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Skin-piercing blood-sucking moths V: Attacks on man by 5 *Calyptra* spp. (Lepidoptera, Noctuidae) in S and SE Asia

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In a chronology of 11 cases, male adults of scarce *Calyptra bicolor* (MOORE), *C. fasciata* (MOORE), *C. ophideroides* (GUENÉE), *C. parva* BÄNZIGER, *C. pseudobicolor* BÄNZIGER are proved for the first time to attack man (the author) and pierce the skin to suck blood under natural conditions in the field. In 12 further records, attacks were not conclusive. All cases occurred in the rainy season, during the first half of the night, in or near forests between 1000 and 1600 m altitude in N Thailand *(C. fasciata, C. parva)* and the Lesser Himalayas of NW India *(C. fasciata, C. ophideroides)* and Nepal *(C. bicolor, C. pseudobicolor)*. The moths initially were on pursuit of ungulates–the normal host–which the author was investigating, before settling on him; but 2 cases involving *C. parva* show that man can be the primary target. *C. pseudobicolor* pierced through the scab of previous leech bites, and sucked saliva and blood by piercing the lips, as did *C. ophideroides;* the other species pierced intact skin of the knee and hand, often causing strong burning pain though sometimes barely anything was felt. No complications ensued. Several cases are documented photographically. Why attacks on man–of very scarce occurrence–have hitherto remained unknown is discussed, as are the causes of pain, skin reaction, geographic regions and circumstances conducive to attacks, and people exposed to them.

INTRODUCTION

With the 1967 finding in the Malayan rain forests of the amazing skin-piercing blood-sucking feeding habits of the moth adult *Calyptra eustrigata* (HAMPSON), the quest was on to establish whether man is a host of the moth. Animal hosts have been shown to include the Asian elephant (*Elephas maximus* L.) and 10 large, wild and domestic perissodactyl and artiodactyl species. But, although under experimental conditions the moth did pierce human skin to suck blood (the author's), until recently no successful attacks on man had been witnessed in nature; nor had any such reports apparently been published.

Observations of the taking of body fluids of human and animal origin by adult Lepidoptera are not new. The attraction which mammalian secretions and excretions left on the ground exert on butterflies was noted already in 1854 by WALLACE (1869) in W Malaysia. COLLENETTE (1928) mentioned assemblages of hundreds of butterflies on damp sand at spots where man and animal had left their body fluids, and noted that unwashed garments previously worn by man attracted great numbers of moths but scarcely any butterflies, in Matto Grosso, Brazil. He also pointed out that such garments were not settled upon by moths in Guinea, W Africa, and that in some tropical regions Lepidoptera were apparently attracted to uncontaminated moisture alone. Possibly the earliest record of Lepidoptera sucking blood is by JOHNSTON (1884), who mentions butterflies being attracted to sprinkles of blood of freshly killed animals. An important re-

view on the general feeding habits of adult Lepidoptera as known until 1936 was given by NORRIS, while WAAGE (1979) discussed the evolutionary aspects of insect/vertebrate associations; ADLER (1982) added new information on soil-visiting moths.

More interesting is the licking of body fluids directly from animal and human skin. The nymphalid *Polygonia c-album* (L.) has been observed taking blood serum from a fresh wound of a horse (SEITZ, 1894). Other butterflies, like lycaenids and satyrids (*Erebia* spp.) can be seen even in temperate regions on hot days to take sweat from animals and man (SEITZ, 1894; DIETZE, 1921; NORRIS, 1934). While this habit of diurnal Lepidoptera does not seem to be more frequent in S and SE Asia than in Europe, nocturnal zoophily and anthropophily can be a common, at times even annoying, occurrence in or near forests of such regions as N Thailand (e. g. BÄNZIGER, 1985, 1987, 1988a). In a more advanced stage of this feeding habit, many of these moths engage themselves in nocturnal tear drinking at human eyes, and, far more frequently, at the eyes of ungulates and proboscidians. Lachryphagous moths belong to 6 families: Noctuidae, Geometridae, Pyralidae, Notodontidae, Sphingidae, Thyatiridae (DE JOANNIS, 1911; COLLENETTE, 1928; SHANNON, 1928; BÄNZIGER, 1973, 1988b) (references of first records only).

Lachryphagous Lepidoptera suck tears with a certain discretion so as not to offend the sensitive eye region beyond the tolerance of, or even perception by, the host. They have mouth parts of the generalized lepidopteran type, i. e. a thin, flexible, little sclerotized, blunt proboscis lacking any cutting armature. On little sensitive hosts such as bovids, though, the persistent *Arcyophora zanderi* FELDER in Sudan and *Lobocraspis griseifusa* HAMPSON in SE Asia may irritate the eye and conjunctiva to some extent by rubbing the proboscis on them (REID, 1954) in order to increase lachrymation; some of the tear drinkers may also "lick" blood and exudates from wounds (MARSHALL *et al.*, 1915), but again without causing any lesions to the underlying tissue (BÄNZIGER, 1973).

On the other hand, the feeding technique of *Calyptra* spp. is entirely different: theirs is a strong, modified proboscis with a fierce drilling armature which, aided by a unique piercing mechanism, can penetrate live tissue (BÄNZIGER, 1968, 1980).

Because of the scarcity of *Calyptra* spp.—some became known to science as late as 1979—and the difficult working conditions connected with this particular type of study, progress during the past 20 years has been slow, though steady. From what was originally thought to be a one-species prerogative, skin-piercing blood-sucking is now confirmed to occur in at least 7 S and SE Asian *Calyptra*, viz. *eustrigata, fasciata* (MOORE), *minuticornis minuticornis* (GUENÉE), *orthograpta* (BUTLER), *bicolor* (MOORE), *parva* BÄNZIGER, *pseudobicolor* BÄNZIGER. It is virtually certain in *fletcheri* (BERIO)—piercing so far not seen in nature but observed in experiments—and is found in an apparently lesser developed degree in *ophideroides* (GUENÉE). It seems to be absent in the Papuan subspecies of *minuticornis*, viz. *novaepommeraniae* (STRAND). Accounts of the ecology, ethology, evolution and other biological aspects of the first 4 species, and the last subspecies, were given in BÄNZIGER (1986), while those of the remaining 5 species are in preparation. Only males were found to be haematophagous.

The present study reports, in chronological order, the first fully substantiated cases which occurred under natural conditions in the field of *Calyptra* spp. drinking human blood following a piercing act.

Pre-piercing and piercing behaviour; drilling mechanism

The piercing behaviour, the morphology and dynamics of the proboscis and its armature have been described, analyzed and interpreted in detail in *C. eustrigata;* some data were given also for *C. minuticornis, C. orthograpta* and *C. fasciata* (BÄNZIGER, 1980, 1986). For the sake of clarity a few basic peculiarities connected with the feeding act of the 23 cases related below are briefly explained.

Palpating and licking is a typical pre-piercing behaviour in which the end-portion of the proboscis is bent downward and backward so as to bring the dorsal part of the proboscis with its slit-like opening into contact with the surface to be examined, and thereby to allow fluids present there to be imbibed. The action may be accompanied intermittently by brief piercing attempts.

The spindle movement results from the proboscis being bent out to the right and the left so rapidly as to simulate a spindle-like configuration. This is the clearest evidence that the moth attempts to pierce. Perception of a rapid vibratory scratching on the skin by the proboscis at the piercing spot is an indication that the tearing hooks of the proboscis' tip start to grip the skin irregularities (fold, hair, pore, fissure etc., cf. Figs. 5–8) into which the proboscis is thrust. As it starts to penetrate, the spindle movement is quickly reduced in speed and amplitude and then suppressed, while stinging and/or burning pain is usually experienced. The head now oscillates vigorously, a clear indication that the proboscis penetrates more deeply. This is achieved by alternate advancing of the 2 stylets (which form the proboscis) with their backwardly erected barbs. Leceration of vessels and tissue is increased by a succession of partial withdrawals and new penetrations with the erectile barbs of the 2 stylets inclined in opposite direction.

