



ANNALS

OF

The Entomological Society of America

Volume IX

SEPTEMBER, 1916

Number 3

THE SLEEP OF INSECTS; AN ECOLOGICAL STUDY.

By PHIL RAU and NELLIE RAU,
St. Louis, Mo.

An object in motion always attracts the attention of children, young and old; a butterfly flitting from blossom to blossom, a locust jumping before one in the dusty road, a bee rummaging in a flower, all arouse one's interest. But naturalists, like children, cease to pay attention to insects when the latter cease their activity. Thus the interesting problem of when, where and how insects sleep has been all but neglected.

The claim of this problem upon our attention is undeniable when we consider the importance of the period of recuperation in the life of all of the members of the organic world. The sleep of plants, or even the sleep of cotyledons, has been made into charming classics by Darwin and others; how much more interesting ought to be the sleep of animate objects.

The records of this phase of insect life are meagre and isolated, and are only incidental observations. The only purposeful study on the sleep of insects has been done by Fiebrig. This excellent paper is unique in that it deals with the physiological condition of insects during sleep, whereas the other observations and the present study are of an ecological nature.

Our observations were made entirely in the field, sometimes after dark with an acetylene lamp, but more frequently between twilight and darkness. The latter method yielded the more attractive results since the behavior could be noted when they

were preparing to retire, while in the former one could learn but little more than the position of the insect in relation to its surroundings when already asleep. A few early morning trips afield were very productive.

WASPS.

Chalybion cæruleum Linne.

A congregation of about thirty of these steel-blue wasps was discovered on the under side of an overhanging rock on the bluffs overlooking the Meramec during July, 1908. It was about 10:30 o'clock in the morning and very dark, due to an approaching storm. It was puzzling to see these wasps, usually of solitary habit, all huddled together in a very small space. They were inactive but alert enough that when an attempt was made to take them they all flew away, but soon returned to the same spot. Three times they thus persistently returned to the identical spot when disturbed. The mud nests of this species are usually situated in a sufficiently sheltered place that it is not necessary for the wasp to seek shelter elsewhere; hence there must be some other reason for each one leaving her solitary nest and all coming together with one accord and seeking the appointed meeting-ground and the company of others. There were many other sheltered nooks among the rocks, but no isolated wasps were in them; this leads one to believe that this assemblage was not due to mere accident.

In 1913, I had another opportunity to study these wasps at Lake View, Kansas, and the results of these observations proved that gregariousness in a modified form does occur in this species. This wasp is not gregarious as is the cockroach, spending almost every hour of its life in the community of others, but in a more anthropomorphic sense. Our nervous little blue wasp only after a day's hard toil of gathering mud and constructing her nest of it mouthful by mouthful, of hunting and paralyzing and carrying home a supply of spiders, at the close of day leaves her work and seeks the chosen spot, there to enjoy the company of other workers who have gathered there likewise to spend the night. The males were also there in numbers equal to the females, but how or where these shiftless fellows spent the day, no one knows.

On July 2, at 7:45 a. m., a number of these blue wasps were found assembled on the ceiling of an open cow-shed. The wasps here had collected in two groups about four inches apart, and a few individuals dotted the intervening space; during the next few minutes they flew away one by one to their day's business after having spent the night there. I watched the spot during the day but none of them returned; at dusk however, they began to arrive, and lo and behold! they settled on the same spot and collected in two groups similar to those of the morning.

I waited until almost dark, and when they were fast asleep I removed about half of them with the forceps to ascertain if both sexes commingled. The twenty insects which I took were 9 males and 11 females. In attempting to take these wasps earlier in the evening when they were not fully asleep, I found them to be more than usually nervous and ever ready to fly away. Sometimes when an attempt was made to take one, simultaneously as if by magic all flew away, but when they were asleep the task was easy; sometimes one grasp with the forceps brought down three insects. Close observation showed that none were in copulo.

I resumed these observations when I again came to the farm six weeks later. I then found a much larger congregation on the same ceiling and the identical spot; they were probably the ones I had left and many newcomers. There were a hundred or more crowded into an area of less than one square foot, and again I noticed that while it was yet slightly light my gentlest approach would invariably start them to flight simultaneously as if by signal, and I sometimes even wondered if they had not a sentinel on watch. When these wasps are engrossed in building or provisioning their nests one can observe them quite closely without arousing such a reaction. On this particular evening they were disturbed three times and each time they left simultaneously, but invariably they returned one at a time.

Careful examinations at various times have convinced me that mating does not occur during these meetings, although both sexes are always present, usually in equal numbers. I have never been able to detect any evidence of their mating in the evening or morning, and during the hours of darkness they are in such deep sleep that they are dead to all the world about them. Possibly they meet here preparatory to the marriage flight when the sun is high.

One morning we took about fifty of these wasps from the ceiling and marked them with paint, to see whether the same individuals returned night after night, and for how long a period. During the next three nights from six to nine marked insects could be distinguished in the clusters. Even so small a proportion as this demonstrates that the same wasps returned to the appointed spot night after night. Doubtless some of the wasps succeeded in cleaning off the marks, and others were probably mortally injured by the forceps or the paint. It was interesting to see that on the first and second night thereafter most of the marked insects took their position on the ceiling to the rear of the joist, a position never taken before (the sacred spot was just in front of this joist), but on the third night even these had become fearless again and joined the main body. Two weeks later, upon leaving the farm, I picked up 38 of the insects to take with me, (19 males and 19 females) and to my great surprise two of them still retained markings of sufficient distinctness to identify them, thereby proving that at least a part of the insects faithfully returned to the roosting place for two weeks or more.

What explanation can there be for this diversity between the habits of *C. caeruleum* and of *Pelopæus caementarium*, a wasp very similar, who builds nests which are indistinguishable from those of this species? The one is gregarious at night, and the other, after a day's hard labor of exactly the same kind, seeks solitary shelter under some friendly leaf.

This discovery that the blue wasps congregate at night solves the problem of the group under the rock at Meramec Highlands. When the sky became clouded and darkness fell over the earth at mid-day, this afforded sufficient stimulus to prompt the wasps to hie them to bed, in much the same way as darkness affects poultry.

