricidae

HOLLAND

R.T.A. Schouten, Museion, Den Haag¹²: Crambidae: Crambinae
H. van der Wolf, Nuenen¹³: Coleophoridae

FRANCE

C. Gibeaux, c/o MNHN, Paris¹⁴: Pterophoridae
C. Herbulot, Paris¹⁵: Geometridae
P. Viette, formerly of MNHN¹⁶: Heterocera especially of Malagasy and the Mascareignes

ITALY

G. Baldizzone, Asti¹⁷: Coleophoridae
U. Parenti, University of Torino¹⁸: Elachistidae
G. Bassi, Museo Regionale di Scienze Naturali, Torino¹⁹: Crambidae: Crambinae
In the context of this article, note should also be taken of the following, major monographic studies conducted since 1960.

**IMPORTANT MONOGRAPHIC STUDIES SINCE 1960**

**NEPTICULIDAE**: M. J. Scoble (mostly southern Africa) (1983)

**TINEIDAE**: L. A. Gozmány & L. Vári (Afrotropical) (1973)

**GRACILLARIIDAE**: L. Vári (southern Africa) (1961)

**LIMACODIDAE**: A.J.T. Janse (southern Africa) (1964)

**THYRIDIDAE**: P.E.S. Whalley (Afrotropical) (1976)


**NOTODONTIDAE, THYRETIDAE**: S. G. Kiriakoff (Afrotropical) (1961-81).

Combining the information from the two lists, a total of 24 of the 89 families of Lepidoptera recorded from the Afrotropical Region have been revised comprehensively or in parts since 1960. While this may sound impressive given the size of the African fauna, lack of coordination between researchers has led to a very uneven distribution of their efforts, so that some large groups have not been revised since the early part of this century or indeed not at all. Cases in point are the Bombycoidea other than Sphingidae and Saturniidae, many Pyraloidea and numerous Microlepidoptera, to name but a few.
If one takes a look into the past, it soon becomes obvious that systematic research on African moths at any one time was carried by a few dedicated individuals, usually employees at the major systematic collections of the colonial powers, together with a few private individuals fortunate enough to have the means to maintain large collections and travel themselves or have collectors work for them.

In many cases, these individuals so dominated the taxonomy of a group that their names have virtually become synonymous with that taxon. For my own field of interest, the Geometridae, the names of William Warren and Louis Beethoven Prout spring to mind; for the Noctuidae, one immediately thinks of names such as Hampson, Gaede and, more recently, Berio. Among the workers who concentrated on microlepidoptera the name of Edward Meyrick still stands supreme, and so forth. There were, of course, also generalists; here the names of Walker, Guenée, Herrich-Schäffer, the Felders and others spring to mind.

Several studies have been conducted in the recent past which have looked at the number of species described per annum over the last 120 years or so. From these studies it is clear that the greatest 'taxonomic output' as far as sub-saharan Africa is concerned was achieved during the heyday of colonialism and exploration, roughly between 1860 and 1920. That this rate has since slowed should not surprise us and is probably only in part, if at all, caused by an actual decline in the number of active taxonomists. Other causes include the fact that the greatest part of the conspicuous (and thus quickly diagnosed and described) fauna has by now probably been documented and the higher demands made on the contents of taxonomic and especially systematic work today.

What is of concern, however, is that taxonomic expertise now as much as 100 years ago is concentrated in the First World, and that there are no signs of a stronger involvement from within Africa. Most practitioners of pure taxonomy, be they amateurs or professionals have been, and still are, white males. Yet, had the meeting to launch ABRI been concerned with any aspect of applied entomology, such as plant protection or control of insect vectors of disease, I am certain there would have been an appreciable number of Black delegates.

Why this discrepancy? Firstly, we need to bear in mind that the professional entomologist has only come into existence a little over a hundred years ago. Through the ages, from Aristotle to Pliny the Elder to Rösel von Rosenhof, Drury, Harris and other naturalists of the 18th century, systematic entomology was a pursuit for what has been termed "the leisured classes". Insects are eminently collectable and the pursuit of taxonomy, more than the applied sides of entomology, is essentially driven by curiosity. Taxonomy and systematics are, furthermore, collection-based disciplines. Hence, in contrast to other branches of the natural sciences, entomology had and still has a marked element of amateur involvement to it.

The lack of such involvement on the part of Africans seems to stem to some extent at least from the absence in African cultures of as sharp a distinction between work and leisure as exists in, say, Europe and the United States, and available leisure time is spent socializing rather than in pursuit of a particular activity such as a hobby that may or may not involve collecting. Does this matter? I believe it does insofar as an activity that is perceived as alien in a society is not likely to be appreciated or supported. To make matters worse for professional systematists, their work is not
likely to generate direct financial benefits or applications. Nor is it intended to: but the severe financial pressures under which many governments have to operate make it that much harder to obtain funding for basic research.

With ever-increasing human demands on the environment, the widespread view not only in Africa of taxonomy and systematics both on a professional and amateur level as an irrelevant and esoteric pastime is worrisome, as effective conservation depends on a knowledge of the biota to be conserved. In the words of the Senegalese conservationist Baba Dioum:

In the end, we will conserve only what we love;
We will love only, what we understand;
We will understand only, what we are taught.

**ADDRESSES OF TAXONOMISTS CITED**

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24 Dr. Marc Epstein, see 23.
25 Dr. Ebbe S. Nielsen, see 3.
MORPHOLOGICAL INVESTIGATION OF THE CHARAXES ETHEOCLES
(CRAMER) SPECIES GROUP (LEPIDOPTERA: NYMPHALIDAE)

By Stephen F. Henning,
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When comparing specimens we are often struck by slight differences in wing-shape, different length of antennae or tails and so on. What do these differences mean and are they significant? In this study some possible ways were investigated to try and quantify these differences and determine their significance.

The problems in identifying the black Charaxes are well known. However, often by just looking at the specimens one can see differences in wing-shape. But this is subjective and difficult to describe - they have been called more square, falcate and so on. However since there are observable differences they must be measurable and once one has measurements one should be able to assess if they were statistically significant.

Therefore a number of measurements were made of the fore-wing (fig. 1) - costal length (called fore-wing length), outer and inner margins and width of the wing from mid costa to tornus. In addition the antennae were measured so that the significance of the somewhat controversial antenna/fore-wing length ratio could be assessed. On the hind-wing only the length of the tails were measured (fig. 2).

Fig. 1 Measurements taken of fore-wing
Fig. 2 Hind-wing showing measurement of tails
As the size of the butterflies often varies, all these measurements were reduced to a number of ratios - antenna/fore-wing; outer/inner marginal length, outer/fore-wing length, inner/fore-wing length and upper/lower tail length.

A sample of 26 species and subspecies of black Charaxes were studied. This meant there were measurements of the males for 26 taxa. Some of these taxa had several female forms which were treated separately, therefore there were measurements for 43 different female forms. The number of individuals measured for each sample varied from 3 to 30 with an average of about 10.

Having carried out the various measurements and calculated the ratios, the significance of the observed differences had to be found. To do this the following basic statistical procedures were used.

- Mean or average

- The standard deviation - if an individual is chosen at random the chances are about 68% that it will belong to the part of the population lying within the range \( X \pm s \). Similarly there is a 95% chance that the individual will lie within the limits \( X \pm 2s \) (or only a 5% chance that the randomly chosen individual will be outside these limits).

- The standard error of the sample mean \( s = \text{std dev} \)
  \[ \text{sample size} \]
  \[ S = \frac{s}{\sqrt{n}} \]

- Standard error of the difference in means
  \[ Sd = \sqrt{ \left( \frac{\text{sample 1}}{n_1} \right)^2 + \left( \frac{\text{sample 2}}{n_2} \right)^2 } \]
  \[ \frac{x_2 - x_1}{Sd} \]

Then

Considered significant if exceeds twice the \( Sd \).
Table 1 shows the calculations for the males of the 26 taxa investigated. These readings are of the outer/inner marginal ratio. *C. manica* was taken as the control species and the other 25 taxa were all compared to it.

### Outer/inner marginal ratio

To determine if the difference in means between *Charaxes manica* and the other species of the *etheocles*-group is statistically significant.

<table>
<thead>
<tr>
<th>Species</th>
<th>§</th>
<th>s</th>
<th>s$</th>
<th>$d</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. manica</em></td>
<td>0.941</td>
<td>0.0192</td>
<td>0.0051</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>C. howarthi</em></td>
<td>0.950</td>
<td>0.0161</td>
<td>0.0036</td>
<td>1.5</td>
<td>NO</td>
</tr>
<tr>
<td><em>C. pseudophaeus</em></td>
<td>0.955</td>
<td>0.0136</td>
<td>0.0048</td>
<td>2.0</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. chintechi</em></td>
<td>0.956</td>
<td>0.0078</td>
<td>0.0026</td>
<td>2.6</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. zambeziensis</em></td>
<td>0.980</td>
<td>0.0000</td>
<td>0.0000</td>
<td>&gt;39</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. fulgurata</em></td>
<td>0.947</td>
<td>0.0198</td>
<td>0.0063</td>
<td>0.7</td>
<td>NO</td>
</tr>
<tr>
<td><em>C. phaeus</em></td>
<td>0.999</td>
<td>0.0025</td>
<td>0.0008</td>
<td>11.2</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. fionae</em></td>
<td>0.948</td>
<td>0.0215</td>
<td>0.0068</td>
<td>8.2</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. vansoni</em></td>
<td>0.965</td>
<td>0.0186</td>
<td>0.0052</td>
<td>3.3</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. brainei</em></td>
<td>0.972</td>
<td>0.0169</td>
<td>0.0051</td>
<td>4.3</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. diversiforma</em></td>
<td>0.966</td>
<td>0.0255</td>
<td>0.0128</td>
<td>1.8</td>
<td>NO</td>
</tr>
<tr>
<td><em>C. williami</em></td>
<td>0.965</td>
<td>0.0059</td>
<td>0.0027</td>
<td>4.1</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. variata</em></td>
<td>0.944</td>
<td>0.0146</td>
<td>0.0047</td>
<td>1.4</td>
<td>NO</td>
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<tr>
<td><em>C. loandae</em></td>
<td>0.969</td>
<td>0.0000</td>
<td>0.0000</td>
<td>&gt;28</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. viola</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>v. <em>viola</em></td>
<td>0.949</td>
<td>0.0207</td>
<td>0.0119</td>
<td>0.6</td>
<td>NO</td>
</tr>
<tr>
<td>v. <em>picta</em></td>
<td>0.961</td>
<td>0.0234</td>
<td>0.0083</td>
<td>2.1</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. kirki</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>k. <em>kirki</em></td>
<td>0.987</td>
<td>0.0140</td>
<td>0.0058</td>
<td>6.0</td>
<td>YES</td>
</tr>
<tr>
<td>k. <em>suk</em></td>
<td>0.991</td>
<td>0.0230</td>
<td>0.0090</td>
<td>5.0</td>
<td>YES</td>
</tr>
<tr>
<td>k. <em>daria</em></td>
<td>1.015</td>
<td>0.0133</td>
<td>0.0047</td>
<td>10.7</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. virilis</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>v. <em>virilis</em></td>
<td>0.973</td>
<td>0.0177</td>
<td>0.0072</td>
<td>3.6</td>
<td>YES</td>
</tr>
<tr>
<td>v. <em>lenis</em></td>
<td>0.969</td>
<td>0.0194</td>
<td>0.0069</td>
<td>3.4</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. marieps</em></td>
<td>0.979</td>
<td>0.0084</td>
<td>0.0034</td>
<td>6.2</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. karkloof</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>k. <em>karkloof</em></td>
<td>0.979</td>
<td>0.0084</td>
<td>0.0034</td>
<td>6.2</td>
<td>YES</td>
</tr>
</tbody>
</table>
Table 1. Standard error of the difference in means and significance for male outer/inner marginal ratios.