To be, or not to be – a guinea pig

The following considerations explain the sometimes inconsistent reactions of the author to attacks by *Calyptra* as recorded in the chronology below. The main problem with being a host to biting insects, besides the possible unpleasant experience one may have to go through, is the risk of infection with pathogens. And, since skin-piercing blood-sucking on man by Lepidoptera is unexplored terrain, a disease contracted in this way may be new, and a cure unknown. Nevertheless, the only way to find out whether man actually is a host of *Calyptra* in nature is to let it bite, and feed to see if human blood is acceptable. An additional advantage is that valuable information about the piercing process can be gained that would be difficult to obtain if an animal host were used.

After an initial all-out approach typical for a youth's reckless enthusiasm, the author adopted a more prudent procedure, though still gambling on the assumption that man is an extraordinary victim – now disproved to some extent – and hence an unlikely host for biologically transmitted pathogens.

At the time when the author made the first experiments with *C. eustrigata* piercing his fingers, he had already 2 years' experience with lachryphagous moths drinking tears from his eyes, both in nature and in experiments. No complication ever ensued from those encounters, other than temporary inflammation of conjunctiva and eyeball epithelium. However, since the proboscis armature and way of feeding and piercing of *Calyptra* would have been particularly well suited for the mechanical transmission of microorganisms, experiments were carried out two or more days after the moth's capture when the survival of potential pathogens was deemed drastically reduced. Later on, when the immatures and host plants of some *Calyptra* spp. were discovered, and it became possible to rear them, laboratory bred individuals were used for experiments. As over the years no complication ever arose, the author felt the danger of contracting a disease to be fairly remote.

However, the situation was different with attacks occurring naturally in the field. The time lapse between an attack on an animal and an attack on the author could be shorter than a minute. Moreover, most attacks occurred in a wholly new area – the Lesser Himalayas, where different, possibly more virulent pathogens might have been present, and where not only the moths belonged to other, not yet tested *Calyptra* species, but also they represented "natural", if rare, suckers of human blood and hence less improbable vectors of pathogens for man. The most serious apprehension emerged when, after several successful attacks had already been appreciated, it became evident that in the Lesser Himalayas some *Calyptra* spp. occasionally also take bovid dung, a feeding not observed in SE Asia except in *C. parva* which was proved to take blood from man only much later.

An additional inconvenience concomitant with being a host to moths was the need to abstain from using insect repellents as these might have kept *Calyptra* spp. from seeking and settling on the author. This meant, however, to deliver himself to attack by blood-sucking Diptera which at times can be merciless at night in the tropical forest.

CHRONOLOGY OF SUCCESSFUL ATTACKS ON MAN

In order to keep the descriptions short, in most cases no details are given of the many lachryphagous and other zoophilous moths which were active along with *Calyptra* spp. on or near the hosts. The most common include *Hypochrosis abstractaria* (WALKER), *H. irrorata* (MOORE) and *Scopula* spp. in Cases 1, 9–11, 21–23; *Arcyophora icterica* SWINHOE, *A. dentula* LEDERER, *Pionea acutangulata* SNELLEN and *Scopula* spp. in Cases 2–6, 20; *P. aureolalis* LEDERER, *Scopula* and *Semiothisa* spp. in Cases 7, 8, 15–19. They will be the object of a separate study.

Case 1: C. bicolor

Near Godavari, 1525 m, C Nepal, 12.IX.1984, 20.15 h. No rain but heavily overcast, 2 days past full moon, hence dark at time of attack.

I was studying lachryphagous geometrids pestering a zebu (*Bos taurus indicus* L.) lying on an asphalted road, when they were briefly joined by a *C. bicolor;* it flew away and approached me instead, landing twice on my chin. It started to lick my lips but I chased it away because of fear of disease contamination. It returned and landed twice on my bare knee, licked and probed the area, now and then making short piercing attempts. Then at once it performed the spindle movement. Piercing was successful after less than 10 sec as was obious visually (slowdown of the spindle movement) and from my feeling of the proboscis tip's firm gripping of the skin, soon followed by burning and stinging pains as it penetrated more deeply. The moth was caught without delay for fear of pathogen transmission and that it may escape. Fig. 18 shows a specimen during an experiment.

Case 2: C. fasciata

Valley near Bhimtal, 1450 m, Uttar Pradesh, NW India, 27.VI.1987, 20.45 h. No rain yet in an exceptionally late rainy season, 24 °C. The action took place in front of a farm house in the dim light of an incandescent lamp at some 15 m distance, where the intensity was no stronger than full moon light.

Several lachryphagous moths were on the wing circling or settling on 3 zebu when a *C. fasciata* arrived in swift flight. It then flew slowly around the hosts' legs before disappearing briefly. It returned and started to circle very low around me,

settling briefly on socks and twice on my bare legs. It then crawled up to the right knee and started to perform the spindle movement, and pierced successfully straight away. Stinging pains were perceived though not so strongly as during experiments; the burning pains occurred only at times. Twelve flash photographs (film subsequently lost in the mail) were taken with much bewilderment of an onlooking farmer. In 10 min 3 holes were pierced, the last with such persistence that the moth had eventually to be "torn" off the spot.

Case 3: C. ophideroides (Figs. 13–17)

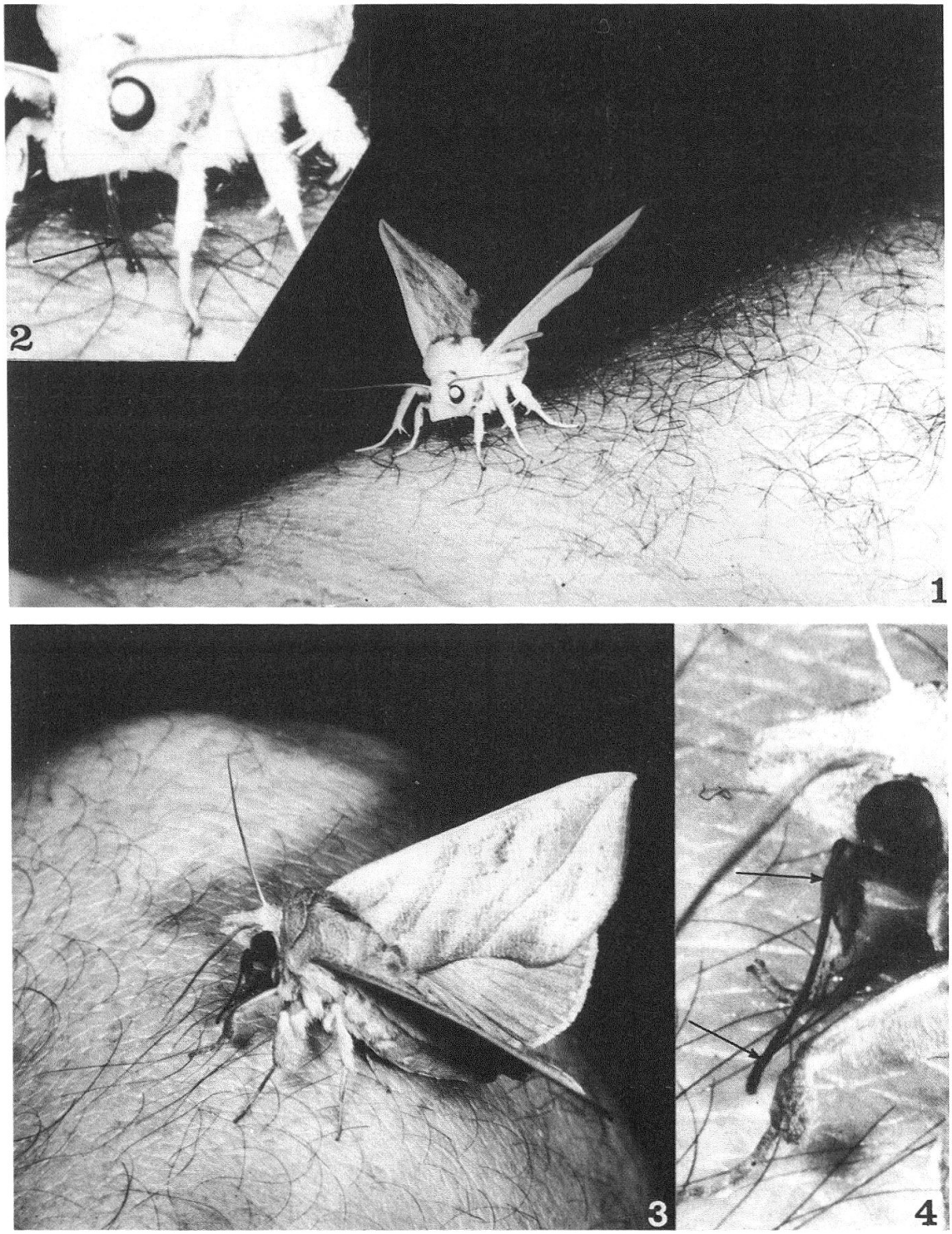
Same general area as Case 2 but near another farm house at the end of a narrow valley with forest covered slopes, 15.VII.1987, 22.00–23.00 h. No artificial light present. Heavy rains fell during the day, everything being wet at night; sky clear, moon last ¼, 18 °C.