This work suggests many interesting problems: Is this gregarious habit at night an incipient stage to higher development and socialization, or is this condition a vestige from the time when they or their ancestors were social insects?

Since the female alone works hard at nest-building and provisioning, what becomes of the male during the day, where does he go, and how does he spend his time?

Since it seems that mating does not occur during the night and since the female is busy at her work during the day, when

and where does mating occur, and is more than one union necessary?

Has this gregarious habit been acquired as a means of protection and mutual guarding, since the sting of this insect is very mild?

Sceliphron (Pelopœus) **cæmentarium**.

Even in localities where *S. caementarium*, the common mud-daubers, occur in abundance, I have only once been able to discover how they sleep and where they spend their nights, since they do not remain on their nests after working hours. During the summer of 1915, from June 1 to 5, two mud-daubers returned each night to two distinct elderberry bushes, and while they did not always take the same branch they usually occupied each the same plant. Night after night I watched them until nearly dark, and found that as it became darker they grew quiet and so remained, resting on the foliage in an easy but not exaggerated posture.

One day late in May it suddenly became cloudy and quite dark at mid-day, and a few drops of rain fell. At this time I discovered eight *Sceliphron* on the elderberry bushes, intently walking up and down the stems. In a few minutes the sun shone brightly again and they flew away. I watched the bushes for their return, but they did not appear. Soon after that another cloud darkened the sky, and four wasps promptly reappeared. They walked about nervously on the stems, and when the rain fell fast they all flew away, probably to better shelter. They may have been only seeking prey; if they were really seeking shelter, they certainly would have found better at their nesting-sites.

On several evenings some of these wasps accompanied *Sphex* (*Ammophila*) *pictipennis* to their regular sleeping places on the elderberry bushes, but each time they soon wandered elsewhere. (see p. 231).

Sphex (*Ammophila*) **pictipennis** Walsh [S. A. Rohwer].*

In my garden are three elderberry bushes fifteen feet apart. At this particular stage of growth they all bore unripe berries. I mention these facts in detail because while the plant was comparatively abundant in the vicinity it was on one bush, the

*Following the suggestion of Dr. Cockerell in the Ent. News, we place in brackets the name of the gentleman who kindly identified the species for us.

middle one, and on only one cluster of green berries that certain sleeping performances of *Sphex pictipennis* were staged.

At twilight, July 14, 1913, three insects were resting on this umbel of berries. They were just beneath the spray; their position was horizontal, their mandibles locked around the petiole of the berry, and most of their legs were hanging free in the air. In this they practically agree with the observations by Mr. Banks. He notes them in a horizontal position on the tall grass, holding on by the mandibles, but with the legs touching the stems.

At first, the insects were disturbed by my presence, but later in the evening they showed no signs of consciousness of me when I pressed close enough to ascertain that the mandibles merely formed a circle around the stem, and did not bite or pierce it or draw out its juices. All three were females. They had to be taken up with the forceps in order to ascertain the sex; one was kept for the cabinet and the other two were replaced but they were too sleepy to hold on and both fell to the ground, and could only summon enough energy to creep half way up again. At 7 o'clock the next morning they were in the same places, but highly alert; when I approached within five feet of them they were up and away, while only a little while before they had been too sleepy for self-protection. After the rough handling they had undergone in the examination I hardly expected them to return, but to my surprise at 6 that evening I found on the identical cluster not alone these two but three additional ones also. From 6 until 7:30 they were nervously walking about on the cluster and twig. The antennæ were actively in motion. Several times they flew to a near-by bush, but always returned soon to their original cluster. At one time they were followed by two *Pelopoeus caementarium*, but these soon left. At 7:30, however, they all seemed to be quietly at rest in their characteristic positions on this chosen spot.

Had these two wasps then really communicated with the other three and induced them to sleep on the same bush? Or had these three followed the original two? Or had these five arrived at the same spot by mere coincidence? Let me say that I could perceive no sociability among these five wasps; while it was still light each nervously examined the vicinity independently, and finally sought a resting place on this one cluster, from one to three inches apart. Therein they differed from *Chalybion*.

I then decided to mark them to see whether the insects coming each evening were really the same ones. It was very near dark, and an inartistic piece of work it was, but they must have been in deepest sleep, for they were motionless while I applied the paint. At midnight not one of them had moved an iota, and they were so lost in slumber that when the candle was brought very near to them it aroused not the slightest response. The next morning found them in the same position; one by one they awoke, rubbed their antennæ as a sleepy child rubs his eyes, and independently flew away without ado, the last one leaving at 7:30.

At 4:30 that afternoon, (July 16), a vigilant watch was begun to see if the marked individuals would return, and if so whether they would come in a body or singly as they had gone forth. At 5:30 one wasp arrived and a half-hour later two more. Two were marked insects, and the third was a stranger. All hovered about from twig to twig and sometimes flitted off to other bushes for a brief sojourn, but the two marked individuals returned frequently to their favorite spray. At dusk the two were settled and ready for sleep in the accustomed place, but the stranger, probably finding the situation not to his liking, sought other quarters and was seen no more. The next morning the two sleepers were just as I had left them. That night the incidents were repeated in every detail, the two marked wasps (they were females) finally remaining and the stranger departing. On the succeeding night, however, only one of the marked wasps appeared to spend the night in the accustomed spot. Again a stranger, perhaps the one already mentioned, accompanied her and in the usual fastidious manner examined the twigs and found the place unsatisfactory and hied itself to another berth.

The next evening, July 19, the two marked wasps and the guest again returned and all of them again buzzed about their particular green cluster, and as usual the stranger departed. But the two old residents this time sought a place on two distinct bushes. A new situation had arisen this evening, however; a lot of disgusting, newly-hatched Hemiptera (*Anasa tristis*) were actively occupying the favorite spray. Hence we cannot be surprised that the two wasps, finding their abode usurped and their peace disturbed, departed after a short visit to other bushes. The one which had spent the night elsewhere gave no evidence to account for its wanderings.

I watched for these old residents every day, but it was not until a week later (the Hemiptera were by that time gone) that one returned to the old home to spend the night, but if it had been marked the paint had worn off. I did not want to frighten it away by marking it. The next evening, July 28, I found three wasps here, all unmarked, but they were more skeptical than ever (as would be expected of first-nighters). Every time I approached them they flew away, but persistently returned. I tried to find marks on them but could not; they may have been my lost friends with their identification marks rubbed away. I could not bring myself to annoy them with markings, so I left them, hoping they would return with their friends the following night, but they returned no more.