In 17 of the 25 cases (68%) there were statistically significant differences. In the females for the same species there were 31 out of 42 (74%) comparisons that were statistically significant. So this can be a very useful characteristic in separating the species of the *etheocles* group. Combining males and females together gives us a total of 48 out of 67 (72%).

Similar statistical investigations were made on the other ratios

Antenna/fore-wing ratio 40/67 or 60% showed statistically significant differences

Outer marginal/fore-wing length ratio 31/47 or 46%

Inner marginal/fore-wing length ratio 53/67 or 79%

Width of wing/fore-wing length ratio 32/67 or 48%

Upper/lower tail length ratio 40/67 or 60%.

The findings were represented graphically by using a computer statistic package (SPSS for windows Base System) which allowed the comparison of the distribution of values between several groups by plotting box and whisker plots and scatterdiagrams.

Boxplots were plotted for all the taxa under investigation. Closely related species were grouped together on each boxplot. The following are some examples (Fig. 3):
Charaxes manica Complex (Males)
Upper/Lower Tail Length Ratios
(Outliers and Extremes are not shown)

Fig. 3a
These same principles could also be applied to differences in the male and female genitalia and to the early stages.

For male genitalia, the following structures were measured - the valve length, aedeagus length, plus the length of the distal and proximal portions of the aedeagus. The ratios valve/aedeagus and proximal/distal aedeagus were compared and significant differences were found in both cases.

Scatter diagrams (figs 4 & 5) were then plotted using the means for each of the taxa. Different ratios were plotted against each other. The relationships of the various taxa could be assessed by observing how closely the readings grouped together.
Fig. 4 Scatter diagram of antenna/fore-wing length ratio against outer/inner margin ratio for the males of the *mania, phaeus, vansoni* and *viola* complexes.

Fig. 5 Scatter diagram of antenna/fore-wing length ratio against outer margin/fore-wing length ratio for the males of the *mania, phaeus, vansoni* and *viola* complexes

**Proximal/distal aedeagus ratio**
To determine if the difference in means between *Charaxes manica* and the other species of the *etheocles*-group is statistically significant in the female genitalia the following structures were measured the length of the signa, corpus, ductus, plus the length of the membranous and sclerotized portions of the ductus. The ratios signa/corpus length, ductus/corpus length and membranous/sclerotized ductus ratios were then compared and significant differences were found for all cases.
<table>
<thead>
<tr>
<th>Species</th>
<th>§</th>
<th>s</th>
<th>s§</th>
<th>sd</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. manica</em></td>
<td>1,000</td>
<td>0,0014</td>
<td>0,0010</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>C. howarthi</em></td>
<td>0,981</td>
<td>0,00008</td>
<td>0,00004</td>
<td>19,0</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. pseudophaeus</em></td>
<td>0,957</td>
<td>0,0058</td>
<td>0,0030</td>
<td>13,9</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. chintechi</em></td>
<td>1,000</td>
<td>0,0000</td>
<td>0,0000</td>
<td>00,0</td>
<td>NO</td>
</tr>
<tr>
<td><em>C. phaeus</em></td>
<td>1,100</td>
<td>0,0239</td>
<td>0,0090</td>
<td>11,0</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. fionae</em></td>
<td>1,090</td>
<td>0,0085</td>
<td>0,0038</td>
<td>23,1</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. vansoni</em></td>
<td>1,043</td>
<td>0,0044</td>
<td>0,0020</td>
<td>19,6</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. brainei</em></td>
<td>1,184</td>
<td>0,0045</td>
<td>0,0026</td>
<td>65,7</td>
<td>YES</td>
</tr>
</tbody>
</table>

Table 2. Standard error of the difference in means and significance for proximal/distal aedeagus ratios.

**Signa/corpus length ratio**

To determine if the difference in means between *Charaxes manica* and the other species of the *etheocles*-group is statistically significant

<table>
<thead>
<tr>
<th>Species</th>
<th>§</th>
<th>s</th>
<th>s§</th>
<th>sd</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. manica</em></td>
<td>0,585</td>
<td>0,0091</td>
<td>0,0052</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>C. howarthi</em></td>
<td>0,786</td>
<td>0,0070</td>
<td>0,0041</td>
<td>30,5</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. pseudophaeus</em></td>
<td>0,689</td>
<td>0,0433</td>
<td>0,0250</td>
<td>4,1</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. chintechi</em></td>
<td>0,804</td>
<td>0,0165</td>
<td>0,0095</td>
<td>20,3</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. phaeus</em></td>
<td>0,618</td>
<td>0,0110</td>
<td>0,0064</td>
<td>4,0</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. fionae</em></td>
<td>0,800</td>
<td>0,0060</td>
<td>0,0035</td>
<td>34,1</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. vansoni</em></td>
<td>0,667</td>
<td>0,0028</td>
<td>0,0016</td>
<td>15,2</td>
<td>YES</td>
</tr>
<tr>
<td><em>C. brainei</em></td>
<td>0,740</td>
<td>0,0059</td>
<td>0,0034</td>
<td>25,0</td>
<td>YES</td>
</tr>
</tbody>
</table>

Table 3. Standard error of the difference in means and significance for signa/corpus length ratio.

Fig. 6 *Charaxes* head showing measurements taken
Scatter diagrams for the genitalia were then drawn by plotting the ratios against each other.

Finally the heads of Charaxes larvae were investigated. The length of the dorsal and lateral horns and the diameter of the facial disc were measured (Fig. 6). Ratios for dorsal horns/facial disc and lateral/dorsal horns were then calculated. There were significant differences found between the dorsal horn/facial disc diameter ratios but not between the lateral/dorsal horn ratio.

**Dorsal horn length/facial disc diameter ratio**
To determine if the difference in means between Charaxes manica and the other species of the *etheocles*-group is statistically significant

<table>
<thead>
<tr>
<th>Species</th>
<th>§</th>
<th>s</th>
<th>s§</th>
<th>Sd</th>
<th>Significance</th>
</tr>
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<tbody>
<tr>
<td>C. manica</td>
<td>0,5838</td>
<td>0,0229</td>
<td>0,0132</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. howarthi</td>
<td>0,6128</td>
<td>0,9233</td>
<td>0,4129</td>
<td>0,1</td>
<td>NO</td>
</tr>
<tr>
<td>C. pseudophaeus</td>
<td>0,6000</td>
<td>0,0000</td>
<td>0,0000</td>
<td>&gt;162</td>
<td>YES</td>
</tr>
<tr>
<td>C. chintechi</td>
<td>0,7371</td>
<td>0,2678</td>
<td>0,1546</td>
<td>1,0</td>
<td>YES</td>
</tr>
<tr>
<td>C. phaeus</td>
<td>0,6905</td>
<td>0,2755</td>
<td>0,1041</td>
<td>1,0</td>
<td>NO</td>
</tr>
<tr>
<td>C. fionae</td>
<td>0,7382</td>
<td>0,1791</td>
<td>0,0633</td>
<td>2,4</td>
<td>YES</td>
</tr>
<tr>
<td>C. vansoni</td>
<td>0,9410</td>
<td>0,1342</td>
<td>0,0548</td>
<td>6,3</td>
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<tr>
<td>C. brainei</td>
<td>0,9378</td>
<td>0,3975</td>
<td>0,1778</td>
<td>2,0</td>
<td>YES</td>
</tr>
</tbody>
</table>

Table 4. Standard error of the difference in means and significance for dorsal horn length/facial disc diameter ratio.

Scatter diagrams of the larval head ratio were then plotted against each other.

**Conclusion**
Thus it appears that the ratios investigated in this study can be taxonomically important both singly or in combination with others. These ratios could be most useful in separating species that are morphologically quite similar.

**References**
HENNING, S.F. 1996. Revision of the Charaxes *etheocles* (Cramer) species group (Nymphalidae: Charaxinae) in the Afrotropical Region. Thesis submitted in fulfillment of the requirements for the degree of Philosophiae Doctor in the Faculty of Science, Potchefstroom University for CHE.
GONDWANAN BUTTERFLIES: THE AFRICA-SOUTH AMERICA CONNECTION

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Abstract: The Mesozoic history of Africa and other Gondwanan landmasses is briefly related, as is the early history of Lepidoptera. The meagre fossil record of the latter is compared with the better documented vertebrate record. Sister-group analysis suggests a Gondwanan genesis for butterflies, and illustrations are given of contemporary genera. Pantropical genera are discussed, and Borbo and Panoquina are suggested as possible synonyms.

Key Words: Aeropetes, Africa, Antarctica, Archimenstra, Asia, Australia, biogeography, Brephidium, Celaenorrhinus, dinosaurs, Eunica, Hesperiidae, India, Leptotes, Madagascar, Manataria, Neptidopsis, Nymphalidae, Oraidiun, Pangaea, Paralethe, Sallya, Satyridae, South America.

The world of yesterday was a far different place than it is today, because the landmasses were aligned differently. As a consequence of recent re-evaluation, the time frames for evolution have been further refined than classical palaeontology would have suggested 25-50 years ago. The fossil record, while incomplete, provides enough data to intelligently extrapolate about groups of organisms that do not have an adequate fossil record to give direct evidence. Comparisons of extant butterfly faunas, which have virtually no fossil records, with sympatric groups that are well represented by fossils are highly informative. Subsequent sister-group analysis can lead us into concepts about evolution and biogeography that were unthinkable half a century ago.

If the geological and fossil records show us anything, it could be that butterflies are far more ancient than previously believed. In prior days, the emphasis was placed on evolution and biogeography of these insects in the Tertiary epoch, at the earliest, and particularly on events during the Pleistocene. This is the view that is stressed in the excellent discussion of African butterfly distributions in the recent Carcasson African butterfly volume (Ackery, et al. 1995), and in most cases the emphasis on the later geological epochs is perfectly reasonable. But, and this is rather a large "but", the Tertiary cannot account for ALL affinities in the African rhopaloceran fauna. Perhaps 1% of the butterflies are apparently of much older lineages than we have previously imagined.

We do not discount the fact that many of today's cosmopolitan or nearly cosmopolitan insects have dispersed over wide distances: clearly such is the case with Danaus plexippus (Linnaeus), Vanessa cardui (Linnaeus) and V. atalanta (Linnaeus), to name a few. We suspect that the presence of the Old World Hypolimnas misippus (Linnaeus) in the New World is a matter of its having dispersed from Africa to South America in much the same way that the cattle egret made its way to Brasil 60-70 years ago and has become widespread throughout the
Neotropics. Simple dispersal, however, cannot account for the occurrence of some of the butterfly sister-group taxa in the Neotropical and Afro-tropical regions, as will be discussed below.