C. ophideroides approached and left a group of four zebu three times. It settled briefly on their legs and face–mainly mouth and nose–alighting for up to 10 sec at the mouth. A farmer brought a smouldering ball of earth mixed with cattle dung producing acrid smoke to drive away mosquitoes from the zebu. The moth returned a fourth time and flew around me, especially the legs, landing and moving upwards with beat of wings. It flew off to a zebu despite the smoke (though this was no more than a thin wisp). The moth left but returned a fifth time, approaching my head. It landed on my chin, and started to intrude the proboscis into my mouth. I could feel distinctly a scratching on the lips, evidently due to the proboscis' armature. Then I felt piercing pain on the inner portion of the underlip where it is moist and soft. To reduce pain I used my tongue to push the proboscis away, and felt a rough scratching on the tongue, but no piercing. Again piercing pains on the soft part of the underlip; now these became so unpleasant that I made a sudden movement with tongue and head, causing the moth to fly away. It disappeared only briefly and approached my head again in the same manner as before, landing again on my chin and poking between the lips. I constantly shifted the proboscis away with the tongue, spitting in order to keep possible contamination to a minimum. I made 8 flash photographs; 2 will later reveal a slight reddish discoloration near where the proboscis was applied, proving that blood was oozing from the wound inflicted on my lip (Figs. 16, 17). Then the moth flew off; I made no attempt to catch it as I was hoping it would return a seventh time but this did not materialize although I waited for one hour.

Case 4: C. fasciata (Figs. 1, 2)

Same site as Case 3 but 16.VII.1987, 21.15 h. Warmer (21 °C), clear night.

Starting 20.20 h, one *C. fasciata* had arrived and left, followed by another later on. They settled briefly on zebu or sucked dew mixed with zebu saliva and other body fluids on grass. A third individual soon turned its attention to me. It made two attacks and finally settled on the back of the left knee and started to perform piercing attempts. While I was absorbed with readying the photographic equipment, I presumed the occasional pricks were due to the moth's piercing attemps. When I was through with the camera I discovered with some consternation that the proboscis had already penetrated ⅘ of its length, which is unusually deep. Originally I did not intend to let the moth more than just prove its intention and capability to pierce as I now was afraid of possible pathogen transmission after the alarming observation that this species occasionally can also feed from



Figs. 1–4. 1. Case 4: *C. fasciata* sucks blood by piercing very deep into the back of the author's knee. 2. Same, enlarged detail. Arrow shows position of proboscis. Compare depth of penetration with Fig. 4. 3. Case 6: *C. fasciata* piercing a spot above the author's knee. 4. Same, enlarged. Arrows show the proboscis. All photographs were taken by the author under natural conditions in the field (except Fig. 18) and document actual cases as described in the chronology.

dung. However, I could not restrain myself from documenting photographically the proboscis' deep penetration (Figs. 1, 2) with 5 shots, after which it was quickly captured. A pale swelling was produced around the pierced spot, an inconspicuous red dot; after an hour it grew to a surface area of 5 by 7 cm diameter, remaining this size for several hours before contracting. Back home, the rest of the night proved to be quite sleepless for me. I attribute this more to psychological apprehension over the possible consequences of the moth's bite than to its direct effect.

Case 5: C. ophideroides

Same date and site as Case 4 but 21.55 h.

At 21.00 h and again 21.15 h one *C. ophideroides* was attempting to settle on zebu (together with *C. fasciata* of previous case). Later another *C. ophideroides* was active for 20 min among the zebu settling at least 5 times on mouth and nose. But after no more than 10 sec it was dislodged by the host which seemed to be disturbed less by the moth than by may attempts to photograph them, in which I did not succeed. The moth also circled briefly around me on three separate instances; it then approached my head and landed on my chin. As on the previous night, the moth rubbed its proboscis on the soft, moist portion of my lips while I was doing my best to keep the proboscis at bay with my tongue, spitting repeatedly the accumulating saliva. After 2 min strong piercing pains were felt at the underlip. Five photographs were made. Pain was becoming too intense to bear any longer and, since I was unable to dislodge the proboscis with my tongue, I caught the tormenter.

Interestingly, the photographs disclosed that, while the *C. ophideroides* of the previous night (escaped) had a dent at the margin of the left hind wing, the specimen of the second night had intact wings, proving that two different individuals were involved.

Case 6: C. fasciata (Figs. 3, 4)

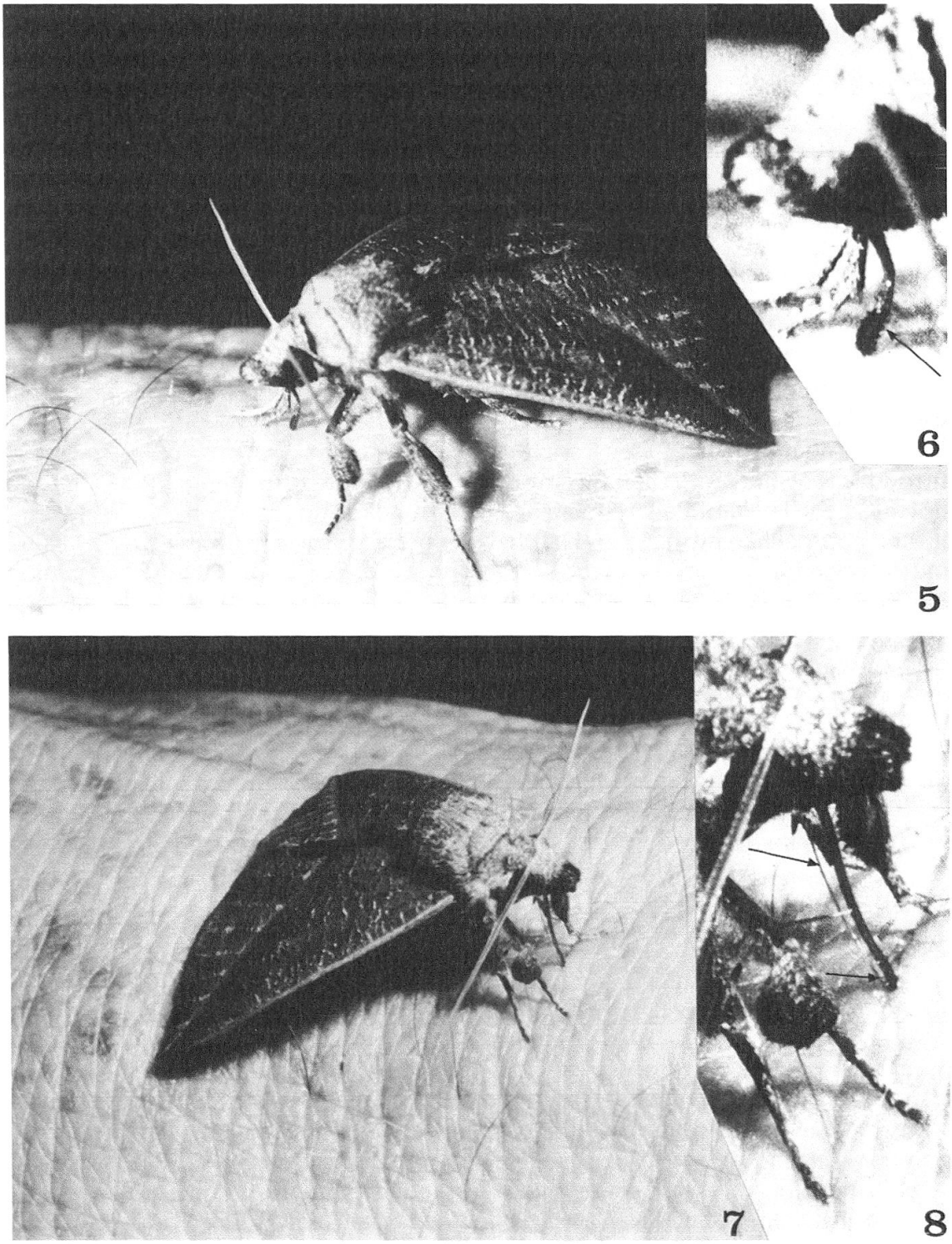
Same site as Case 4 but 20.VII.1987, 20.50 h, 21 °C, rain during the day.