Later in the season, October 7, I saw three wasps of this species asleep out in the field. Here too they were in their characteristic position, the body stretched out horizontally, the mandibles encircling a twig and most of the legs hanging free in the air while the others lightly rested, in a casual way, upon the twigs beneath. Two were on sweet clover and one on goldenrod. Others of both sexes were seen during the last half of August, in the regular position upon erigeron or white snake-root. One was found hanging vertically by the mandibles. Their way of spreading out their legs in the air may be a form of relaxation.

***Elis 5-cincta* Fabr. [S. A. Rohwer].**

These wasps are probably parasitic upon certain beetle larvæ; they build no nest, but sting their prey in its natural habitat, deposit an egg thereon and leave it.

On a hot day in July, 1912, we found at 4 p. m., hundreds of *Elis 5-cincta* at rest on the partly submerged vegetation of a temporary pond. When we neared them they all flew away but eventually returned. The remarkable aspect of the affair was that all of them were males. We supposed that the excessive heat of the day had driven the males to rest early, and that the females would soon follow. No similar congregations were to be found on the surrounding vegetation, although this field abounded in both sexes of this species, and especially the females were plentiful and at work on the white flowers of the melolotus at the time that these males were at rest.

In August of the following year at Lake View, Kansas, sufficient observations were made on the sleeping habits of these insects to prove that in this instance the males had not congregated for the purpose of meeting the females, but that the males alone of this species are gregarious in habit, and perhaps all in the region 'round about occupy one centrally located sleeping place.

One such colony we discovered asleep on a clump of *Aster multiflora*. The plants were two feet high, and with their low, spreading branches covered an area of two by three feet. They were three feet from a small creek and about ten feet from a high mud bank on the other side. Although for a good many evenings we examined all the vegetation in this vicinity we found no sleeping *Elis* elsewhere. Only the males occupied this bush, and only at night; they did not use it as quarters for mid-day rest.

While it was still a little light these too were shy and were easily frightened away, but before night they crept back one by one to their own roost. Several times each night for several nights I gently stirred the bush to see them scamper off, but always when I returned after an absence of fifteen or twenty minutes the bachelor quarters were again filled. These oft-repeated disturbances did not discourage them. For a period of five nights and mornings I examined this bush and saw only males, but still I thought that closer examination surely *must* show a few females present. So early one morning, when just a faint streak of daylight was appearing, I found all on the bush fast asleep, and with rapid sweeps of the net I took about one-third of them, 105 individuals; there was not a female among them. Even while I was picking the insects out of the net some of those which had escaped returned to the bush; even the commotion of sweeping the bush had not permanently frightened away those which had escaped me, and the bush was again teeming with inhabitants.

The following details for 1914, both at St. Louis and in Kansas, show that the sleeping conduct already recorded is not due to local or environmental conditions, but that their behavior is constant despite the intervention of time and space.

On July 18, at Lake View, Kansas, another large colony was discovered still asleep at 5:30 a. m. I shook the plant vigorously to note their behavior; they did not fly high in the air as they

do early in the evening, but dropped to the grass below, spreading their wings to ease their descent. Here we have at once conclusive evidence that this massing together of great numbers does not afford protection from the birds, because they all behaved thus stupidly, making no effort to escape when attacked at an hour in the morning when the whole bird population is alert and riotous with activity. I cannot say whether the weather, light or some other factor caused their behavior to differ this time from the previous morning experiment.

About the middle of August a colony was found in a clump of *Erigeron canadensis*. Night after night they returned to these same four or five stalks, several hundred strong, and all males. The whole made a pretty group; the tall, stately plants were in themselves graceful; the stem for about one-third of its length was literally covered with the delicate, bright-colored bodies, while each slender leaf bore one, or occasionally two, on its lower surface.

On August 13, it was cloudy and dark at 6:30 a. m. About two hundred males of *Elis 5-cincta* were still asleep on five plants of *Erigeron canadensis* within a radius of three feet. They were ranged without crowding in single file on the long, narrow leaves and stately stems. When disturbed they dropped languidly to the lower leaves or the ground.

The next morning the gloom continued. At 10:15 a. m., the *Elis* still remained on their customary sleeping-quarters, too indolent to bestir themselves on a dull day. By 4:30, a high wind was blowing; they were rocked violently to and fro on their tall stems without being stirred to flight, but the approach of my forceps at once caused turmoil among them. By 6:30 the sun shone brightly, but *Elis* remained at home.

On the same dull day three other colonies were found on the under side of the broad leaves of some weed, but I cannot say whether this was their regular sleeping quarters or whether they had thus come together for only temporary shelter from the threatened storm. One group comprised 25 individuals, another 15 and the other 12.

A thick mass of weeds, especially *Erigeron*, bordering a large, open space of ground, seems to be a favorite habitat of *Elis*. In the middle of one such spot about two hundred yards in length, we found a crowded clump of 27 plants each bearing

from 2 to 60 males. Although it was past seven o'clock on an August morning and the sun was high, all were still at rest.

At 5:30 in the afternoon, while it was yet full day, I examined two large dormitories of *Elis* and found almost all of them in their sleeping position already, although they were yet very susceptible to even a slight movement at some distance. One of these groups occupied certain plants in the heart of a clump of *Erigeron*. By 7:05 o'clock when I returned to the place they were at rest on these plants in great numbers. Suddenly, without apparent provocation, they all arose and flew about in circles for several minutes before they again settled. Some cause other than myself was responsible for the disturbance, for I stood fifteen feet away. The behavior was the more strange because they had become well settled in the hour and a half since first I had found them there. Furthermore they settled promptly to perfect quietude again, so that only a few minutes later I removed a whole plant with one vigorous stroke of the knife and carried it some distance without perceptibly disturbing them.

One month later, September 24, one lone male *Elis* was found sleeping at 6 p. m. in the head of a white snakeroot. This one, the belated straggler of the season, was the only one I ever saw sleeping in solitude. It was the last seen that year; neither have I been able to find them earlier in the season than June 16.