It is necessary to establish a minimum age for the Lepidoptera and to extrapolate from the ages of the extant fossils to groups unrepresented in the fossil record. The reason we state "minimum" is that logically the oldest fossil recorded almost certainly is not the oldest lepidopteran. The chance of the first specimen being fossilized is so remote as to not warrant consideration. Whalley (1986) summarized evidence of the earliest fossil lepidopterans, listing an undoubted one in Jurassic amber from Lebanon, but suggested that earlier possible lepidopterans included those from the South African Molteno formation (Anderson & Anderson 1984) of upper Triassic age (about 200 million years old) in South Africa and other contemporaneous insects from Russian and Australian strata. As indicated by White (1990), these presumed lepidopterans must have been pre-Gondwanan, and therefore were Pangaean in nature. Whalley (1986: 268) states unequivocally that the Lepidoptera were present in both northern and southern hemispheres before the breakup of Pangaea at roughly the Triassic-Jurassic boundary (180 million years ago).

What did the world look like in the late Triassic and early Jurassic periods? To obtain the answers to these questions, one must look to the specialists in paleomagnetism. This science involves examining the orientation of ferrous metal crystals (magnetite) in ancient rocks. The metal grains will orient according to relative position of the rock and the earth's magnetic pole was when the rock was formed, and since these inclusions cannot move after the rock lithifies, the original orientation of the magnetite granules is preserved. Paleomagnetic data also can tell us the latitude and longitude of our area in question at the time of the rock's formation. When enough rocks of the same age in different areas are sampled, we can obtain an idea of the relative positions of continents and islands in the distant past. Figure 1 illustrates the best available paleogeographic reconstruction for the early Cretaceous, 120-135 million years before present (mybp), when early Lepidoptera were present. Note that all of the continents were aggregated into a supercontinent called Pangaea, though it was almost completely sundered (Smith, et al. 1981). The presence of a single landmass before the Cretaceous, coupled with the relatively equable climate that paleoclimatologists tell us prevailed would indicate that the species composition of most areas would be similar. Indeed, we find that this was true based on studies of dinosaurs and other fossils. Dinosaurs had not become so regionalised during the Triassic and early Jurassic as they were in the Cretaceous, and there was not the dichotomy shown by northern and southern hemispheric species and genera (Sereno, et al. 1996). By extrapolation, primitive Lepidoptera were also present on Pangaea.

Does this imply that we think that butterflies were present during the Triassic or the Jurassic? Of course it does not, but their progenitors WERE present on Pangaea, as stated above, and this sets the stage for the further evolution of the Rhopalocera.
Figure 1: Reconstruction of Gondwana, 135 mybp. AF = Africa; AN = Antarctica; AR = Arabian peninsula; AS = Asia; AU = Australia; IN = Indian subcontinent; IR = Iran; M = Madagascar; NG = New Guinea; NZ = New Zealand; SA = South America; SEA = southeast Asia; TI = Tibet; TU = Turkey (modified from White 1990).
As Pangaea finally was divided by the Tethys Sea into the southern continent, Gondwana, and the northern one, Laurasia, the outlines of landmasses were markedly changed. We know that Gondwana was comprised largely of South America, Australia, Africa and Antarctica, but in some respects the "minor players" in the formation of Gondwana are of great importance in evolution. Madagascar was accreted to Africa early on, and attached to it was the Indian subcontinent. Furthermore, the Arabian peninsula, Iran and Iraq were part of the horn of Africa. These minor players became very important in transporting Gondwanan faunal elements to Laurasia in the early Tertiary, as we shall see.

These northern and southern continents evolved very different animals and plants from one another. There now were two faunas where a single, more or less uniform one had existed previously. So there were Laurasian dinosaurs, such as Apatosaurus, and Gondwanan ones, such as Brachiosaurus existing simultaneously, but geographically separated. The study of Gondwanan dinosaurs is one of the more exciting paleontological investigations that are currently being undertaken, and, as expected, the number of dinosaur species has nearly doubled over the past decade. Other organisms evolved in relative isolation during the mid- to late Mesozoic as well, and it is not logical to believe that the Lepidoptera would have stagnated. In fact, we are not persuaded that the butterflies, with the possible anomalous exception of the Papilionidae, arose anywhere but on Gondwana, while other groups of lepidopterans must have evolved on Laurasia. The fossil evidence, meagre as it may be, tends to support such a supposition: the supposed fossil noctuid egg of Cretaceous age from North America (Gall & Tiffney, 1983) suggests a Laurasian genesis for that superfamily.

Gondwana persisted through the Jurassic, but it began to break apart in the Cretaceous with the first break being between South America and Africa happening about 135 million ybp. This breach of Gondwana was followed about 40 million years later by separation of India from Madagascar and the rapid northward movement of the former to its eventual accretion to the Eurasian continent about 50 million years ago. Note also that South America, Antarctica and Australia along with some satellites remained connected into the Tertiary (Figure 2). Now one should not think of this as an inhospitable land: the coalescence of Antarctica and the other continents allowed all to be bathed with warm waters (Hallam 1981; Hays & Pittman 1973). We know Cretaceous and early Tertiary coals formed along the Antarctic coast, and these contain fossils of the southern beech, Nothofagus, a genus of tree that today survives in southern South America, New Zealand, Australia and the mountains of New Guinea. Was this Antarctic corridor important to lepidopteran distributions and those of other insects? Indeed this is the case with satyrids (L Miller, in prep), castniid moths (J Miller in prep) and chironomid midges (Diptera, Brundin 1966), but space precludes a further discussion here.

This slow dance of the continents continued, with continents separating from each other and accreting to different landmasses, a process that is still ongoing today. One need note where the great earthquakes occur to know the locations of significant tectonic movements. Here is when the first deductive argument for the antiquity of butterflies comes into play.
Figure 2: Reconstruction of the southern hemisphere in late Cretaceous time about 70 mybp. Note the separation of Africa from the rest of Gondwana and the continuing accretion of South America, Australia, New Zealand and Antarctica. Abbreviations as in Figure 1 (modified from Smith, et al. 1981).
Sister-group analysis must be employed to support much of the remainder of the hypothesis. In the senior author's (Miller 1968) treatment of the Satyridae, the most primitive members of the tribe Parargini he considered (as Lethini, a junior synonym) are the southern African Aeropetes-section, comprised of the genera Aeropetes Billberg and Paralethe van Son with no apparent close relatives. At the same time, the Neotropical genus Manataria Hübner was placed as a genus of uncertain affinity because it was so far removed geographically from any other parargine. Thanks to the growing acceptance of plate tectonics, L Miller reexamined the three genera structurally as well as superficially and found them to be much more closely allied to one another than to any other satyrid genera (Figure 3). Their genitalia are similar and different from those of other parargines, as are legs, wing patterns and venation. Therefore, we must conclude that they had a common ancestor that lived presumably when South America and Africa were in at least close proximity, and this places the time of the common ancestor as some time in the Cretaceous. Have we any fossils to prove this? No, but what other explanation is logical concerning such a non-vagile group's spread to two continents without leaving so much as a trace behind?

A similar distributional pattern exists in the "Blues" (Lycaenidae: Polyommatinae) where one genus, Brephidium Scudder, is represented in both hemispheres and its sister genus, Oraidium Bethune-Baker is represented in southern Africa. All are halophiles and feed on Chenopodiaceae as larvae. Again, these butterflies are not vagile and their intercontinental dispersal is highly unlikely.

Consider the nymphalid pair, the African genus Neptidopsis Aurivillius and the Hispaniolan Archimestra Munroe (Figure 4), as discussed by Miller & Miller (1989). The fact that no intervening populations exist between these two genera is puzzling: we do not believe that they were isolated or even extant in the Jurassic, but we also cannot accept that these relatively sedentary butterflies could have flown to or from Hispaniola over water recently. Nevertheless, the relationship is clear.

It is of some interest to note here that these wholly African-Neotropical genera are few in number and not at all speciose: Aeropetes, Paralethe, Oraidium, and Archimestra are all monobasic, Neptidopsis has but two species and Brephidium and Manataria have three species each. This precisely fits the definition of a relict group of organisms, very primitive animals with few species and limited distributions, far from their closest relatives. These are truly living fossils in the best sense of the term. Note here that these disjunct butterfly distributions include groups thought to be highly evolved, the Nymphalidae, Satyridae and Lycaenidae, rather than the more likely primitive groups, such as the Pieridae. It is further of interest that most of the Tertiary fossil butterflies also represent "advanced" butterflies, rather than "primitive" ones. Does this imply that our placement of groups is flawed, or does it further hint at the antiquity of the butterfly families? We are convinced that the latter explanation is correct, and that all of the families, or their progenitors, were present on Gondwana during the Cretaceous.
Figure 3: Primitive paragine Satyridae: top left, *Manataria hercyna* (Hübner), Brasil; top right, *Paralethe dendrophilus* (Trimen), southern Africa; bottom, *Aeropetes tulbagha* (Linnaeus), South Africa. (line = 1 cm)
A nearly identical distributional pattern involves a sister-group relationship between the Neotropical *Eunica* Hübner and the afro-tropical *Sallya* Hemming (Figure 5). These genera have been considered congeneric by some authors (Fox 1964), but most maintain them as separate. *Sallya* has a Madagascan species, which is not surprising given the proximity of that island and the African mainland. Another factor enters into the equation for these animals: a few *Eunica* are very good dispersalists, and at least one is a migratory species. We conclude that the dispersal of *Sallya-Eunica* was of a different nature than that of the sedentary beasts mentioned previously. Note the groups under discussion are two (or one) very speciose genera, and the observed distributions are not those of relict animals.

Now, we are not ascribing as much importance to the few pantropical genera of butterflies, and their relationships seem rather obscure. The hesperiid genus *Celaenorrhinus* Hübner is one of the best documented of these. Specimens from Africa bear close resemblance and relationship to that from Madagascar but is less reminiscent of the Indo-Malayan or Neotropical representatives. This is about what one would expect based on the proximities of the separate landmasses. Nonetheless, we suspect that the history of the group involves African-South American proximity and migration in the latest Cretaceous or earliest Tertiary. The similar approximation of Madagascar and India to Africa in the late Cretaceous and the relatively speedy passage of the Indian subcontinent from its prior position near Madagascar to its final accretion to the Eurasian plate in the Eocene is also important. From there it was dispersal over Laurasia and into Indonesia during the Tertiary that resulted in today's distributional patterns. Another group with a very similar distributional pattern is the lycaenid genus *Leptotes* Scudder.

A final Paleotropical genus that we would like to discuss is the hesperiid, *Borbo* Evans (Figure 6). Structurally, it is virtually indistinguishable from the New World genus *Panoquina* Hemming. Should this suggested synonymy be proven, *Panoquina* Hemming has priority over *Borbo* Evans and would supplant it.

In summary, we have encapsulated some of the geological and tectonic evidence for the mobility of continents that alternately established and obliterated barriers to the interbreeding of insect populations. Fossil evidence has been summarized for the evolution of contemporary groups, and these suggest the possible courses of evolution of groups without an adequate fossil record. Sister-group analysis shows that tectonic events must have affected the distribution and evolution of these organisms in space and time.
Figure 5: Sallya and Eunica species; left, *E. margarita* (Godart), Brasil; centre, *S. consors* (Rothschild & Jordan), Africa; right, *S. madagascariensis* (Boisduval), Madagascar. (line = 1 cm)
Figure 6: *Panoquina* and *Borbo* species: top left, *P. ocola* (W. H. Edwards), South America; top right, *B. borbonica* (Boisduval), Africa; bottom left, *B. ratek* (Boisduval), Madagascar; bottom right, *B. impar tetragraphus* (Mabille), New Guinea. (line = 1 cm)

References
African Butterfly Research Institute

By S.C. Collins,
P.O. Box 14308, Nairobi, Kenya.