In a first attack one *C. fasciata* circled shortly around me and disappeared; 15 min later in a second attack *C. fasciata* landed on my left leg. For some time it crawled up and down sucking perspiration. It then performed the spindle movement at a spot just above the knee and soon about ½ the proboscis' length penetrated. At first I felt no pain for quite some time, but then it burned twice strongly, somewhat more than a bee's sting, though not for long. Seven photographs were made before it was caught. The spot itched for ½ h after the piercing. A white swelling of ¾ by 1 cm diameter formed; around this a zone of 1 cm width was reddish. Later on it was more swollen and hot. The following day it was still somewhat swollen, warm, and slightly painful on touching.

Case 7: C. parva (Figs. 5, 6)

Open-walled shelter near hut of tiny hamlet, N slope of Doi Chiang Dao, 1150 m, N Thailand, 24.V.1988, 21 h; no rain but very sultry moonlit night, 23 °C. Great numbers of ceratopogonids biting especially the scalp were a constant torment, alongside mosquitoes concentrating on more exposed body parts.

For 20 min one *C. parva* attempted to settle on various body parts of a horse which had a small cut on the leg and a dry wound at the base of the chin—in vain,



Figs. 5–8. 5. Case 7: *C. parva* piercing into a fold of the skin on the back of the author's hand. 6. Same, enlarged detail. Note the erected barbs of the proboscis' armature (arrow). 7. Case 8: *C. parva* piercing at a hair pore in a fold on the skin on the author's hand. The proboscis is well visible. 8. Same, enlarged detail. Note the hair (arrows) near the proboscis.

the host was too restless. The moth then turned on me and settled on trousers, pierced through the cloth but after a min flew off onto the back of my left hand near the wrist. The typical, nearly imperceptible vibratory scratching was felt at times when it made short but frequent piercing attempts. After 5 min it pierced 5 holes – a first set of two holes and 4 cm away a second set of three – at irregular intervals during which it sucked blood for some 5 min. I felt very little, only at times a slight stinging of short duration, comparable to a mosquito bite. The moth did not react to flash photographs and had to be forced off the hand into the killing jar. The first set of piercing spots felt itchy and was barely swollen; the second developed into a whitish swelling of 1 by 1½ cm diameter which felt numb. But slight pain was experienced when pressure was applied. The following morning all that remained was very slight pain on pressing.

Case 8: C. parva (Figs. 7, 8)

Vicinity of Case 7 but another horse "stable", 28.V.1988, 21.45 h. Biting Diptera as mentioned.

I first went to the shelter of the previous case as the horse's wounds were worsening, hence it would be more attractive to zoophilous moths and my own chances to be attacked also better. Unfortunately, however, the hut and "stable" were deserted, the owners arrested. I learnt later it was a robbers' hideout. In the other "stable" one *C. parva* was attempting to settle on two horses. Later another specimen alighted on the back of my right hand. It crawled around extensively while palpating the skin. After 2 min it started with brief piercing attempts not far from the wrist. An extremely short and feeble stinging was felt three times but the moth did not persist. But finally it pierced two main holes and for a brief period a third one. Initially a brief stinging was felt, and only once a short but distinct burning; 2 min later it was caught after 5 flash photographs. The bitten area felt quite itchy and I scratched it repeatedly; it swelled, but 2 h later nothing remained but a slight pain on scratching the area.

Case 9: C. pseudobicolor

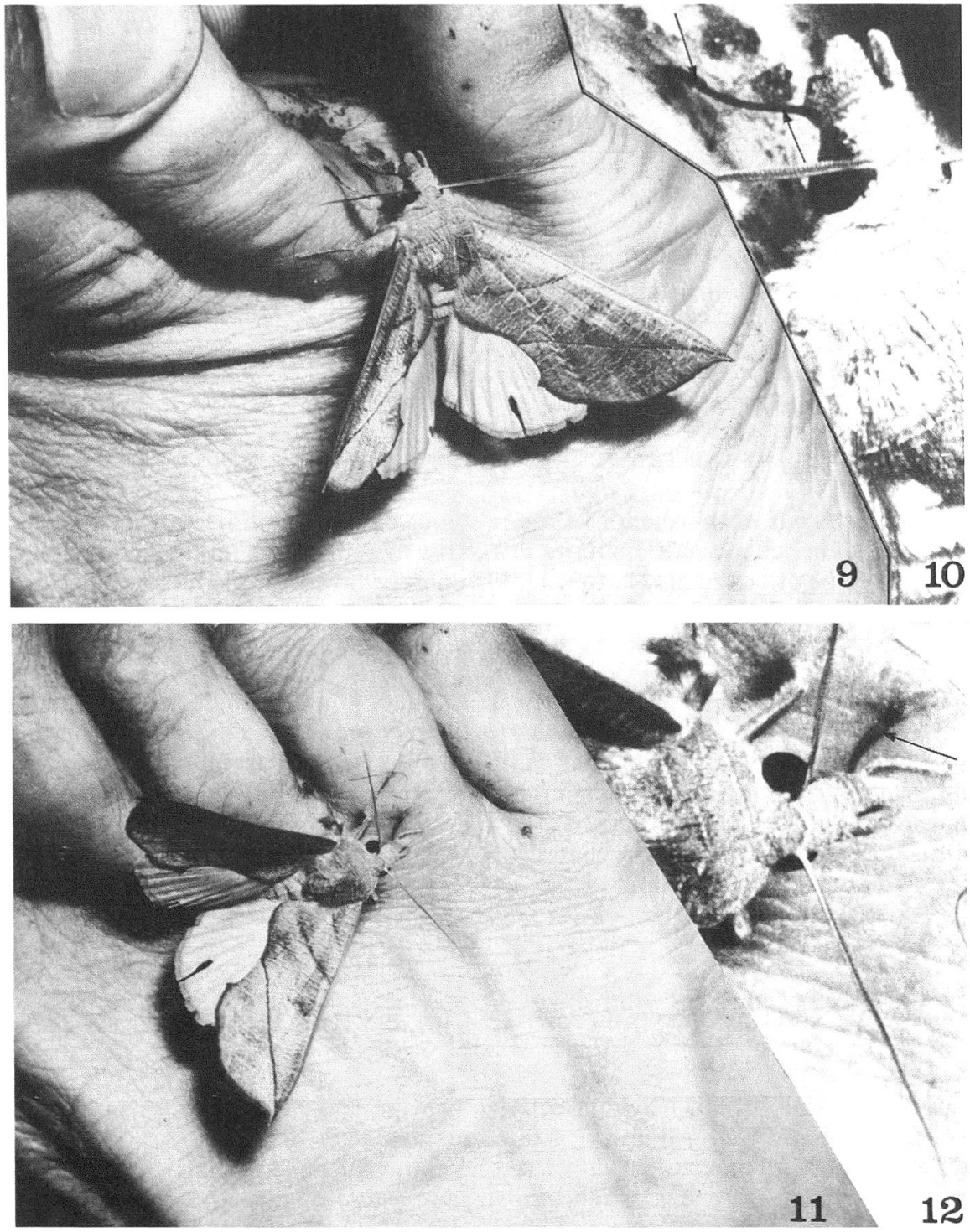
E of Botanical Gardens, Godavari, 1500 m, C Nepal, 11.–12.IX.1988, 00.10 h. No moon, cloudless sky, 17 °C, peach tree orchard above gully with secondary vegetation. Land leeches very common, every night several individuals managing to take blood from my feet; socks and shoes with patches of fresh and old blood.