Thus it is clear that this gregarious sleeping institution is not a thing merely of local origin but one deeply ingrained in the species. Yet in spite of these observations on so many hundreds of the wasps, we have no light upon the question of why the males congregate thus and where and how the females sleep.

***Priononyx atratum* Lept. [S. A. Rohwer].**

One side of the road was lined with clumps of *Erigeron canadensis*. These tall, slender plants were at this stage of their growth about five feet tall. They seemed to be the dormitory of the wasps of this species which worked in a near-by corn-field.

At 5:30 o'clock on the morning of August 13, I found six wasps sleeping very close together at a point about three inches from the apex of one plant. The other stalks harbored no insects at all although they grew very close together in this one clump. I mention this to show that they could as easily have

chosen plants of the same species and equal desirability very near for independent sleeping quarters if they had been so inclined.

In another clump of the same plant a short distance away, three wasps were asleep in the same huddled condition, and on the identical part of one plant, clinging to the stems with the legs instead of the mandibles, as do some other species of wasps. On another scattered group of *Erigeron* not far away, four of these insects were asleep on the tops of four distinct stalks.

At the same hour of the morning three days later I examined a patch of *Erigeron* in another location and found that the wasps rested in the same manner very near to the top of the plants. Five of these plants harbored one each, and five others bore from two to eight. In every case they were crowded together near the top. The sex was ascertained for 24 of the last lot; they were exactly equal, 12 males and 12 females. Early in the evening they were alert and easily alarmed, but by ten o'clock they could be approached with a strong light, or the stalk upon which they rested could be stirred without arousing any response in the wasps. Even the strong light and warmth from the carbide lamp held for several minutes within five inches of them did not arouse them or delude them with the idea that daylight had come.

Records of about fifty other individuals of this species, at different times and places, show conduct as varied as this; about half of them slept alone, near the head of ironweed, white snakeroot and similar weeds, while the others spent the night in groups of from two to eight, or in one case as many as sixteen. Thus the gregarious tendency is sometimes, although not always, present. In only one instance am I positive that a certain individual came back a second night to sleep on its own particular twig, but the habit of returning night after night each to its chosen spot may be common among them. It would be of interest to ascertain whether this is a fixed habit among them, or only a trait appearing occasionally, a habit developing or declining.

I could ascertain no conditions deciding the question of whether they would sleep singly or in the company of others. Both sexes were present, but I have never observed mating in these night assemblies; the only instance of mating that I have witnessed in this species occurred during the day. I do not see

how safety would be increased by either their aggregation or isolation; if the insects' color and weapon prove sufficient protection for it through its solitary life by day while its enemies are alert, I do not see why it should need further provision for protection at night. Hence the question of the cause or purpose of this imperfect gregariousness still remains open, and even more important than this is the problem again of whether this tendency is ascendant or declining. We may have here the opportunity for a study of the rise of instincts; if so, it will be worth long observation and careful treatment.

Priononyx thomæ Fabr. [S. A. Rohwer].

June 8, 1915, this wasp was asleep on the top of a weed about four feet high on a northern slope of a hill. After being handled rather roughly it eventually roused itself enough to walk when prodded, feebly dragging one foot after the other, but it could not summon enough energy to resume normal activity.

Another was found July 22, at 7:15 p. m. on the top of a dried plant on a hilltop, and a third was clinging to a sweet-clover stalk on a gloomy September evening.

Chlorion (Protosphex) **ichneumonidæ** [S. A. Rohwer].

One July evening at 7:35 when it was almost dark I came upon a sand-wasp at rest, apparently ready to retire for the night. It sometimes turned its body languidly about and occasionally cleaned its face and antennæ, and once it cleaned its wings by thrusting its abdomen above them and rubbing them down.

Two months later, on a gloomy September morning at 8 o'clock, a female sand-wasp was found still asleep on a stink-weed, rather inconspicuous among the fine-cut foliage.

Bembex nubilipennis Cress. [S. A. Rohwer].

These wasps who work so intensely at digging their holes in the earth during the day find shelter in the same hole at night, at least the females do; we have never been able to locate the males' whereabouts at night. It seems the wasp uses her hole in whatever condition it may be, finished or unfinished. At the approach of twilight she creeps into her burrow and from inside she throws up a loose mound of earth to cover the opening. In the morning, when the sun is high enough to begin to

warm the earth, she may be seen scrambling and wriggling out through this loose dirt; if perchance a shower has packed it during the night she emerges looking not a little dishevelled and excited from her exercise butting down her door.

We have opened the nests at twilight and found the mother sometimes in a hole only begun, sometimes almost finished, and at other times already occupied by the larva and its food.

One hole has continued to arouse our curiosity. We had watched it for over a week, waiting for its permanent sealing. Finally at twilight one evening, in company with Mr. E. A. Schwarz, we broke open its temporary closure, and to our amazement found six *Bembex* in the hole to spend the night. In my astonishment I let four escape, but the other two were females. I can hardly think this nest was for sleeping quarters exclusively, for we have never found another like it, and only the day before I had seen a female enter and depart several times as if it were a normal domicile. Is it possible that this may be an example of the beginning of the gregarious or social habit of wasps?

***Philanthus* sp.** [S. A. Rohwer].

In a Kansas wheatfield on August 14, at 6:30 in the evening, a *Philanthus* was found very artfully concealed among the long beards of a head of wheat which had been missed by the harvester and had by this time turned dark grayish-brown.

***Astata pygidialis* Fox** [S. A. Rohwer].

At the end of a dreary August day we found an open hole in our wasp-field which had not been there that morning. There was a little mound of earth outside, but no pretense of closing the hole. It ran down diagonally for about an inch and a half, and snug inside was the owner, *A. pygidialis*. It remains a mystery where this little proprietress spends her nights when her burrow is finished and sealed, or when she has no hole at all.

***Rynchium dorsale* Fabr.** [S. A. Rohwer].

On a July evening just before twilight I found the hole of a *R. dorsale*, with its occupant therein ready for the night. I removed it with the forceps but when I tried to tuck it back in its nest it flew away.

It was deep twilight a few evenings later when we opened the hole of another and found the owner snug in its burrow, resting as calmly as though it were not expecting intruders at such an hour.