Introduction to (A.B.R.I)
Established in 1996. Its aim is to facilitate the study of African butterflies and their life histories, and to act as a coordination link point for people across the continent and elsewhere in the world.

The institute is privately funded and is actively looking for corporate sponsors. Unlike many national institutions it remains slim, flexible and dynamic.

Update:
Since May 97. A questionnaire was developed as a result of the conference, see copy, anybody who has not filled it in would be welcome to photocopy and send to ABRI; as they will be included in future database and mailing list of interested parties on African Lepidoptera.

General Public Awareness
A public display area is to be established for educational purposes.
Lectures will be available to the general public.
There will be a live flying house.

Update
The Education Centre has been established at ABRI. It has displays related to the national school curriculum that can be incorporated for practical school outings. It will be opened together with the flying house which has had the architects drawings, and it is now in for submission for financial support. The botanical section is being developed with IUCN (International Union Conservation Nature) support. Meantime a continual stream of scientists and interested general public visit the collections, flying house and breeding areas.

Scientific Research
Consolidated collections of material put together by associates of ABRI are available for serious students of African Rhopalocera.
Research facilities for the study of Molecular Biology, Genetics to be developed, Systematics & Life History.
Staff and facilities include Collection Manager, Preparators, Computer Data Base, Good Reference Library.

Update
Curation continues with Incorporation of the Heath Zambian material, Kielland Tanzanian material. The Mijburgh collection has recently been acquired and the generous donation of the Ruth Southey collection by Jonathan Ball is in hand.
I. Financing proposals for the database programme, a 3-year programme coordinated by ICIPE (International Centre of Insect Physiology & Ecology) with an outside expert coming to Kenya for that period to oversee project. Project + finance proposal are at donor level. Initiation expected 1stQ 1998.

II. A proposal for molecular biology/genetical research has been submitted by the BMNH London and Royal College of Sciences on Genetics of African Papilio: the work will be carried out from ABRI and is expected to start in 1998.

III. The Library continues to expand with acquisitions of a complete set of the proceedings of the Allyn Museum, and donations from the Library of the late G.R. Van Someren (VGL’s son) and a complete set of Gowan Clark. Early stage illustrations generously donated by Dr. J. Ball.

IV. Coordination

V. People working in field in Kenya, Tanzania, Central African Republic, Cameroon & West Africa.

Update

VI. Ist Conference of African Lepidoptera 1-8 May 1997, Nairobi - coordination

VII. Many demands for information from scientists wishing to acquire material live or dead: ABRI endeavours to put suitable collaborators in direct contact.

VIII. Material has come in from Tanzania, Kenya, RSA, RCA, Cameroon, Ghana, Senegal, and Guinea Conakry since May.

IX. Agreements are in place to supply surplus material to Transvaal Museum - Pretoria, Allyn Museum - Florida, and Tervuren Museum - Belgium who have undertaken to process material thereby broadening database.

Breeding Work

X. Breeding programmes of new life histories, and surplus pupae for flying houses elsewhere in the world.

XI. Botanical Host-plant nurseries Nairobi, Kakamega (in Western Kenya), and Shimba Hills (Coast).

Update

XII. Continues to expand, we have recently been nursing Dr. Alan Gardiner’s Ethiopian material, whilst he continues fieldwork in Burkina Faso.

Consultancies

XIII. ABRI will undertake Biodiversity Studies of different environmental areas on request, supplying staff and results analysis.

Update

XIV. Input into the East African Coastal Forest Diversity book published by IUCN, Chapter on butterflies.
XV. We have material identification programmes going on for Frontier Tanzania, Usungwa Arc (Tanzania) Programme meeting December 97. Displays prepared for various institutes in Kenya.

XVI. Botanical butterfly/plant relationships lists developed in conjunction with Ivan Bampton for the Nairobi Arboretum.

XVII. Information provided to several universities as to locations and timing for specific material.

Publications

XVIII. ABRI will help support scientific publications until such time as there is capability for own in-house journal, also to stock current books on African Rhopalocera.

Update


XX. One of the main objectives has been the publication of the J. Kielland’s Supplement to the Butterflies of Tanzania: this is in press and is expected December ’97 - January ’98.

XXI. Support the checklist to the Butterflies of Zambia which is in its final stages.

XXII. Publications of various journals in Belgium, France and Lep. Society of Africa with Dr. Larsen, Prof. Libert, Th. Bouyer, Dr Miller in conjunction with ABRI are currently ongoing.

XXIII. ABRI web page in planning stages linked to other institutions with similar interest.

XXIV. A review of the status, progress and future direction of the institute is made.

1998 Objectives:

XXV. Initiate Database and Molecular Biology programmes

XXVI. Open education centre, flying house and entomological shop to public

XXVII. Have curator, collections manager installed in Nairobi

XXVIII. Continue publications and find support to B. D’Abrera’s Afrotropical parts II & III

XXIX. Develop functional East African arm of Lepidopterists’ Society of Africa

XXX. Plan and support 2nd African Lepidoptera Symposium, R.S.A. 1999

XXXI. Fieldwork: Tanzania, Zambia, Guinea Conakry, Cameroon, Ethiopia

XXXII. Expand ABRI buildings with further collection space, computer room and laboratory.
AN EXAMPLE OF ANT/CATERPILLAR COMPETITION BETWEEN THE ANT
HOST OF BARTERIA FISTULOSA (PASSIFLORACEAE), TETRAPONERA
AETHIOPS (PSEUDOMYRMECINAE), AND TINTHIA LAMBORNELLA
(SESIIDAE)

By Thierry Bouyer,
57 rue Genot, B-4032 Chênée, Belgium.

Barteria fistulosa (Passifloraceae) is a myrmecophyte associated with the ant
Tetraponera aethiops (Pseudomyrmecinae). The ant, housed in hollow horizontal
stems, colonises the whole tree when the colony is fully developed. It is extremely
aggressive and protects the plant against any external invader plants (particularly the
creepers) or defoliators. Despite the fact that the plant synthesizes alkaloids, some
insects feed on the foliage, especially caterpillars of Acraea sp (Nymphalidae). But
two other insects, a Curculionidae beetle and the caterpillars of Tinthia lambornella
(Sesiidae) feed on the pith of young trees, and are then in competition against the
ants foundations.

Just after fertilisation, the ant queen takes to the wing to find a host-plant that is
not yet externally colonised. After landing on the plant, she begins to inspect the plant
to find an unoccupied portion of the branch to burrow into. When she is inside, the
hole closes, and after some days she is able to begin laying. The first brood doesn’t
go out immediately but starts to nurse the queen for preparing the following broods.
The ants live inside the hollow stems, which are then called domatia, and a mature
colony is formed by the queen, the brood and the workers. The colonisation usually
begins with many queens but only one survives on each tree.

The branches of young trees can then be occupied by ants and larvae of
Curculionidae or Sesiidae that are in competition during the time when ant
foundations are not sufficiently developed to protect the plant.

In the laboratory, workers or queens of T. aethiops always killed caterpillars. But
in nature, sometimes dead queens and/or workers are found together with living
caterpillars in the same room. In the hypothesis where ants were in the room before
the caterpillars we tried to understand how the caterpillar is able to kill the ant. We
discovered that fresh pieces of foliage or stem released a volatile toxin that kill ants
and other kind of insects. We then made the hypothesis, non verified, that the
A caterpillar is able to release this toxin inside the room by gnawing the stem and then uses a chemical way to kill the ants.

THE STUDY OF THE EARLY STAGES OF AFRICAN LEPIDOPTERA:
ENVIRONMENTAL AND SYSTEMATICS CONSIDERATIONS

By Colin Congdon & Ivan Bampton,
ABRI, P.O. Box 14308, Nairobi, Kenya.

Abstract: The researchers are engaged in discovering and recording the life histories of butterflies. The environmental impact of their work is discussed, and its contribution to conservation efforts assessed. The value of the early stages of butterflies in taxonomy is considered. Some butterfly life histories are discussed, giving examples of the discovery of new butterfly and plant species, and of the relationships between the groups of butterflies.

Introduction
Ivan Bampton needs no introduction to anyone connected with butterflies in Eastern, Central and Southern Africa, where he has been working on butterflies for nearly 30 years. Undoubtedly our most experienced expert in the early stages of African butterflies, he has covered Africa from east to west and north to south.

Colin Congdon joined him in 1993 at Steve Collin’s suggestion when it became clear that they shared a common approach and were in danger of duplicating efforts.

Background
The researchers seek to discover and record the life histories of butterflies. They work as a team. There is a lot of synergy, and neither would be as effective on his own.

Bampton has an excellent working knowledge of both butterflies and the plants on which the majority of them depend, as well as incomparable experience of raising the early stages.

Congdon shares this work, does the photography, deals with the paperwork, and uses contacts with the Herbarium, Royal Botanical Gardens, Kew to get difficult plants identified.

The researchers have developed skills in knowing what to expect, where to look and what to look for. The research is environmentally acceptable, and of genuine scientific interest.

Environmental effect
Most people start by just collecting butterflies, and this is still important in adding to our knowledge of them. But it is suggested that simply collecting butterflies in order to possess them can no longer be justified in these days of increased environmental awareness. In their early stages. In practice this probably has little overall effect. Only in very exceptional circumstances is collecting likely to have a long term detrimental effect on populations, and the research team are well qualified to recognise these circumstances when they are encountered. On the other hand, remote habitats are visited, findings regularly reported, and warnings sounded where necessary. By using butterflies as informal indicators of biodiversity, the team helps to prioritise conservation efforts.

It is therefore concluded that on balance the environmental impact of their research is beneficial.

Scientific value
The researchers discover life histories of butterflies, which can lead to new species of butterflies, and also to new species of plants.

Fresh specimens of butterflies are obtained by breeding, which can be useful in separating closely related species. Perhaps more importantly, light is shed on butterfly taxonomy through a study of early stages, providing a fourth criterion for classification, in addition to wing venation, external appearance, and the structure of the genitalia of the adult butterfly.

The research may help to elucidate butterfly and plant taxonomy through the food preferences of groups of butterflies for groups of plants. For example Mylothris and Iolaini on Viscaceae, Loranthaceae and Olacaceae - (Ximenia) and Santalaceae - (Osyris).

Examples of life histories
Photographic slides were shown to illustrate particular points.

Charaxes
- **berkeleyi** ) Members of the difficult black Charaxes group. Ch. fionae
  - **chintechi** ) larvae are notably different from the others.
  - **congdoni** )
  - **fionae** )
  - **howarthi** )

Cymothoe
- **aurivillii** - One of the group on Rawsonia (Flacourtiaccac)
- **egesta** - a species on Rhinorea (Violaceae). Reference the recent work of Prof Jean-Louis Amiet on Cymothoe in Cameroon.

The host-plants look remarkably alike.
Iolaini
Some 51 spp. of Iolaini have been recorded in Tanzania, of which the life histories of 39 have been recorded, being over 75%.

- *Epamera australis* - On heavy leafed host-plants (*Vanwykia*, etc.). Also on *Helixanthera tetrapartila* (Loranthaceae).
- *E. stenogrammica* - These species have heavy, dark larvae, although their relationship may not necessarily be very close.