From 21.30–23.45 h two grazing zebu were sought after by several lachryphagous moths and 4 times by one *C. pseudobicolor* for short periods and 7 times by at least 5 other *C. pseudobicolor.* Another *C. pseudobicolor* attacked me as mentioned in Case 22; 3 *Hypochrosis abstractaria* alighted on, and imbibed fluids from, my forehead, nose and lips. At 00.10 h another *C. pseudobicolor* flew shortly around my head, then quite suddenly landed at my mouth. At once the proboscis was felt on the lips and less than 10 sec later quite strong piercing pain at the inner wet part of the lower lip. The moth was caught at once.

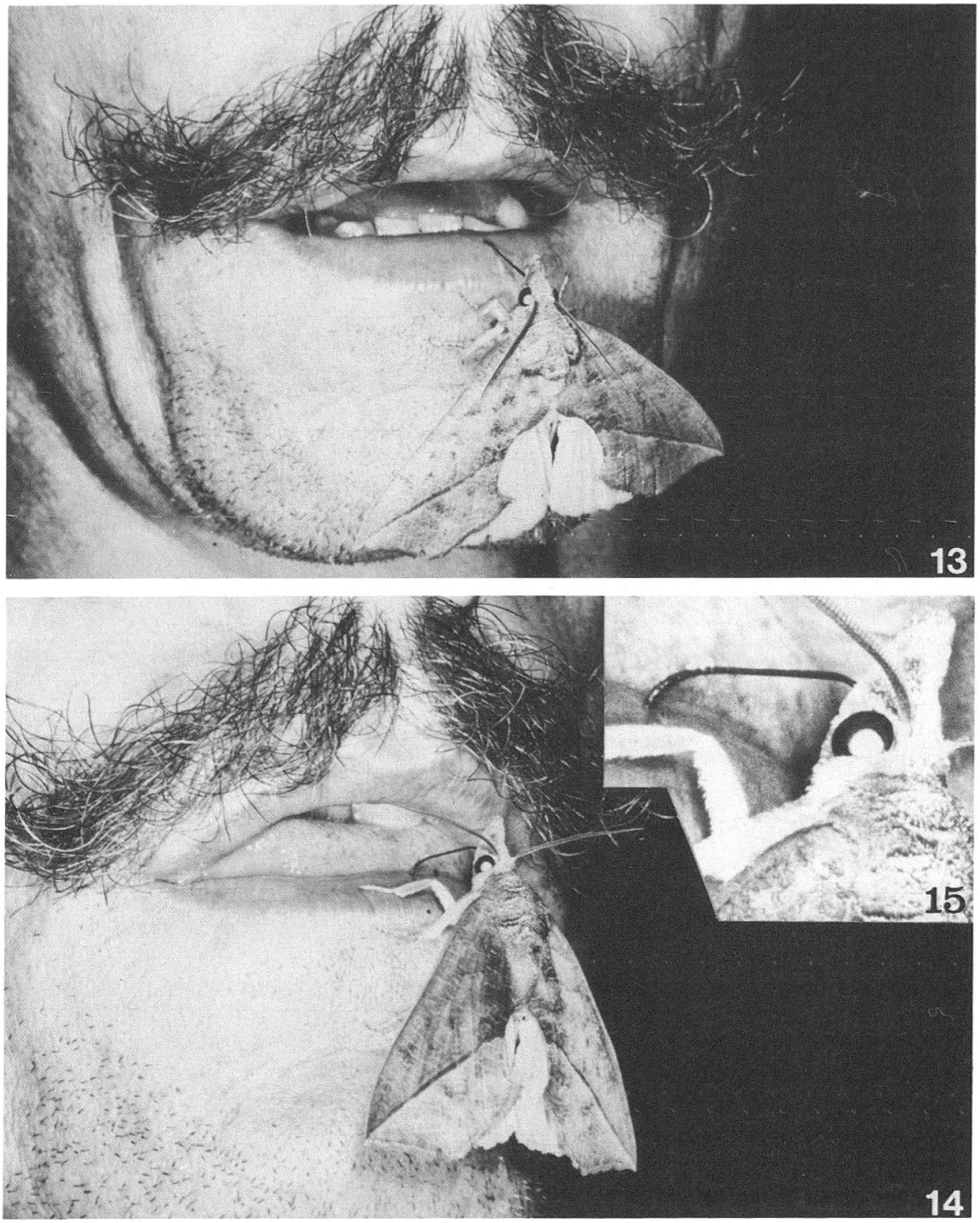
Case 10: C. pseudobicolor (Figs. 9–12)

Same site as Case 9 but 12.IX.1988, 22.55 h, 19 °C, no moon, cloudless sky.

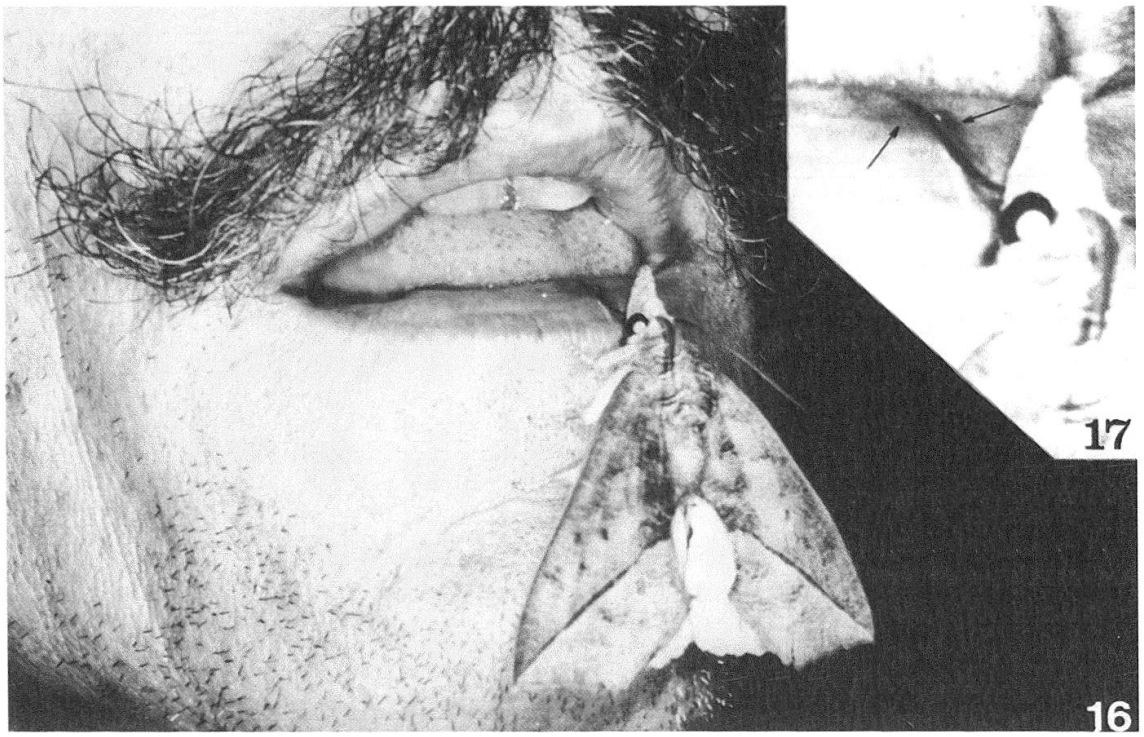
From 21.15–21.55 h *Calyptra,* presumably *pseudobicolor* (specimens not caught), circled and landed on a young zebu bull seven times for short periods.