Odyneris firmus Cress. [S. A. Rohwer.]

Odyneris geminus Cress. [S. A. Rohwer]

Odyneris sp. [S. A. Rohwer].

The individuals of these species show marked variations in their habits of sleep, sufficient to lead one to suspect that they curl up and sleep wherever it is convenient at the moment of twilight. We have found *O. firmus* sleeping in its burrow and on vegetation; one was curled around a leaf of Erigeron, and another was in the seed-cluster of a pigweed, in such deep sleep that it unresistingly allowed itself to be picked up repeatedly. *O. geminus* was found in September, clinging to the Melolotus stalks, and a turret-building Eumenid was sleeping in her finished burrow, beside her egg and its first caterpillar.

Vespula germanica Fabr. [S. A. Rohwer].

At 6:10 a. m., on August 18, this *Vespa* was just beginning to wake up and stretch itself under a green curled leaf of Hibiscus.

Polistes.

When one comes upon a paper nest of *Polistes* at night he finds the inhabitants quietly at rest, their bodies and legs spread flat against the surface of the nest. I believe they are fully asleep; one may hold a strong light near them for several minutes before they show the slightest response.

Despite the fact that the nests are filled with sleeping wasps, one occasionally finds solitary stragglers asleep among the vegetation. They are often seen foraging or getting nectar when it is almost dark, and it is probable that these are overtaken by night while away from home. During the summer probably twenty individuals in all were seen asleep on the flowers of snakeroot, ragweed and sweet clover. The species were *P. pallipes*, *rubrigenosus*, *aurifer*, *annularis*, *variatus* and probably *bellicosus*. They are up and busy early in the morning; a *P. aurifer* came to a pond for water at 6:15 one August morning, and a *P. pallipes* was flying from plant to plant at 6:30.

HORN-TAILS.

Tremex columbia Linn. [S. A. Rohwer].

On a number of evenings from July to October, I noticed these horn-tails nervously flying about my mulberry bushes, and finally as twilight fell, selecting a roosting place on the under side of a leaf, and always among the lower branches. Whenever I noticed them during the night or early the next morning, I always found them in the same position.

On the evening of October 2, one, after buzzing about for a few seconds, alighted on the under side of a low leaf of a sycamore tree, and there she remained, sleeping until dawn. An examination by candle-light at 10:30 found her unchanged.

While this horn-tail was buzzing about seeking a leaf among the lower boughs under which to sleep, the upper branches of the old sycamore were filled with uproarious sparrows but she feared them not and sought her place and went to sleep, while a little later the sparrows did the same. This circumstance at once suggested an explanation of the usual peculiar choice of this insect. The under side of the leaf, which was invariably chosen, would afford protection from the view of birds, but this only among the lower twigs, which likewise were always selected. It is obvious that a species which followed an instinct or habit of sleeping on the upper side of leaves, or even on the under side of leaves among the topmost boughs, would rapidly be eliminated by the bird population.

BEES.

Melissodes obliqua Say. [J. C. Crawford].

In an open field which sloped toward the River des Peres, St. Louis, was a burnt area about ten feet square. The grass was burned off, but the charred stalks of weeds two or three feet tall were still standing.

When walking along a path through this plot at 6:15 in the evening of July 19, we disturbed a number of bees. They buzzed about the plants, waiting for us to go on, excepting perhaps a half dozen which remained undisturbed. Two of these were huddled together on one dead leaf, so frail and dry that we wondered that it did not break down with their weight.

An examination of the surrounding vegetation revealed no others, although the swarm was buzzing impatiently about awaiting a quiet chance to alight. So we left the spot and returned an hour later. Now we found the 28 bees clustered near the tops of a small clump of stalks. Since it was now almost dark, my presence did not disturb them. They were huddled together in groups of 2 to 5, with only 3 insects occupying their sites singly. They were settled for the night in their characteristic posture, resting on their support with the head downward, the abdomen ventrally curved as far as their chubby forms would permit.

It is hard to refrain from calling this a case of protective environment rationally chosen by the insect. I surely would not have seen their brown bodies blending with the dingy burned leaves, had I not known just where to look for them. In another field about a quarter of a mile distant the sweet clover was abundant, but a careful search revealed no bees.

The next evening 29 bees, only one more, were asleep on these five stems, all clustered on the apical three inches of the dead plants. On the top of another plant ten feet away, 2 were at rest. All were in the same characteristic position. If they had chosen this site for protection alone they would have rested singly on the plants, but since they huddled in groups, they must have sought sociability also. They were so close together in some cases as to arouse my suspicion about their mating, but a close examination proved the idea false.

The following night, July 21, 24 of these bees were here to spend the night in the same way. On the 22nd, 30 were present. On this evening I marked part of them with white paint in order to make sure whether this uniform group was made up of the same individuals night after night. As fate would have it, by the next evening a cow had broken down their chosen stems, so none of the bees were there. However, 15 were found on similar weeds near by; 7 of these bore the white markings. This gave evidence sufficient to prove that the same bees return to their chosen spot regularly. Part of these were taken to see whether one or both sexes were thus gregarious; of the 18 taken, all were males. They made no attempt to move when picked up with the forceps, while earlier in the evening they could not be approached without a heavy buzzing and flying about.

For some reason the group dwindled from this time on, and each night a smaller number came back; perhaps the disturbance of the cow's intrusion drove part of them away. Up to the end of July from 2 to 4 were usually found asleep at night; these faithful ones were always on the same twigs near the original roost.

A second burned area was found some three hundred feet away, similar in all respects to the first and surrounded by green vegetation. Around the periphery of this burned patch no bees were found, but in the center, on a cluster of five brown stems, 14 bees were at rest. Most of them were huddled together in groups of 2 to 7. All were at rest on or near the tops of the plants, head downward, with the characteristic ventral curl of the abdomen. Here again the bees had chosen this dull spot which so delicately suited their coloration, and away from the edge of the patch. In the early twilight many of the bees were busy cleaning their necks, eyes and antennæ with their front feet. No others were found anywhere in the vicinity.

This group of bees, about 14 to 16 in number, also came repeatedly until the end of July, when the group dwindled and suddenly and mysteriously disappeared. By marking the insects we assured ourselves that the same individuals came back night after night.