- *Etsiolaus catori* - also dark, but on *Manilkara* and *Pachystela* (Sapotaceae) in Kigoma and Bukoba. It has recently been reported that Alan Gardiner has raised this species on *Loranthus*. This is possibly the basic *Epamera* larva shape, which the next group discussed have largely lost. All three feed on *Plico sepalus* (Loranthaceae).
- *E. mimosa* - The general similarity of both larvae and adult butterflies should be noted. The eggs of *E. jacksoni* are often laid one on top of another on the tips of soft leaves of the host-plant.
- *E. congdoni* - Species with fleshy projections from the caudal segments. The cryptic pupa of *E. congdoni* was noted. The first two species were discovered as a result of raising larvae found in the wild. The larva of *E. pollux* are close to those of *E. helenae*, but have the dorsum green, not yellow.
- *E. tajoraca* - Members of this group are closely related, but their eggs show clear differences. *Epamera bamptoni* was discovered by breeding larvae found in the wild.
- *E. jacksoni* - The authors believe that the larvae of these species are close to the primitive larval form of *Epamera*. Note that the larval host-plants of *E. mermis*, *Helixanthera verruculosa*, was new to science and was discovered in the course of the research.
- *E. congdoni* - The host-plant of *E. fontainei*, *Tapinanthus erectotruncatus*, was new to E Africa.

- *Pseudiolaus poultoni* illustrates the value of experience gained through work on life histories. Knowing the early stages, Collins was able to go straight to its South African vicariant, *P. lulua*.

- *Stugeta bowkeri* - Species with similar larvae. A good series of *S. mimetica* was obtained through breeding. The species is otherwise extremely rare in collections.

- *Argiolaus maritimus* - These species all have larvae and pupae which are broadly similar, and clearly this group is monophyletic.
- **A. montana**
- **A. pamae**
- **Argiolaus poecilaon** - Larva are quite unlike those of other *Argiolaus* species studied, and are close to basic *Epamera* type. The pupa is close to that of *Tanueteira timon*. An undescribed species of *Phragmanthera* (Loranthaceae) was found at Kikuru, where *poecilaon* flies.

Examples of myrmecophilous butterflies studied:

- **Spindasis ella** (from coastal Tanzania) - found in galls of *Acacia zanzibarica* (Leguminosae), but also found on *Ximenia* (Olacaceae).

- **Lipaphnaeus loxura** - found in dead leaf shelters. The browsing pattern on the host-plant, *Maesa lanceolata* (Myrsinaceae) was shown.

- **Chloroselas azurea** - found under loose bark near ground level, and underground.

- **Axiocerses coalescens** (from coastal Tanzania) - Usually found underground at the foot of *Acacia zanzibarica*, but occasionally in galls, particularly in the early instars. *Spindasis ella*, *C. azurea* and *A. coalescens* are all found on *Acacia zanzibarica*, and each with a different host ant (*coalescens* with 2).

  Axiocerses larvae were also found in the Southern Highlands of Tanzania, on *Julbernardia globiflora*, *Burkea* and *Dichrostachys* (Leguminosac). When relocated to coastal Tanzania where these plants are unavailable, all were moved onto *Ximenia*, which they readily accepted. The recent comprehensive revision of *Axiocerses* by Henning and Henning was to some extent stimulated by Bampton’s breeding work on the genus.

**Conclusion**
Research on butterfly life histories adds to our knowledge of butterfly systematics, leads to the discovery of new species of butterflies and plants, stimulates further taxonomic work, and is environmentally beneficial.

**Acknowledgements**
The authors wish to express their gratitude to the Tanzania Commission for Science and Technology for permission to pursue their research.
CURRENT STATUS OF THE SYSTEMATICS OF THE PYRALOIDEA OF THE AFROTROPICAL REGION

By K.V.N. Maes,
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Abstract: A brief discussion on the distribution, ecology and economic importance of the Pyraloidea is given. Characters to recognise the Pyraloidea and its two families are provided. The problems encountered while studying the Pyraloidea from the Afrotropical region are discussed. Some solutions are proposed. The limited value of the Pyraloidea in conservation programmes is pointed out.

Introduction
Butterflies constitute about 15% of the 140 000+ species of Lepidoptera (adapted from Heppner, 1991), the rest are moths. Within the moths four large groups come forward: Geometroidea, Noctuidae, Gelechioidea and the Pyraloidea. The Pyraloidea and Noctuidae are both the largest groups, each of them consisting of probably ± 40 000 species (Nielsen et al., 1996).

Pyraloidea can be found on all continents and in the most diverse habitats, from Arctic plains to tropical rainforests, from alpine altitudes to sea level. They occur on all continents (some Phycitinae were even collected on Antarctica), but have their greatest distribution in the tropical regions.

Their caterpillars may consume dried or decaying plant or animal matter, wax in bees’ and wasps’ nests, and living plants. Some are known to be inquilines in ants’ nests (some Galleriinae and the Wurthiinae), predators of scale insects (some
Phycitinae), and aquatic scavengers in flowing water (Nymphulinae), the only group of Lepidoptera living in water.

Pyraloidea larvae are in most cases stem borers, young larvae boring into soft parts of stems and at later stages they can live freely among loosely spun together leaves.

Plant specificity is demonstrated on different taxonomic levels: Evergestinae feed on Cruciferae and the genus Diaphania is known to feed only on Cucurbitaceae. Some subfamilies are entirely related to a certain type of habitat: Crambinae are almost all living in grasslands; Nymphulinae are linked to wetlands together with Schoenobiinae and Musotiminae.

A large number of species are of economic importance. Stem borers are for example a major problem in different gramineous crops like maize, sorghum, rice (Chilo spec., Scirpophaga spec., Adelpherupa spec., Maliarpha spec.), other species are known pests in stored products (Ephestia spec). Most crops have some pyralid pest: Dichocrocis crocodora on coffee; Leucinodes orbonalis on egg plant; Maruca testulalis on beans, Sylepte derogata on cotton, to name just a few.

Systematics of the Pyraloidea
The Pyraloidea can easily be separated from other Lepidoptera by a combination of characters:

1. Hind wing: Sc+R1 fused, approximated to Rs beyond the cell;
2. Head: maxillary palps present;
3. Proboscis: scaling on base of proboscis;
4. Presence of abdominal tympanal organs.

Not all of these characters may be present at the same time. In some species the maxillary palps are absent and the proboscis may be reduced or atrophied completely.

The Pyraloidea themselves consist of two families: the Pyralidae and Crambidae. Both families can easily be distinguished on characters found in the tympanal organs.

Pyralidae: Praecinctorium and tympanum in the same plane, arranged at an angle of 180°.

Crambidae: praecinctorium and tympanum not in the same plane; angle around 90°.

To delimit the different subfamilies is much more problematic. Smaller subfamilies can easily be identified but the larger ones like the Pyraustinae give considerable
problems. This subfamily is at this moment defined on the fact of “lacking” a number of characters compared with the other subfamilies. Ongoing studies begin to show that there are quite a few exceptions, indicating that the definition of a number of subfamilies needs reconsideration.

Pyraloidea of the Afrotropical region

The Pyralidae consists of 5 subfamilies and all of them have representatives in Africa. The Crambidae consist of 15 subfamilies from which only 11 occur in Africa. 12% of the known described species of Pyraloidea occur on the African continent. This number is very low compared with other regions.

Most Pyraloidea have been described during the last century and for Africa large numbers also at the beginning of this century. Genera and species were described on a typological basis, most of the time not including descriptions of the genitalia. Recent studies show that only the genitalia, and in no degree do the the tympanal organs provide valid characters for identification and establishing relationships between taxa (Maes,1995).

The study of the Pyraloidea from Africa is even more difficult since most species were placed in genera that were described from other zoogeographical regions. When compared with the number of species from the Oriental and Neotropical regions, Africa has a poor fauna and to my opinion mainly because the group has not been thoroughly sampled or studied. Once this has been accomplished, the number of species in this group can be expected at least to double. At this moment it is not difficult to find new species. In reality it is rather a set-back. When a new species is found it is too difficult to place it in a known genus. In a large number of cases new genera will have to be created. But before one can do this a thorough study of at least the type of species of the genera of the world is necessary. There is a close relationship between the Afrotropical and the Indo-Malaysian faunas. To understand better the pyraloids from the Afrotropical fauna at least the genera of the Indo-Malaysian fauna region should be studied.

Pyraloidea and environmental studies

Because of the close association with plants, moths in general show a rapid response to environmental change. Adult moths can be sampled in a qualitative and quantitative manner using UV lights. Therefore moths can be used for environmental monitoring.

If this is applied to the Pyraloidea it can be said that many Pyraloidea are large enough to be sorted visually to species and are readily identifiable using reference collections. They are very well represented in light traps and are linked to specific habitats. Regional identification guides could be made but a revision of the systematics will be needed first.

The same argument is also applicable when Pyraloidea are to be used as biological control agents. A typical case is provided by the genus Panotima of the subfamily Musotiminae. Larvae were found to feed on Equisetae and this species (?) was proposed as a biological control agent for this weed in glasshouses in Europe.
Some trials to breed larvae were done but gave very fluctuating results. A superficial revision of material available in three museums in Europe showed that only 2 species were described whereas 31 more await description. Importers mixed up several species and were thus not able to breed successfully.

**Discussion and conclusion**

A number of problems encountered during the study of the African Pyraloidea have been mentioned above. In order to advance our knowledge of this group, the following approach is being followed: presently a checklist is being compiled of the African Crambidae, linked to a systematic database and a colour slide collection of the types. This checklist is part of a world checklist of the Crambidae. A checklist of African Pyralidae will be worked out in the near future. At the same time the type species of the genera of the world are studied, in order to avoid the mistakes made by earlier authors.

Problems encountered during the study ispecialized life-cycles. At this stage it is necessary for all species to be dissected. Identifications can only be based on type-material since too many new species await description.

Although this checklist is only a limited achievement, it offers a basis for efficiently solving the common problems of classification (synonyms, species complexes) and indirectly helps in the discovery and description of new species. The world approach on genus level permits also to have a better understanding of the distribution of species within a genus and of the genera themselves.

It is evident from the scattered knowledge of the systematics of the Pyraloidea that this group is at this moment only of limited use in environmental assessment studies. However, it cannot be denied that because of the high species diversity and the highly specific life-cycles and adaptions to a wide range of habitats the Pyraloidea come become a very useful tool in conservation programmes.

Species totals for subfamilies of Lepidoptera (1758-1990)
(from HEPPNER, 1991)

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References

HEPPNER, J.B. 1991 Faunal regions and the diversity of Lepidoptera. Tropical Lepidoptera (Gainesville), 2 (Suppl.1):1-85


CHEMICAL COMMUNICATION BETWEEN LYCAENID LARVAE
(LEPIDOPTERA: LYCAENIDAE) AND ANTS (HYMENOPTERA: FORMICIDAE)

By Stephen F. Henning,
1 Harry Lawrence Street, Florida Park, 1709, South Africa.

A causal explanation for myrmecophily in the Lycaenidae was long sought, Henning
(1983, 1984, 1987) published evidence suggests that this association between ants
and lycaenid larvae is mediated by chemical signals.