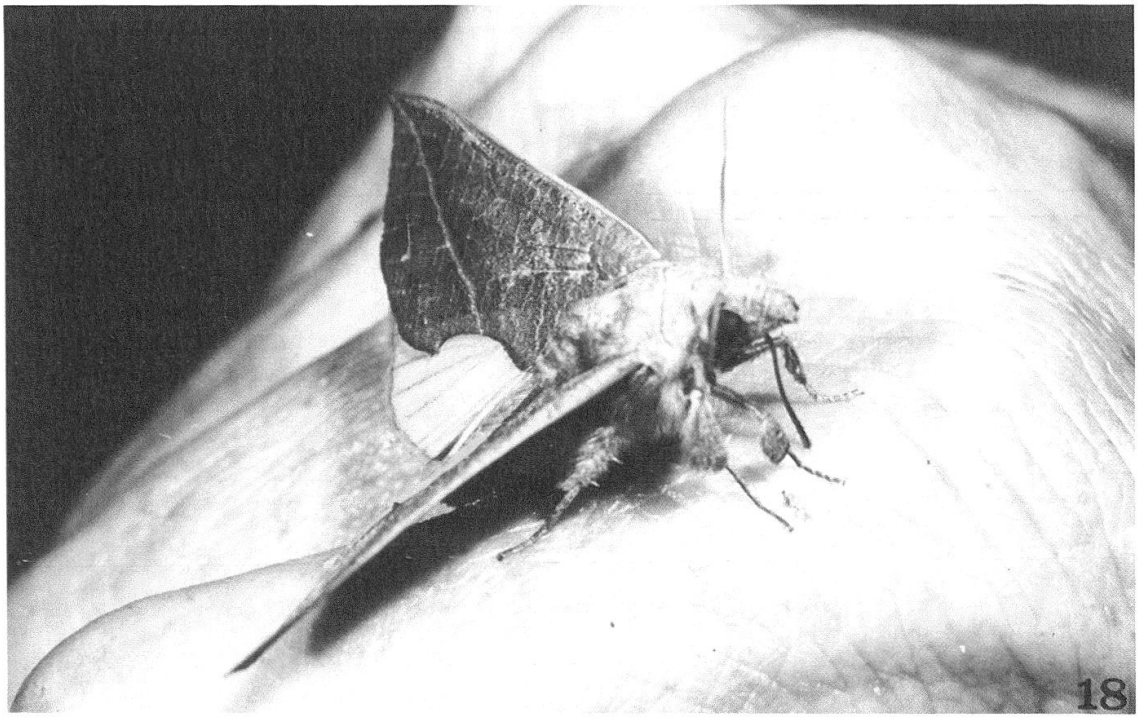


Figs. 9–12. 9. Case 10: *C. pseudobicolor* piercing the scab of a leech bite between the toes of the author's foot; he spreads the toes to show the piercing proboscis. 10. Same, enlarged detail. Arrows show the proboscis. Dark spots are blood crusts of leech bites and coagulated blood flows. 11. Same *C. pseudobicolor* piercing the scab of another leech bite after the author forced the moth off the previous one. 12. Same, enlarged. Arrow shows the proboscis.



Figs. 13–15. 13. Case 3: *C. ophideroides* sucking saliva from the author's lip. The proboscis is well visible. 14. Same *C. ophideroides* starting to pierce the author's lip. 15. Same, enlarged detail. The distal portion of the proboscis is recurved and the utmost tip is penetrating.





Figs. 16–18. 16. Case 3: *C. ophideroides* drinking blood mixed with saliva from the author's lip. 17. Same, enlarged detail. The dark suffusion on the lip (arrows) on either side of the proboscis is blood (red in the original colour slide) oozing from the bite after the author forced the proboscis off with his tongue due to the pain. 18. *C. bicolor* sucking blood from the author's hand. Indoor experiment.

H. abstractaria sucked at my nose and mouth and one *Scopula actuaria* (WALKER) imbibed perspiration from my bare leg. One *C. pseudobicolor* shortly flew around me and landed on my bare legs and arms, crawling constantly. It then flew to my face, stopping shortly at mouth and moustaches without trying to pierce. It flew back to leg and tennis shoe; I bared the right foot and the moth instantly settled on the big toe, where the proboscis rasped around and below the nail for at least 5 min. It then moved on, found the crust of a 2-day-old leech bite and pierced it causing strong burning pain. After 4 photographs I gently forced the moth off the spot but it found the crust of another leech bite which was pierced as before (Figs. 11, 12). After 8 more flash photographs it was caught.

Case 11: C. pseudobicolor

Same general area as Case 9 but S of Botanical Gardens, 1530 m, 20.IX.1988, 21.10 h. Very strong rain in the afternoon but night illuminated by ½ moon, 17 °C; pasture with some trees, secondary forest 50–200 m away.

One *C. pseudobicolor* flew very low and slowly around the legs of a grazing zebu; as this walked away the moth attacked me, landing briefly on my bare legs and arms, finally settling on socks. It pierced through these but left again, flying up while circling around my legs, eventually reaching my face where it settled on my chin before moving to the moustaches. It remained there for half a min, then crawled down and I felt the proboscis probing on and between my lips. A few sec later I felt strong piercing pain on upper lip about where the wet part begins but I caught it without delay.

ADDITIONAL RECORDS: ATTACKS INTERRUPTED OR BEHAVIOUR INCONCLUSIVE

Below are listed attacks by *Calyptra* spp. in which no piercing took place after the moths settled on man, or attempts to pierce were not successful, or the cases were otherwise not clear.

C. fasciata

Case 12, N Thailand, already mentioned in Bänziger, 1986, p 121. No piercing attempt witnessed.

Case 13, site of Case 4 but 19.VII.1987. In three separate attacks the moth settled on both my legs, crawled around, and flew off.

Case 14, Mae Nai, Doi Suthep-Pui, Chiang Mai, N Thailand, 29.X.1988. The moth landed twice at the mouth of a zebu; after some time this vehemently wiped the moth off against the ground (moth piercing?). As it flew off it was accidentally caught in the full light of my torch which seemed to attract the moth to me (they generally flee the light). It landed on my right hand and after 15 sec of palpating, it pierced the skin which connects the base of the index finger and the thumb. At first no pain was felt although the tip of the proboscis could be clearly seen penetrating; then a burning was experienced while at the same time the piercing spot became wet with saliva. The moth was caught at once. This case is not mentioned in the chronology because, despite an actual piercing taking place, the clue behind the attack is not clear: was the moth initially attracted by the light, settling accidentally on my hand which in turn triggered the feeding response, or was it attracted by a "more natural" factor?