In the centre of a thick clump of white snakeroot almost ready to bloom was a dried stalk of the same plant from last year. Crowded together upon the head of this one dead plant were 40 of these bees. All were head downward, in precisely the same position as described before, and were quiet excepting for movements of the legs when cleaning themselves or kicking their neighbors. They were thus settled for the night although the sun was still well up at 6 o'clock on an early August evening. Here is another case of bees selecting dried plants of their own color.

Alongside the green plants bearing *Priononyx atratum* mentioned before was a dried stem; this too was the chosen resting place of 4 of these bees, although green plants were much more abundant all about.

On August 4, 19 bees were still at rest on some bushes at 8 a. m., when the whistle of a passing train caused some of them to fly away. It must have been about their normal hour of rising, for within the next three minutes all the others departed singly for their days work.

A considerable number of other observations in St. Louis and eastern Kansas find these insects usually coming together in groups of 2 to 50 to sleep, although occasionally solitary individuals are found. In almost every case a dead dark colored weed was sought out and given the preference over the surrounding green vegetation. None have been seen in the vicinity of St. Louis later than about the middle of August, although they have been sought.

In one case a single bee was found repeatedly snuggling in the heart of a large group of *Priononyx atratum*. It came here regularly with the wasps before 5:30 p. m.

When the bees were at rest one could see some of them completely covered with yellow pollen. Since about twenty were taken in this condition from sunflowers I take this to be sunflower pollen. Others were dusted with whitish powder, probably snakeroot pollen. One evening I was intensely interested in watching one insect caressing the abdomen of a neighbor with her own. I expected to witness an actual courtship and copulation, but it soon proved that she was only cleaning the pollen off her own body on to her neighbor. They frequently cleaned themselves before going to sleep.

The problem of the purpose or cause of some of the insects coming together thus to sleep remains an open question. So far as we can see they could sleep as well on the individual flowers upon which they feed or near their places of nidification. Their persistent choice of the dull, dead plants strongly suggests an element of protection in this selection. Besides the fact that this dull color is in harmony with their own, it may be that their enemies would be less likely to seek for prey upon old dead vegetation than among the green plants which usually harbor insects. But it does seem that the selection of these dark, dried twigs is a conscious choice.

Melissodes argilis Cress. [J. C. Crawford].

This species of long antennæ bee we observed both at St. Louis and Lake View, Kansas. They hied them to the sunflowers at twilight and almost always squatted flat in the disk, usually one in each flower. They did not hold on with the mandibles, but I think they slightly buried their tarsi in the florets. They seemed to be heavy sleepers and seldom awoke when handled or when the light was flashed upon them.

In one instance, on September 2, the stem and flower containing a sleeping bee were rudely jerked off, carried about a quarter of a mile rather roughly and placed in a cage. The next morning the bee was still asleep in exactly the same position, evidently having not moved during the night.

In all, ten bees were observed in the two remote localities. In every case they chose the sunflower and they always spread themselves flat so that their abdomens touched the florets. By thus sleeping beside their work they were ready to resume their tasks bright and early the next morning. I have seen them at 5:45 on an August morning flying from flower to flower already laden with yellow pollen.

Melissodes obscura Say. [J. C. Crawford].

Melissodes bimaculata Lep. [J. C. Crawford].

Melissodes verroniana Robt. [J. C. Crawford].

On some dead dock plants standing amid green vegetation on a hill-top were three little bees huddled close together around the stem. All three were of different species, one *M. obscura*, one *M. verroniana*, and the third escaped without identification. On a similar plant, similarly situated a few feet distant, was another group of three curled around the stem in the same manner; two were *M. obscura* and the third was a distinct black bee, *M. bimaculata*. I should like much to know whether these little bees of this genus are always so select of their company and the nature of their sleeping place.

Apis mellifica Linn. [J. C. Crawford].

On June 9 the sun was getting high by 6 o'clock in the morning. I was walking along Watson Road, St. Louis, when I noticed two worker honey-bees still asleep on a cluster of elderberry flowers. One was picked up with the forceps; it was sufficiently awake to move the legs. The second one moved not at all, even when picked up. Closer inspection revealed a white flower spider, *Runcinia alætor* Htz. [N. Banks] clinging to the ventral surface of this bee, which was dead. Here this little protectively colored spider had succeeded in capturing the bee asleep. I think it could hardly have discerned the prey in the dark, but that it probably saw the bee and captured it with the first rays of dawn. Bees are supposed usually to spend the night in the hive, but in all probability these were foraging when darkness overtook them. They probably work both early and

late, for on August 18 six honey-bees were seen in the newly opened flowers of the jimson-weed, while the same week many were to be seen flying from flower to flower covered with green pollen at the early morning hour of 5:45.

Emphor bombiformis Cress. [H. L. Viereck].

Seven individuals of this species came to the elderberry bush in my garden while it was still light; at 9 o'clock they were in such deep sleep that they could easily be marked. Owing to poor light however, the work was awkwardly done, and the next morning two were found disabled. The others never returned.

Triepeolus helicanthe Rob. [J. C. Crawford].

Triepeolus lunatus Say. [J. C. Crawford].

Triepeolus concolor. [J. C. Crawford].

Triepeolus concavus Cress. [J. C. Crawford].

We have discovered no hard and fast rules for the sleep of these little bees, excepting that, like most bees, they faithfully keep regular hours, from about 6:30 p. m. until the sun is well up in the morning, and that they habitually choose a leaf or twig of a weed about two feet above the ground as their resting place, although the vegetation was of various heights from two to six feet.

The specimens of *T. concolor* which we have seen were simply sleeping on stems in the position they assume during the day. Our three individuals of *T. concavus* followed each his own fancy in settling to rest; one was curled around a stem, another tightly clasped a leaf of *Erigeron* with its mandibles while its legs were free and the body horizontal, and the third assumed a comical position, just hanging over a little stem by its middle like a small boy hanging over a rail fence on his stomach.

The little *T. lunatus* were found still in deep sleep at 6:35 on an August morning. They were sitting in an easy, natural attitude, each on the top of an *Erigeron* leaf, and they were so helpless at this hour that when brushed off they fell down as if dead.