Lycaenid larval organs
Several lycaenid larval organs have been linked to the ant/lycaenid associations.
First of all there is the dorsal medial honey-gland (dorsal nectary organ) on the
seventh abdominal segment. In itself it does not appear to produce pheromones and appears to be what can be called an appeasement gland, possibly analogous to the appeasement glands of myrmecophilous staphylinid beetles. Analysis of the secretions of the honey-gland by Maschwitz et al 1975 showed that in addition to water, the main constituents of the secretion were fructose, sucrose, trehalose and glucose. The total concentration of these sugars being more than 10% which was much higher than the carbohydrate content of the haemolymph which is only about 2%. This indicates that the gland concentrates the sugars in the secretions to make it more attractive as a food for ants.

The paired tubercles of the eighth abdominal segment are each frequently set in the tip of a cylinder into which they are retracted. When everted by blood pressure they are seen to carry on their surface a rosette of slender, spiculate setae, each associated with a gland cell.

In addition there are small epidermal glands concentrated on certain areas of the larva which were termed perforated cupolas by Malicky (1969, 1970). He believed that they produced a volatile substance that causes the attendant ants to palpate the larvae with their antennae in the area where they were concentrated.

**Pheromones**

Now how were the larvae communicating with the ants and modifying their behaviour? It had been found that in the social biology of ants much of their behaviour is released and controlled by pheromones and various types have been found and described. It had been determined that workers of many speromones and in addition to ones involved with recognition and brood tending. It is also well known that alarm pheromones possess several functions clearly separate from that of merely causing alarm in workers. The most important for the purpose of my study was that it serves as an attractant in low concentrations (Holldobler, 1971 - with the formicine Camponotus socius) fortifying their recruitment trails with alarm pheromones to attract excited workers.

Three butterfly species were studied - Aloeides dentatis (Swierstra) with its host ant Acantholepis capensis Mayr and Lepidochrysops ignota (Trimen) with its host ant Camponotus niveosetosus Mayr and thirdly Euchrysops dolorosa Trimen a species not observed to be ant associated but feeding on the same host plant as L. ignota in the study area at the same time. It served as a type of negative control and was used to see whether it could be induced into an ant association if provided with appropriate conditions. Due to the shortage of time I will only mention the results pertaining to the myrmecophilous species as all those of E. dolorosa were negative.

Ant colonies were established in the laboratory so that the interaction between the lycaenid larvae and ants could be easily studied recorded.

Having recorded the normal interactions between the ants and the lycaenid larvae, it now had to be established if this was brought about by pheromones or some other cue.

To do this the pheromones have to be extracted from the bodies of the larvae and the ants. The solvent used to extract these chemicals was dichloromethane.
The ants and larvae were killed by chilling. The worker ants then decapitated and the abdomens removed. The head and abdomen were immediately transferred to separate airtight bottles of solvent. The honey-gland, tubercles and cuticles were stripped from the lycaenid larvae. The honey-gland or the tubercles with the surrounding cuticle and the cuticle from the thoracic area were transferred to separate bottles of solvent. To obtain enough pheromone 30 heads of the small *Acantholepis capensis* where used per sample, while only one final instar *A. dentatis* was sufficient per sample.

Following the method of Glancey et al (1970) corn cob grits (corn crushed small enough for the ants to pick them up) were extracted in dichloromethane using a Soxhlet apparatus to remove impurities. The corn cob grits were then soaked in the various extracts of both ants and lycaenid larvae for 24 hours. The grits were then removed and then placed in the respective formicaria to obtain the ants reactions. The response of the ants to untreated grits and to grits soaked in only dichloromethane were also recorded (Henning, 1983).

In addition gas-liquid chromatographic analysis of the extracts were performed on a Packard-417 gas chromatograph equipped with flame ionisation detectsses, column packed with 20% Carbowax on Anachrom ABS (90/100 mesh). Nitrogen was employed as the carrier gas at a flow rate of 20 ml/min. The column temperature was maintained at 80 °C for 5 minutes then programmed at 5 °C per minute to a final temperature of 200 °C, held for 10 minutes. Carbowax 20M was chosen as the liquid phase, as it approximates the polarity of the suspected sample components.

The ant and lycaenid extracts were run alternately on the gas chromatograph so that conditions applying at the same time were virtually identical for both. This allowed the chromatograms to be compared directly by superimposing one upon the other over a light box. Comparison of the retention times of components of the extracts as recorded by the Autolab Minigrator confirmed the observations made over the box.

Relative retention times of peaks were calculated by selecting a peak common to both ant and lycaenid extracts, and using it as a standard to calculate the retention times.

\[
\text{Relative retention time} = \frac{\text{retention time of unknown peak}}{\text{retention time of std peak}}
\]

Results

**Interaction between *A. dentatis* and *A. capensis***

An ant on encountering larvae would run up to them and begin stroking them with their antennae concentrating on the area dorsally on the thorax and around the tubercles. The larvae responded by extruding their tubercles, usually both at the same time, which resulted in the ants within a range of 2-4 cm becoming alerted. The ants rate of locomotion increased, they made short fast runs with frequent changes of direction, with mandibles held open and had increased antennal movement. The ants within a 2 cm range were also alerted, but were also attracted directly towards the
lycaenid larva. The larvae were accompanied at all times by the ants. In the nest the larvae congregated together and remained motionless most of the time. The ants constantly attended the larvae, either stroking them slowly with their antennae or just standing on or near them. The droppings were removed by the ants.

The reactions of the ants to the glandular extracts absorbed on to corn cob grits is summarized on Table 1 (Henning, 1983).

Gas chromatography of the volatile secretions - *A. capensis* and *A. dentatis*
Peaks on the chromatograms of the two *A. dentatis* extracts were numbered and then compared using relative retention times with those of *A. capensis*. The relative amounts of each chemical were also compared by taking the areas under the peaks and calculating the percentage of each. For the abdominal extract of *A. capensis* (fig. 1), because of the large number of peaks, only those corresponding to the one on the *A. dentatis* chromatograms were numbered.

A comparison of the chromatograms showed that a number of the peaks were common to all the extracts, these are 5, 7, 10, 12, 13, 14 and 16. The abdominal extract had relatively few peaks in common with the *A. dentatis* extracts. All the peaks on the head (fig. 2) and brood (fig. 3) extract chromatograms have an equivalent in *A. dentatis*.

*A. dentatis* thoracic area chromatogram (fig. 4)
The peaks on this chromatogram correspond most closely to the peaks obtained on the brood extract chromatogram of *A. capensis*. Peaks 1 and 3 were only found on the thoracic area and brood extract chromatograms and not at all in the others. Peaks 3, 4 and 15 were also common to the head extract chromatogram. Peaks 6, 9 and 11 were found in the brood extract but not in the thoracic area extract.

Considering the crudity of the extracts and the fact that all the peaks are not common to both, the relative amounts of each chemical in the brood and thoracic area extracts are remarkably similar.
Table I. The reactions of *A. capensis* workers to various glandular extracts absorbing to corn cob grits.

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<thead>
<tr>
<th>Glandular extracts</th>
<th>Reaction</th>
<th>Investigation</th>
<th>Carrying &amp; brood tending</th>
<th>No alarm</th>
<th>Reaction of <em>A. capena</em> workers</th>
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Table 8. The reactions of *Camponotus niveosetosus* workers to various glandular extracts absorbed on to corn cob grits.

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<tr>
<th>Glandular extracts on grits</th>
<th>n</th>
<th>Reactions of <em>C. niveosetosus</em> workers</th>
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<td>Alarm Behaviour</td>
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<tr>
<td><em>C. niveosetosus</em></td>
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<tr>
<td>Mandibular gland</td>
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<td>Abdominal extract</td>
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<td>Brood extract</td>
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<td><em>L. ignota</em></td>
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<td>Thoracic area</td>
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<td>Honey-gland &amp; surrounding area</td>
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<tr>
<td>Dichloromethane</td>
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<tr>
<td>Untreated</td>
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\[ n = \text{number of individual grits} \quad ' = \text{After alarm behaviour} \]
Therefore from these results it appears that the crude extracts of the volatile secretions from the thoracic area of *A. dentatis* appear to mimic the crude extracts of the brood pheromone of *A. capensis*.

**A. dentatis tubercles and surrounding cuticle** (fig. 5)
The peaks obtained on this chromatogram appear to be made up of a mixture of those from the head and brood extract chromatograms. All the peaks on the head extract chromatogram are to be found on the tubercle area chromatogram. The remaining peaks on the latter are to be found on the brood extract chromatogram.

As this chromatogram appears to mimic both the alarm and brood extracts of *A. capensis*, the relative amounts of each chemical were difficult to compare, although the results are not too inconsistent from what would be expected from a mixture of these extracts. One must also remember that the behavioural response may be released by only one or two of the chemicals indicated on the chromatograms.

From these results then it appears that the crude extract of the tubercle area of *A. dentatis* produces a volatile secretion which appears to be a mixture of the alarm and brood pheromones of *A. capensis*. The alarm component emanating from the tubercles themselves, the brood component from the perforated cupolas surrounding the tubercles

**Conclusion**
From the above study it appears as if the association between *A. dentatis* and *A. capensis* is mediated by means of chemical signals. From the experiment with the corn cob grits it was demonstrated that *A. dentatis* produces a volatile secretion which releases a behavioural response in the ants similar to the one shown by them to their own brood. This volatile chemical compound also gave a chromatographic fingerprint pattern rather similar to that of the brood extract chromatogram of *A. capensis*. It was also found that a volatile chemical compound produced by the tubercles elicited an alarm reaction in the anact chromatogram of *A. capensis*.

The "mimic" of the brood pheromone is most likely produced by the perforated cupolas which were the only glands common to both areas of cuticle under study. The gland that produced the alarm pheromone was not located, but there are probably pyriform secreting cells at the base of the setae of the tubercle of the type described by Ehrhardt 1914. Ehrhardt and other authors suggested that the pyriform cells secreted an odiferous substance, but were never able to prove it.

**L. ignota and Camponotus niveosetosus**
Workers encountering larvae would investigate them by touching them with their antennae usually in the vicinity of the honey-gland but also in the thoracic region. Third instar larvae that had stopped feeding were picked up and carried away by the ants. The larvae rolled themselves up when the ants attempted to pick them up by closing their mandibles between the last thoracic and first abdominal segments. This allowed the ants to carry the larva with ease. One worker carried a larva from the flower-head to its nest some 3 metres away.
Reactions of the ants to the glandular extracts absorbed on to corn cob grits is summarized in Table 2 (Henning, 1983)

**Gas chromatography of the volatile secretions**
The peaks on the chromatograms from the two *L. ignota* were numbered and compared using relative retention times with those of *C. niveosetosus*. The relative amounts of each chemical were also compared by taking the areas under the peaks and calculating the percentage of each.

Comparison of the chromatograms showed that only two peaks were common to all the extracts, these are peaks 9 and 10.

**L. ignota thoracic area chromatogram** (fig. 6)
The thoracic area chromatogram has all but one of the peaks found in the brood extract chromatogram of *C. niveosetosus* (fig. 7). The peaks common to the brood extract chromatograms are 6, 9, 10, 11, 12 and the one missing is 8. The other relative amounts of the chemicals involved in this chromatogram are remarkably similar to that of the brood extract chromatogram of *C. niveosetosus*. The major peak on both chromatograms is peak 11 and it makes up nearly 50% of the extract. Two other peaks 10 and 12 make up the majority of the rest of the extract, both being about 20%.

From the above results one can say that the crude extract of the volatile secretions from the thoracic area of *L. ignota* gives a similar "fingerprint pattern" to the crude extract of the brood of *C. niveosetosus* and thus appears to mimic it.