C. m. minuticornis

Cases 15 and 16, N Thailand, already mentioned in Bänziger, 1986, p 120–121. No piercing attempts witnessed.

Case 17, site and date of Case 7. Moth settled on my bare leg, palpated the skin, and flew off.

C. parva

Case 18, site of Case 7 but 31.X.1983. Moth settled twice on my hand, took perspiration for 15 min making short but frequent piercing attempts, none successful; it was caught as it flew off.

Case 19, place less than 1 km from Case 7, briefly after nightfall, 9.X.1984, full moon, no clouds, no host animals present. An unidentified moth settled on my chin and introduced the proboscis between my lips, the roughness of the armature being distinctly felt as it advanced deeper. Assuming that the intruder was one of the many lachryphagous moths seeking my tears and secretions, I caught it—only to discover that it was *C. parva*. Had I known it was this species, I would not have interfered but studied the natural course of its behaviour which may well have included piercing attempts.

Case 20, site approx. 1½ km from Case 7, 1020 m, 16.VII.1986, shortly after nightfall, slight rain falling, no animal host present. While attempting to repair my four-wheel drive car which broke down on a steep mud road in deep forest, Mr. P. Schwendinger and myself were troubled by lachryphagous moths. One *C. parva* settled on my colleague's wrist and after some time he uttered in subdued bewilderment and displeasure while shaking his arm vigorously: "But this moth stings like a mosquito!" (He did not know at that time about skin-piercing blood-sucking moths.) Presumably the moth's proboscis had just succeeded in penetrating the skin. The moth returned to the attack twice, once landing on me to palpate the skin and make occasional piercing attempts, all without succeeding. It was not caught when it flew off, as I hoped it would return yet again, but it was no more seen.

Case 21, site and date of Case 7. Moth settled for less than 1 min on my hand palpating the skin but left spontaneously to circle around a horse.

C. pseudobicolor

Case 22, site and date of Case 9. Moth circled around my leg, settled on my tennis shoes and socks humid with dew and stained with 1–2 days old blood from leech bites. It moved to my right leg, licked the skin and tried to pierce; many, short-lived, faint stingings were felt. After a few min it became restless, frequently beating the wings, and was caught as it flew off.

Case 23, near Case 9 but 19.IX.1988. Moth persistently circled around me for some 10 min. It did not settle permanently anywhere though it landed shortly several times on my bare legs. It disappeared, and reappeared from, behind my back (landing on rucksack, shirt?) several times for long periods but then was seen no more.

DISCUSSION AND CONCLUSIONS

Geographic area, environment, where attacks occur

From knowledge gained so far, attacks by *C. bicolor, C. fasciata, C. ophideroides, C. parva* and *C. pseudobicolor* on man can be expected in a geographic belt extending between the southern part of the subtropics and the northern part of the tropics, in mountain areas between 1000 and at least 1600 m, from NW India to Nepal and N Thailand. (So far, *ophideroides* and *pseudobicolor* are not known from Thailand, while *parva* is absent from NW India and C Nepal.) It is quite possible that attacks by one or the other species may take place also in more westerly, northerly and easterly regions, and at higher elevations, since some of the species involved may occur or have actually been caught in the past (museum specimens) in such areas, though their zoophilous behaviour has not yet been studied there. They include mountain regions in E Pakistan, Bhutan, NE India, Burma except the S, SW China (Yunnan, Kwangsi, Kweichow, S Szechuan, and southernmost tip of Tibet), N Laos and N Vietnam. At an elevation of 2650 m in Nepal, *bicolor* and *pseudobicolor* were still very active at artificial lights (this rep.); there is even a record from 3600 m (DIERL, *in litt.*). However, these moths may well just have been flying through those places or been blown there by winds; there is no indication that they were feeding or seeking hosts there, though this is well possible.

Altitudes significantly lower than 1000 m, or more southerly regions than N Thailand (except perhaps some sites high up the Dawna Range), seem less likely places for attacks on man, at least if he has no festering wounds. Such localities have been intensively investigated and no piercing of human skin was witnessed, be it by *eustrigata, m. minuticornis, orthograpta* present in lowlands or by confirmed "man-biting" *fasciata* which in lowland N Thailand (less than 600 m) attacked only animals.

Blood feeding on man occurred from May to September, i. e. only during the rainy season although in N Thailand *bicolor, eustrigata, fasciata, m. minuticornis* and *orthograpta* were found to be attracted to animals also in March and April (dry hot season). In this *Calyptra* spp. differ conspicuously from lachryphagous Lepidoptera which, at least in N Thailand, tend to settle on man just as often, if not more, during the driest and hottest part of the year.

Host seeking and feeding activity was observed during the first half of the night, with or without moonlight, clear or clouded sky, though mainly in sultry or slightly rainy weather, but not in heavy rain and wind; temperatures ranged between 17–24 °C.

The biotopes included pastures and orchards, in or not too distant from forests. The type of vegetation included the lowest part of Lower Temperate Mixed Broadleaved and the upper reaches of Subtropical Semi-evergreen Hill Forest in Nepal (terminology by STAINTON, 1972) and the lower ranges of Forest of Banj (*Quercus incana* ROXB.) in NW India (terminology by OSMASTON, 1927). In N Thailand the biotopes were clearings (mostly hamlets) at the upper reaches of Mixed Deciduous and the lower parts of Hill Evergreen Forests (terminology by SMITINAND, 1966).

Large ungulates, the normal hosts of the moths, were mostly present in the close neighbourhood when attacks on man were witnessed, and evidently were the primary target the moths were seeking. But, as Cases 19 and 20 with *parva* indicate, the presence of animal hosts is not a prerequisite for attacks on man, and he can indeed be the primary victim.

Artificial light, e. g. incandescent light bulbs, interferes with the host-seeking action of zoophilous moths; however, if the light is not intense, and at any rate comparable to that of a full moon, the *Calyptra* spp. can attack successfully. Also smoke, unless profuse, does not completely keep them at bay.

Attacks on man in houses have not yet been observed. *Calyptra* distinctly prefer to seek the hosts in the open. But they do not hesitate to venture below shelters consisting of a roof, and occasionally also into local-type "stables" (in N Thailand a roof with 1–3 walls). In the few cases where *Calyptra* have been found in houses, either flying, resting, or dead, all evidences are that they were attracted and trapped by artificial light.

Approaching, settling and piercing

Approaching, circling around and settling of *Calyptra* spp. on humans were not distinct from the behaviour exhibited when seeking animals (cf. BÄNZIGER, 1986, and in prep.). But there seemed to be a preference to pierce near joints, i. e. the knee, the hand's wrist, and the toes' base.

Successful cases of the 5 *Calyptra* spp. piercing the skin amount to: *bicolor* 1, *fasciata* 3 (in one of the cases 3 holes pierced), *ophideroides* 2 (in one of the

cases 2 separate, consecutive attacks), *parva* 2 (in one of the cases 5 holes, in the other 3 holes pierced), *pseudobicolor* 3 (in one of the cases 2 holes pierced). Unsuccessful or inconclusive cases are 3 in *fasciata* (in Case 14 piercing successful but circumstances possibly not fully natural), 4 in *parva* (in 1 case piercing almost certain), 2 in *pseudobicolor.* In the 3 cases in which *m. minuticornis* settled on man no piercing attempt was performed. Hence this species is no further mentioned among the "man-biters" in this study.

On animals *Calyptra* pierced mainly sores, scabs of healing wounds or otherwise damaged skin. Except the two instances of Case 10, on man *Calyptra* pierced intact skin only. However, the author had no sores or other comparable wounds, though in Cases 1, 9–11, 22, 23, he had scabs of leech bites, a few days old ones, as well as fresh. They were, however, covered by socks or shoes. It can be safely assumed that the author would have been more frequently sought after if he had sores on bare skin areas, and that these would have been the preferred piercing spots. It is possible that the somewhat "inconsistent" piercing behaviour, e. g. the long palpating activity followed by drilling not just of one but of several holes, may be in part due to lack of a clue (fresh, decomposed or dried wound exudates?) which might activate the piercing response.