We have observed *T. helicanthe* upon only two occasions. They were grouped in small colonies of three and five. In every case they clung to a little stem by the mandibles while the feet rested lightly upon the vegetation and the body rested head downward.

Calliopsis nebraskensis Cwfd. [J. C. Crawford].

On August 7, when it was nearly dark, I opened a nest of this little bee. She was near the top and I suspect she was still at work for some of the loose soil on top of the mound at the mouth of the burrow seemed quite fresh.

Chrysis perpulchra Cress. [S. A. Rohwer].

These beautiful green cuckoo-bees are very conspicuous near the top of the *Erigeron* at about the height of a man's shoulder or eye, where they settle to rest in the late afternoon. As long as the daylight lasts, however, when they may still be seen, they are too alert to be in any danger of being captured; only when covered by darkness are they helpless. They usually wrap their tiny bodies horizontally about the small vertical stem or petiole of the leaves or flowers. They probably return to the same sleeping quarters night after night, for I found them on the same clump of plants on three successive nights.

FLIES

Proctacanthus milberti Macq. [F. Knab].

Robber flies have a most tantalizing way of evading capture; as one draws near them they remain alluringly motionless until one brings down the stroke intended for their capture; at that instant they fly away with a loud buzz only a short distance and alight again to tempt one and repeat the performance. In the evening they behave in much the same way when approached until twilight is far advanced, when they relax into deep sleep at about 8 o'clock, resting on the vegetation at a height of about three feet from the ground, and may be picked up with perfect ease. Their night position is not different from that of the day, but the feet automatically grip the support firmly. Whenever taken, whether awake or asleep, they always exude from the anus a drop of brown, pasty substance; I do not know whether this is the normal function of excretion or some special means of protection to ward off the attacks of enemies.

A pair of these robber-flies in copula were watched at Lake View, Kansas, August 18, at 7 o'clock in the evening. These two followed the same tactics of resting and flying for short distances when pursued.

Sparnopolius** brevirostris** Macq. [F. Knab].

Near a dozen yellow velvety bee-flies were seen at twilight early in September, gracefully resting on various flowers and leaves, but not one could be caught, even by extreme effort, so quick and agile were they.

While I feel confident that they spend the night in the position in which one finds them at dusk and they eventually relax in sleep thus, yet they are more active and alert throughout the twilight period than any other insect I have met among the higher, swiftly-moving insects. Only late in the season, when the weather grew chill, could they be taken at the twilight hours when most other insects could easily be picked up. They do not congregate in definite swarms to sleep, but frequently a half dozen or so are seen occupying neighboring ragweed or other plants.

Argyromoeba obsoletum Loew. [F. Knab].

On July 29, two of these bee-flies were seen asleep, one on the under side of an overhanging rock by the Meramec River, and the other on a twig sheltered by a protruding rock by the roadside. It was quite dark and both must surely have been asleep, for neither my bright light nor my hand when I picked them up disturbed them, although they are normally very active Diptera.

DRAGON-FLIES.

Libellula pulchella Drury. [R. P. Currie].

Libellula luctuosa Burm. [R. P. Currie].

Anax junius Drury. [R. P. Currie].

Dragon-flies are swift and agile in their flight and are difficult to apprehend during the day, at least those species which are abundant in this vicinity. The sharp contrast between this and their behavior after dusk leaves little doubt that they lapse into deep sleep at night. I have noticed only a few individuals at night, but all of these had chosen for their roost a gray, dead twig among green shrubbery, about five feet from the ground. They rest with the head up, holding on with their feet and automatically clinging tenaciously. After they are soundly asleep, at 7 or 8 o'clock, they are indifferent to a strong light or even to being pulled off their support and handled.

ORTHOPTERA.

Dissosteira carolina Linn. [A. N. Caudell].

These grasshoppers are very numerous in the open fields or in the short grass at twilight, but one may beat the bushes and weeds in vain for them. They are protectively colored for their life on the ground by day, and they continue to make use of the same protection for sleep at night, resting on the gray earth or grass of open spaces.

Hippiscus rugosus Scud. [A. N. Caudell].

This fancy hopper is usually a long jumper, but at 6:30 on a September evening this one made two short flights when I attempted to take him, and refusing to move further he was bottled.

Arphia corinata Scud. [A. N. Caudell].

This grasshopper seemed to sleep more soundly than most of its brothers. One which was found on July 29, on the under side of an overhanging rock was not awakened by either my strong light nor my fingers' grasp.

Melanoplus femur-rubrum DeG. [A. N. Caudell].**Melanoplus atlantis** Riley. [A. N. Caudell].**Melanoplus differentialis** Thom. [A. N. Caudell].

These hoppers, like the others, seem to sleep at night right where they live by day. They are usually found at night or in the early morning clinging, head up, to the stems of stalky plants, such as Erigeron, horse-weed, corn, etc. Sometimes they are alert enough to escape when touched, but they are usually languid, especially in the morning.

Dichromorphia viridis Scud. [A. N. Caudell].

Only two observations were made upon this short-horned grasshopper, at 9:20 p. m. on June 10, at St. Louis. One insect was to all appearances asleep on a grape leaf and the other was actually feeding upon a leaf of poison-ivy, *Rhus toxicodendron*.

Stagmomantis carolina Linn.

Just how or when the devil's horses get their sleep I have never been able to discover, although I have kept many of them under close observation. The males are frequently to be seen

at the lights, and the females in cages are able to capture prey in the dark. They also construct their egg cases after dark, and some of them remain in copulo during the night. These activities were observed during the daytime also. It may be possible that they snatch a little nap between activities whenever opportunity offers.

Amblycorypha oblongifolia DeG. [A. N. Caudell].

Perhaps a dozen of these green katy-did nymphs were seen at rest on the poison ivy, which at that time, mid-June, was tender and bore green berries. Five of these were actually eating the *Rhus*. Three others were at rest on pokeberry plants near by.

Orchelimum nigripes Scud. [A. N. Caudell].

This brown and green hopper was found at rest on the vegetation by 8:30 on different evenings in mid-August, but they were probably awake or sleeping only lightly for occasionally they would move slightly, and one which was picked up bit me so severely that I flung it away in astonishment and it escaped.

BUTTERFLIES.