**L. ignota honey-gland and surrounding cuticle** (fig. 9)
The peaks obtained in this chromatogram are identical to those on the thoracic area one (fig. 6), except for peak 12 which is missing. The peaks common to the brood extract chromatogram are 6, 9, 10, 11 and those missing are 8 and 12. Peaks 2, 5 and 7 are again common to the head extract.

The percentage areas of the peaks involved are again remarkably similar to that of the brood extract. Peak 11 provides 64.2% of the volatile chemical produced which is a far higher proportion than in the brood and thoracic area extracts. The missing peak 12 lies very close to peak 11 therefore these two chemical substances may well have passed through the column together giving this high result, because if you combine the areas of peaks 11 and 12 in the brood and thoracic extracts they are 67.4% and 63% respectively.

From these results it appears that the crude extract of the honey-gland and surrounding cuticle gives a similar picture to that of the crude extract of the brood of *C. niveosetosus* indicating that the larva may produce a volatile chemical that mimics the brood pheromone of its host ant.
<table>
<thead>
<tr>
<th>Ant species</th>
<th>Extracts on grills and alien</th>
<th>Reaction of worker ants</th>
<th>Reaction of worker ants to the extracts of E. doloresae larvae and their own brood.</th>
</tr>
</thead>
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<tr>
<td>E. doloresae</td>
<td>E. doloresae</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>C. maculatae</td>
<td>C. maculatae</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>E. doloresae</td>
<td>E. doloresae</td>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td>C. nicoletti</td>
<td>C. nicoletti</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>E. doloresae</td>
<td>E. doloresae</td>
<td>28</td>
<td>1</td>
</tr>
</tbody>
</table>
Conclusion
From the above study it appears as if the association between L. ignota and C. niveosetosus is mediated by chemical signals. The volatile chemical secretion produced by the L. ignota larva gives a gas chromatographic fingerprint pattern rather similar to that of the brood extract chromatogram of C. niveosetosus. There are also several peaks in common with the head extract chromatogram which suggests that it may also mimic certain components of their host alarm pheromones, i.e. ones involved in attraction.

The behavioural experiments showed that this volatile secretion attracted the ants and induced them to carry the larva as it would its own brood. The glandular origin of this secretion produced by L. ignota is most likely the perforated cupolas as these were the only glands common to both areas under study.

_Euchrysops dolorosa_ Trimen
The peaks on the chromatograms from the extracts of E. dolorosa were compared using relative retention times with those of the brood extracts of A. capensis, C. niveosetosus and C. maculatus (Table 3). The relative amounts of each component were also compared by taking the areas under the peaks and calculating the percentage of each.

From this study it appears that _E. dolorosa_ produces a volatile secretion that can attract certain ant species. The chromatogram of this secretion (fig. 10) appears to be most similar to the chromatogram of the brood extract of _C. maculatus_ (fig. 11). The chromatogram was also found to resemble that of _C. niveosetosus_, but the proportions of the various chemical constituents were different. Although there are some common peaks in the chromatograms of _E. dolorosa_ and the two ant species mentioned above, the actual chemical concerned with carrying must be absent, as the extracts on the corn cob grits only caused them to be investigated and not carried (see Table 3). The chromatogram of the brood extract of _Aetely ignored by the ants_.

Discussion
This study showed that chemical communication appears to play an important part in the relationships between some lycaenid species and their host ants. This work supports the conclusions reached by several authors from their behavioural studies (Ehrhardt, 1914; Malicky, 1969, 1970; Claassens, 1974, 1976 and many others).

In the studies undertaken here it was found that a volatile lycaenid secretion appeared to mimic the brood pheromone of the host ant. This volatile secretion of _L. ignota_ caused the ants, _C. niveosetosus_, to carry the lycaenid larvae into the nest. In the case of _A. dentatis_ the larvae are too large to be carried by their host ant _A. capensis_, but they do appear to be groomed and generally tended as the workers would do their own brood. Small corn cob grits soaked in extracts of _A. dentatis_ larvae were carried by their host ant, indicating that a similar chemical signal was being employed as in the case of _L. ignota_. However, size may not only be the
reason that some lycaenid larvae are not carried by ants, since, *L. ignota* larvae are not carried into the nest until the third instar. Ants have been observed trying to pick up *Lepidochrysops* larvae of all stages (Claassens, 1976), but they are unable to do so until the larvae themselves release their hold on the substrate. It was found during the course of this study that third instar *L. ignota* larvae could be induced to release their hold on the substrate and roll up into a sphere by gentle stroking with a paint brush, indicating this was a response to a tactile stimulus. First and second instar *L. ignota* larvae when stroked with a paint brush just tightened their grip on the substrate. Claassens (1976) observed that an ant before attempting to pick up a *Lepidochrysops* larvae would investigate it with its antennae, thus possibly producing a tactile stimulus similar to the one obtained with the paint brushes also observed that third instar *L. ignota* larvae were always investigated by the ant with their antennae before they released their hold on the substrate. So it appears that both chemical attraction of the ant and the tactile stimulus of the larva may be needed before the ant can carry the lycaenid larvae.

The discovery that the tubercles of *A. dentatis* produced a volatile secretion that appeared to mimic the alarm pheromone of the host ants may be a remarkable example of co-evolution. From observations it appears that only certain components of the alarm pheromones are actually involved. As was pointed out earlier the term alarm pheromone is rather misleading. The behaviour encompassed by this term includes alerting, attraction and biting. The volatile secretion of the tubercles of *A. dentatis* appeared to be involved only in alerting and attraction.

Having now established the importance of chemical communication in some ant/lycaenid associations the actual chemical components of the pheromones should be identified. This could be achieved by running the volatile secretions through a gas chromatograph- mass spectrometer combination thus obtaining the mass spectra of each component. The mass spectra so obtained could be compared with the spectra of known chemical substances. Having identified the components and calculated the quantities of each, behavioural experiments could be carried out with the pure chemicals to determine which are most important in releasing different behaviour patterns.

Further associations could be investigated as above, particularly those involving ants and obligate carnivorous lycaenids, and those feeding on lichens, so that a better understanding could be obtained of the adaptations of the Lycaenidae to the ants.

References


Gas chromatogram of the volatile material extracted from the head of *A. capensis*.

Fig. 2

Fig. 3
Fig. 4
Gas chromatogram of the volatile material from the thoracic area of *A. dentatia*.

Fig. 5
Gas chromatogram of the volatile material from the tubercles and surrounding cuticle of *A. dentatia*. 
Gas chromatogram of the volatile material from the thoracic area of *L. ignota*.

Fig. 6

Gas chromatogram of the volatile material extracted from the brood of *C. niveosetosus*.

Fig. 7
Fig. 8

Fig. 9
A BRIEF HISTORY OF LEPIDOPTEROLOGY IN SOUTHERN AFRICA

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It was Winston Churchill who said that "the more you look back, the more you look forward". We as the present generation of lepidopterists owe a great debt of gratitude to those who have gone before. In a way, we are connected to previous lepidopterists, by example, knowledge bestowed and inclination. Talking of connectedness, Aristotle (384 - 322 BC) wrote in his Metaphysics, over two millennia ago, 'All things are ordered together somehow, but not all alike - both fishes and fowls and plants; and the world is not that one thing has nothing to do with another, but they are connected.' That is one of the reasons why we are here, to learn and ultimately to assist in the custodianship of the sumptuousness of the Afro-tropical biota, including the lepidoptera. We are now going to briefly look back at some of the contributors to lepidopterological knowledge in southern Africa.

No lepidopteran fossils are known from southern Africa. One fossil butterfly has been described from Tanzania. Fossilised butterflies are extraordinarily rare, only 38 species having been recognised (de Jong 1996). The oldest known butterfly fossil is about 55 million years old. A fine example of a butterfly fossil, *Prodryas persephone*, is known from the Lake Florissant fossil beds, Colorado, USA (Sandved and Brewer 1976). One of the earliest extant butterfly illustrations from Africa is part of a limestone frieze from the tomb of Ka-em-Nofiet at Sakkarra, Egypt, carved about 2450 BC (Sandved and Brewer 1976). The only Khoisan insect paintings recorded from southern Africa are bees (Woodhouse 1984). These have been found in caves near Elliot in the Eastern Cape Province, and also in Natal, Namibia and Zimbabwe. In many of these paintings dancing human figures (demonstrating joy at the finding of an important food, and belief in its power) are seen near rounded honeycombs and buzzing white bees..

The Khoisan called Table Mountain, Hoeri'kwaggo, which means 'sea mountain' (Moll 1987). Aeons ago (during the 'ice ages' when polar capping occurred (Pielou 1991)) it was an island. An illustration of a 1713 Dutch print of Table Mountain introduces us to the cascade of events that started with European discovery and settlement at the southern tip of Africa. Europeans started regularly rounding the Cape of Good Hope in the late 1500's in the rush for Empire. The first plant recorded from the Cape was the giant kelp *Eclonia maxima*, illustrated by Cornelis de Houtman 1595-97, from an account of an expedition for the Dutch East India Company (Gunn and Codd 1981).

Bernard d'Abrera (1997) writes of the colonial cycle of 'explorer, trader, missionary, soldier, explorer, and so on,' an observation very pertinent to the continent of Africa. Seafarers, explorers, travellers and hunters then started to
become aware of the animals inhabiting the sub-continent, particularly those they could eat, and those that wanted to return the favour! Apropos the latter, I particularly enjoy the Ogden Nash poem called the lepidopterist:

The lepidopterist with happy cries,  
devotes his days to hunting butterflies.  
The leopard, through some feline mental twist,  
would rather hunt the lepidopterist.  
That's why I never adopted lepidoptery:  
I do not wish to live in jeopardoptery.

The plants of the Cape also began to be noticed, and eventually the butterflies and moths as well. Table 58 from the illustrated books by James Petiver, Gazophylacii Naturae et Artis, published from 1702-1709, shows a number of specimens of Cape fauna and flora, including an illustration (Gunn and Codd 1981) of what appears to be Brephos decor (Linnaeus), the decorous red tiger moth (identified ex Pinhey1975). The Swede Carolus Linnaeus was the first to describe southern African lepidoptera. This was in the tenth edition of his magnum opus, Systema Naturae, published in 1758. The lovely Cape butterfly, Chrysoritis thysbe thysbe was described by Linnaeus in 1764 as Papilio thysbe. He was not the first to use the binomial system for naming fauna and flora. Casper Bauhin used such a system in his book Pinax of 1623 (Gunn and Codd 1981). (The Bauhinia plant genus is named after the two Bauhin brothers). Linnaeus, however was the first to consistently use such a binomial system. He named the plant genus Moraea (Iridaceae) after his wife's maiden name. One hundred and three of the one hundred and nineteen species of this genus are found in the southern African region (Goldblatt 1986). Any observant naturalist who has roamed the glorious Namaqualand hills near Springbok and Steinkopf in spring will have noted the tiny geophytic iris, appropriately named Moraea serpentina Baker (describing the coiled or serpentine leaves).

The orange-banded protea-butterfly, Capys alphaeus alphaeus was one of the first butterfly discoveries from the Cape of Good Hope. This was described by Pieter Cramer in 1777. He wrote a four-volumed masterpiece on butterflies, Papillons Exotiques, the first volume of which appeared in 1775.