The piercing of lips to obtain blood is an unexpected new finding. It was previously thought that when settling at the mouth essentially only saliva was taken. This mode of feeding is discussed in the penultimate section.

Calyptra landed on, and palpated, clothed parts of the body in just 4 cases. Only in two of these did the proboscis of one *parva* and one *pseudobicolor* penetrate through cloth, for a short time, without piercing the skin. This was intact at the spot; if there had been a sore, the proboscis might have succeeded in piercing. Blood soaked bendages over wounds, especially if festering, might be particularly attractive.

Once the proboscis penetrates the tissue and the moth sucks blood, it becomes increasingly persistent and oblivious of what is going on around it. Flashlight, movements of the observer or the animals in the herd, or of the host himself may be completely ignored, as clearly exemplified in Cases 2, 7. Hence, unlike mosquitoes and many other bloodsucking Diptera, *Calyptra* run a much greater risk of being crushed by the host. The behaviour is probably another vestige of the fruit-piercing behaviour: fruits cannot flip off intruders.

From preliminary experiments with *ophideroides* on the skin of the author's finger, it seems that the method of piercing in this species differs from that of the other above-mentioned *Calyptra.* Details about this are in preparation.

Pain, itching, and skin reaction

Two findings were made which differ from previous observations. This is possibly due to the fact that the latter were based essentially on experiments with *eustrigata,* a species which does not seem to attack man in nature. The moth's feeding behaviour may have been somewhat "abnormal".

One is that the pains are not always strong (*parva,* Cases 7, 8), and sometimes may be nearly completely absent (*fasciata,* Case 4) with only short-lived pricks being felt. This observation is of some consequence, as absence of pain greatly facilitates successful attack and engorging by *Calyptra* on man, as he does not perceive the intruder's activity. There may be cases, while sleeping or drowsy,

or busy in his occupation, or otherwise in a state of reduced alertness due to other reasons, when man may oversee in the darkness that a *Calyptra* is drawing his blood. This means that, should *Calyptra* ever be shown to be a pathogen vector, man is at a greater risk to be inoculated with disease pathogens than when pain can warn him of the danger.

The second finding is a new interpretation of what causes the pain. The author had originally described the pain experienced as being like the stinging and burning inflicted by the piercing of a hot needle (BÄNZIGER, 1968). The two types of pain were difficult to separate at times. Pain was continuous but at times it was more intense (BÄNZIGER, 1986): this was thought to be due to intense vessel and tissue laceration by the proboscis's armature to increase blood flow during phase IV of the piercing act. The moths evidently are extreme pool feeders (telmophages of LAVOIPIERRE, 1965, 1967). It is now thought that the burning pain is due to the interaction of the saliva with the tissue and that it is strongest when tissue is lacerated, if and when saliva is injected. The burning was occasionally experienced while the proboscis was inactive in the piercing shaft (no anti-parallel movement, no oscillations of the head, nor penetration or withdrawal taking place—a fairly common resting feature setting in intermittedly during feeding). At times the burning started just after saliva was seen to flow down the proboscis, or was seen to collect at the piercing spot (Case 14). Reduction or absence of pain can now be interpreted as resulting whenever no saliva is injected and when the piercing stylets miss, or hit only a few of, the pain receptors.

The skin reaction to bites of *Calyptra* included the formation of an edema over an area of up to 5 × 7 cm lasting for several hours; but mostly a much smaller one was produced and in some cases no pale swelling was detectable. It is not clear if any interstitial fluid was imbibed by *Calyptra* but this seems likely. Haemorrhage occurred around and in the shaft drilled, the biting area felt slightly hardened a day later and in some cases a slight pain was experienced on pressure; this may be due to temporary, localized infection. The reddish ring which formed around the edema in Case 6 is indicative of a reaction against an infection, as is the increased temperature. At other times a slight numbness occurred, while in still other cases itchiness set in which could persist for well over an hour. Besides the temporary and localized reactions mentioned no evident consequences have so far been experienced.

Other fluids imbibed

The feeding by some *Calyptra* spp. upon fluids taken from lips of the author is, as mentioned above, another new result. The 4 species previously studied in tropical, mainly lowland areas, viz. *eustrigata, m. minuticornis, orthograpta* and *fasciata,* only very exceptionally settled and fed upon secretions on the head of animal hosts. They were strict in taking blood form the body and legs. The species in the subtropical/temperate, mountain zone of the Lesser Himalayas behaved somewhat differently in as much as they alighted frequently also at the mouth, and sometimes the nose, of human and/or animal hosts. So far *ophideroides* pierced the author's lips twice in Case 3, and once in Case 5, as did *pseudobicolor* in Cases 9, 11; *bicolor* (Case 1) and *parva* (Case 19) took saliva only but they were given no chance to pierce as they were chased off or caught shortly after settling. The fluid imbibed from mouth is obviously saliva and to some extent blood, but

stomach regurgitates of ruminating bovids may have been sucked as well. As will be described in more detail in a study dealing with *Calyptra* spp. of the Lesser Himalayas (BÄNZIGER, in prep.), these species, and even more so *parva,* show a much broader feeding habit than the *Calyptra* spp. of the tropical lowland. *C. fasciata*'s apparent restriction to animal hosts in N Thailand's lowlands as against its feeding from man and animals in mountains has been mentioned; this euryphagy was found to be even more pronounced in NW India. It is not clear whether this discrepancy in feeding habits is due to ecological factors or to the presence of distinct races.

C. m. minuticornis, a proven blood sucker of animals in the tropical zone, has not yet been seen to be attracted to mammals in the Lesser Himalayas. However, so far only a few specimens have been encountered there; they were piercing fruit. Both males and females of the mentioned species except, so far, *eustrigata* and *orthograpta,* were also found to pierce various wild, and to some extent also cultivated, fruits (BÄNZIGER, in prep.).

People at risk

Persons who might be attacked are woodcutters and other forest produce gatherers, caravan- and herdsmen, campers, hunters, belligerents who, sleeping or active, pass at least part of the night in the open, under a shelter or in a room with a large opening to the outside, and are unprotected by mosquito net or blanket. The geographic area, the environment and other circumstances favouring attack have been mentioned. Also villagers who come out of their home at night to feed their animals or to relieve themselves may be targets. Proximity of animal hosts increases the chances to be attacked, as does the presence on the host of wounds and sores, especially if festering.

However, in the light of the present results, successful piercing of human skin must be considered as a very rare event. *Calyptra* spp. are scarce and localized, and animal hosts much preferred to man. (Approximate frequency ratios: 20 attacks on man against 160 on animals observed during 250 night inspections at places where the 5 spp. are confirmed to occur; several hundred more investigations were carried out at sites of suspected presence.) During the rainy season villagers remain less often in the forest at night, and then generally only with some measure of protection against biting insects since they are then a scourge. The often painful bite should alert the victim in many cases. By contrast, the accumulation of 11 successful attacks on the author occurred only because of his willingness to be bitten, and after many years of search for the right species at the right locations.

Lack of previous reports from N Thailand and the Himalayas about a moth drinking human blood also points to the rarity of its occurrence. Actually, this lack is surprising. Unless *Calyptra*'s behaviour is the outcome of a sudden, recent development of a taste for human blood—a most unlikely possibility—one would have expected knowledge about it to emerge over the millennia, be it only as a legend or fairy-tale. Possibly such lie concealed in some text not yet translated into a western language, or in the oral lore of little studied highland tribes. Yet there may be a more plausible explanation. The few people naturally exposed to the moth tend to live in remote areas, enjoy little schooling, and be seasoned to a life of hardship: what should they care for the systematics of just another of the many intruders they might have swatted in the darkness?

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