The butterfly Catacroptera cloanthe cloanthe, known as the 'pirate', was described by Stoll in 1781, from the "Cape of Good Hope". This locality was used very loosely, and butterflies from Natal to what is now called Namibia sometimes received this rather loose locality record! This butterfly occurs as far west in the Cape Province as the Gouritz River (personal observation). Stoll published a supplementary volume to Papillons Exotiques in 1791. In it, many south African butterflies were described in colour. By 1800, 67 southern African butterflies had been described (Ball 1994).

Carl Thunberg (1743-1828), was known as the 'Father of Cape Botany'. He was a favourite student of Linnaeus. He spent 3 years at the Cape, from 1772-1775, during which time he amassed a herbarium of 23 510 specimens, as well as 25 000
insects, including many butterflies and moths (Gunn and Codd 1981). He succeeded Linnaeus as professor of Botany at Uppsala University. He was the first of a number of 'super-Swedes' who made huge contributions to lepidopterology in this region.

Another early traveller of note was William John Burchell (1781-1863). His training was in botany, and he was one of the most scientific of the early explorers in southern Africa. Between 1811 and 1815, he undertook an epic approximately 7000 kilometre journey through the northern, eastern and southern Cape Province, as well as what is now called Botswana. He returned to England with 60 000 specimens (50 000 botanical) and many insects (Gunn and Codd 1981). He wrote the two volumed Travels in the Interior of southern Africa (1822 and 1824). Burchell caught the montane fynbos satyrid butterfly now called *Pseudonympha hippia* (Cramer) on Table Mountain (Cape Town) in 1811. He subsequently described it as *Hypparchia montana*, which is illustrated on p. 45 in the first volume of his southern African books.

Another Swede, Johan Wahlberg (1810-1856), an explorer and naturalist, arrived at the 'Cape' in 1839. He did most of his collecting in Natal and the Transvaal. He collected over 5 000 species of insects, as well as numerous other specimens of natural history. He was killed by a wounded elephant at lake Ngami, Bechuanaland (Now Botswana). His portrait and broken elephant gun hang in the Royal College of Forestry, Stockholm (Gunn and Codd 1981). The lycaenid *Argyrocpusa malagrida malagrida* was described by the Swedish clergyman and taxonomist Wallengren in 1857 from a Wahlberg specimen. This had the erroneous locality of Caffraria. This was probably caught by him on the western Cape Peninsula in March 1845, after his exploration of the Saldanha area (own deduction based on knowledge of the species and details of his travels as recorded in Gunn and Codd 1981).

Colonel James Bowker (1822-1900) was the the ninth son of some 1820 Settlers (to the Eastern Cape Province). He had a distinguished military career (Mitford-Barberton 1952). At one stage, he was the High Commissioner of Basutoland. Bowker was also a natural scientist of note, and co-authored the three-volumed South African Butterflies (with Roland Trimen) 1887-1879. He discovered numerous butterflies, including the only three specimens known of the lycaenid, *Deloneura immaculata* Trimen. He retired to Malvern Hill, near Durban. Here he had a pet ground-hornbill (*Bucorvus leadbeateri*), that slept in his room, and trailed him like a dog. A story is told of once when he was ill, and the bird brought him a frog, then a lizard and finally a snake as a "gift" whilst he was rather immobile in bed. Bowker said afterwards that he was "greatly touched by the fidelity, thought and intelligence of the bird". Colonel Bowker's father was the first to breed Merino sheep in the eastern Cape Province.

Mary Barber (1818-1899) was the sister of James Bowker. She was one of the most distinguished naturalists of her day, corresponding with Charles Darwin and the Hooker's of Kew (Gunn and Codd 1981). She discovered the world's second smallest butterfly, the minute lycaenid *Oraidiium barberae* (Trim) at Highlands, near Grahamstown in the eastern Cape Province. Further history of interest is that the
town of Barberton, in the old eastern Transvaal, was named after Mary Barber's two sons, Frederick and Harry and their cousin Graham. They discovered the gold bearing reef in the eastern Transvaal in 1884. Gold had been found earlier at Pilgrim's Rest (1881), but here it had to be panned. Between 1800 and 1899, 423 southern African butterfly species were described, the majority of these descriptions (364) in the halcyon years between 1850 and 1899 (Ball 1994). Roland Trimen (1840-1916) was the first resident taxonomist of lepidoptera in southern Africa. He first came to the 'Cape' in 1858. He later became the curator of the South African Museum in Cape Town, from 1872 to 1895 (Summers 1975). He is best known for his three volumed South African Butterflies (1887-1889, assisted by Colonel Bowker). He was probably not a very robust man. Despite living in Cape Town, he obviously did not do much climbing on Table Mountain. This is borne out on page viii from the preface of volume 1 of the first volume of South African Butterflies, where he wrote that "Cape Town and its neighbourhood is absolutely not more productive of species than Brighton (in England)....." Claassens and Dickson (1980) recorded 53 species of butterfly on Table Mountain, which is a little less than the 68 species recorded from the entire British Isles, and considerably more than the species total from Brighton in England. He described a few birds, including the rackettailed roller, *Coracias spathulata*. He was the first to record *Aloeides barklyi* (Trimen) (a 'silver copper'), which he found in Namaqualand in August 1873. The Brenton Blue Butterfly, *Orachrysops niobe* (Trimen), was another of his discoveries, Trimen found three specimens of this now threatened species near Knysna in 1858. No more specimens of this butterfly were found for 119 years, until I found it again near Nature's Valley (southern Cape) (Pringle et al. 1994).

Five of the first eight curators of the South African Museum collected insects, and the museum was important from a taxonomic point of view from the late 1800's (Summers 1975).

Another director of the S.A. Museum in Cape Town (1906-1924) who did a small amount of work on the lepidoptera (he was pre-eminently a coleopterist) was Louis Albert Peringuey (1855-1924) (Summers 1975). He was a Basque from France, who served in the Franco-Prussian war (1870-1871). He had a great disliking of the Germans, and named one of the Gryllacrid insects (in the Orthoptera) *Bochus contemptendus*, which means the 'contemptible German'. This hapless insect was later found to have a specific name synonymous with the name *puncticeps* (Hesse unpublished) So it is now known as the 'German with the pricked head!' Aurivillius named the large copper *Tylopaedia sardonyx perinqueyi* after him.

Robert Mark Lightfoot (1864-1921) worked for many years at the S.A. Museum as a general factotum (Summers 1975). He was the first to collect *Chrysoritis aridus* (in the 1890's), later described by K.M. Pennington in 1953.

Frederick Courtenay Selous (1851-1917), was a famed hunter, naturalist and explorer. Wherever possible he collected butterflies. He arranged the safari for President Theodore Roosevelt in East Africa in 1909. He was killed by an Askari at Kisaki (now in Tanzania) whilst fighting the Germans during World War I. Selous discovered *Charaxes manica* Trimen, presumably in Mozambique in 1892.
One of the giants of butterfly taxonomy was P.O.C. Aurivillius. He wrote Rhopalocera Aethiopica in 1898-1899. He also edited the 13th volume of Seitz's Die Gross-Schmetterlinge der Erde, describing many southern African butterflies in the process.

Anthonie Janse (1877-1970) was one of the giants of African lepidoptera. He was our foremost expert on moths (Vári 1971). He settled in South Africa in 1899. He was first a teacher, later becoming the honorary professor of systematic entomology at the Transvaal University College (later Pretoria University). His magnum opus was his eight-volumed The Moths of South Africa (1932-1964 (the eighth volume was published posthumously)).

Sir Guy Anstruther Knox Marshall (1871-1959) was one of the most renowned British entomologists. He spent a number of years in the then Rhodesia (1893 - 1906) during which time he made many entomological discoveries, and a number of butterflies are named in his honour, including the lycaenid, *Aphanaeus marshalli* Neave.

Charles Francis Massey Swynnerton (1877-1938) made a large contribution to the knowledge of our lepidoptera, especially in what is presently Zimbabwe and Tanzania. He met the great Guy Marshall in 1897 in Natal who was instrumental in getting Swynnerton to Salisbury (now Harare). He became the first director of the Tsetse Reclamation and Research Institute.

Ken Misson Pennington (1897-1974) or KMP as he was often known, was a barrister, teacher and eminent lepidopterist. Whilst serving in the Royal Flying Corps during World War I in Mesopotamia, he had the distinction of being shot down by the Turks twice within 20 minutes (the second incident whilst in a second (rescue) craft) (Dickson 1974). He described 30 species and 3 subspecies from southern Africa. He discovered numerous butterflies, including *Lepidochrysops macgregorii*, which he first found at 16h00 on the 5/9/1968 near Nieuwoudtville, in the northern Cape Province.

Henri Stempffer wrote the epic 'The Genera of the African Lycaenidae' in 1967, which formed the basis of much further study.

Georges van Son (1898-1967), was born in Russia, to a noble family. His father, a Dutch diplomat was shot during the Russian Revolution. After some time in Leiden, he came to South Africa in 1925. He was a superb entomologist, and wrote the four comprehensive volumes of The Butterflies of Southern Africa (1949, 1955, 1963 and 1974 (edited posthumously by Lajos Vári, who is also a preeminent lepidopterist). *Thestor vansoni* Pennington from the mountains north of Ceres in the Western Cape honours his memory.

Charles Dickson (1907-1991), spent most of his life in Cape Town, many in his beloved home called Blencathra. He was the gentleman's gentleman. He described numerous Cape butterfly taxa. He also discovered numerous butterflies, including the stunning *Chrysoritis adonis* (Pennington), on the Gydo mountains near Ceres (Western Cape Province) on the 18/XII/1945). He described 102 new taxa and was the author of 90 publications on lepidoptera (Pringle 1991).
Gowan Coningsby Clark (1888-1964) was a giant on the world's Natural History illustrative stage. He completed 263 detailed life-history paintings of southern African butterflies, and partially completed a further 67 plates (Ball 1997). This represents 37% of the southern African butterfly life-cycles. Clark was also a fine wood-carver, and carved many life-sized models of southern African fish, including a coelacanth, still to be seen in the Port Elizabeth Museum. Numerous entomological discoveries were made by him and the lovely little 'rocksitter' lycaenid, Durbanella clarki (Van Son) honours his memory.

David Abraham Swanepoel (1912-1990) or 'Swannie', was probably one of the greatest collectors of butterflies of this sub-region. He enthused many collectors, largely through his book, Butterflies of South Africa (1953). His discoveries were legion (Henning 1991).

The number of butterfly species known from southern Africa is now about 870. Through time constraints, many other names and faces have been left out of this talk, they are not however forgotten or unimportant. We have taken a look back, but now we need to look forward. We need to educate our youth and lobby decision makers as to the wonder, splendour, fragility and inter-dependence of the 'blue planet's biota. We need to examine our ethos and grasp the vision of sustainable living and conservation of our natural heritage.

Caldwell said, "The environmental crisis is an outward manifestation of a crisis of mind and spirit. There could be no greater misconception of its meaning than to believe it is concerned only with endangered wildlife, human-made ugliness, and pollution. These are a part of it, but more importantly, the crisis is concerned with the kind of creatures we are and what we must become in order to survive" (from Miller 1995).

Finally, to quote Aldo Leopold (1949), "We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect." That is the hope not just of our lepidoptera, but of global biodiversity, and ultimately the survival of the creature erroneously given the specific name of sapiens.

Will some of our children's children be able to live their lives in 'jeopardoptery'?

References