Pieris protodice [H. Schwarz].

A stretch of vacant land in St. Louis about the size of two city blocks bore a good many patches of the white snakeroot, *Eupatorium ageroides* Linn. At the time when these observations were made the plants had gone to seed, and instead of the pure white flowers at the apex of each stalk was a fluffy mass of awned seed ready to be puffed away by the wind. These gray-white, feathery tufts seemed to be the favorite resting place of *P. protodice* for the period from October 6 to 18.

When walking through the field at deep twilight I saw a number of white spots on top of the grayish heads of this plant, very conspicuous indeed. In this one patch of about twenty-five square yards I counted thirteen of these butterflies, but on the other plants near by, such as sweet clover and yellow daisy, none were sleeping.

It was noticeable that they all thus chose the same kind of plant, but more remarkable was the fact that every one of these butterflies rested horizontally on top of the seed mass with the

head toward the south. A soft wind was blowing from that direction, and a south wind in October may have been sufficient stimulus to excite this choice of position.

An inspection of the field on several other days yielded the following data:

October 7, at 5:30 p. m., 26 individuals of *P. protodice* were asleep on three species of plants as follows:

| | |
|---|----|
| On the seed-mass of white snake-root..... | 17 |
| On the white flowers of <i>Aster multiflora</i> | 7 |
| On the white flowers of <i>Melolotus alba</i> | 2 |

The goldenrod in bloom in abundance near by bore none at all. They all were fast asleep so they could be picked up and replaced on the twig or even on my coat. Two of them clung thus to my coat all the way to my home, a distance of two blocks. These 26 insects rested horizontally on the top of the flower with their heads in the following direction:

South, 15; East, 4; North, 3; West, 4.

The direction of the wind could not be ascertained on this evening; there was very little and it seemed to be variable.

On October 14 at 5:40 p. m. the wind was directly from the south. The butterflies were again at their old haunts and asleep. Of the 34 examined this evening, 28 were resting horizontally on the tops of the white snakeroot, and 3 just below, in a vertical position head upward, and 3 were on the goldenrod in a vertical position. And, it surely cannot be mere coincidence again, every one of the 34 directly faced the south.

In addition there were this evening three yellow butterflies, *Colias eurytheme* and *C. philodice*, on the goldenrod and snakeroot. Two were in the same position in relation to the wind as above, and the one on the goldenrod was in a vertical position with the ventral aspect of the body toward the wind.

The next observations were at the same hour on October 17. The temperature had fallen by this time, and a chill wind was blowing from the southwest. There were only 14 butterflies to be seen, 12 of them resting on the tufts of the snakeroot, and 2 on melolotus, but each and every one of these insects was facing the south.

By October 18 a more pronounced drop in temperature had occurred. A careful search revealed only one butterfly. The wind was from the southeast, and this numbed insect was

facing north. The next day was cold and none were to be found in the field.

The above notes on the position of sleeping *P. protodice* were for only October. We thought that the insects' behavior may have been influenced by the autumn weather, and it seemed desirable to know their sleeping behavior during the entire summer. The notes below give this data for the following year.

A hillside gently sloping toward the north was covered in the early summer with horseweed, wild tansy, ironweed, poison ivy, dock, etc. In the center of this variety of vegetation was a patch, about fifteen feet across, of the white milkweed in flower. On these plants at about 5:30 p. m. were hundreds of these white butterflies feeding, flying about, and a few pairs mating. "What an opportunity," thought I, "to return at twilight and see how the insects orient themselves in reference to wind, light, etc., when preparing to sleep, with sufficient numbers in a limited area to make the data conclusive."

At 7:25 I returned to this spot, but where I looked for hundreds to be asleep on the plants upon which an hour before they had been so exuberantly drinking in all the goodness of life, I found but two fluttering from flower to flower, sipping here and there, and soon these too disappeared. They had left off their gregarious habit of the day and each one had individually sought his own resting place for the night. A few of them were found on near-by bushes, iron-weed, horse-weed and low grass, but these were only a small part of the splendid flock; most of them had flown to some distant place. The nearest butterfly was ten feet from the food-plant, and not one rested on the milkweed.

Since so few were in the immediate vicinity, they never occurred more than one on each plant, and they all rested in a vertical position, with head up. In the question of their relation to the wind we have two points of environment to consider: some of the butterflies rested on low plants and grass in places protected from the wind, and others rested on or near the tops of tall plants, in places exposed to the wind. A gentle breeze was blowing from the east at this time; when we examined the butterflies at rest on the high plants in the full sweep of the wind we found them with the ventral side of the body facing:

East, 22; North, 1; West, 0; South, 1.

Northeast, 3; Southeast, 1; Northwest, 2; Southwest, 0.

This shows that not one was holding its position with its wings against the wind, but that 26 out of 30 were facing entirely or partly toward the east, so the wind could not force their wings open.

Of those in the sheltered places in the low grass we have a smaller number, and in the following positions:

East, 1; North, 5; West, 1; South, 0.

Northeast, 0; Southeast, 1; Northwest, 0; Southwest, 0.

Here in the sheltered spots we find 5 out of 8 facing northward. We could find no reason for this condition unless the moving air was deflected from its course there among the lower vegetation.

If the sleeping butterflies were disturbed early in the evening they would fly to another plant; if disturbed later, just about dark, they would drop helplessly to the ground or a lower leaf and remain there. We routed twelve sleeping butterflies in the early twilight to see in which direction they would fly in choosing their new location. Every one of them flew westward, with the wind. Three of them at first fluttered faintly toward the east, but in a moment they righted themselves and floated westward.

Similar observations at twilight on June 16, when an east wind was blowing showed 39 out of 45 facing windward.

On August 26, about 90 sleeping *P. protodice* were counted, mostly upon the ragweed. The vegetation upon the field was stunted and low, and the wind had a clear, open sweep across it. The wind was from the east, and all but eight of these had their heads or bodies accordingly facing eastward.

On September 8 a strong wind was blowing from the southeast. Each and every one of the 55 butterflies in the field was facing toward the wind. Each one of these was picked up and thrown into the air; about half of them floated with the wind and the others went with much force against the wind, but in every case they soon whirled around and followed the wind.

Seven other countings of *Pieris* in different places and times showed the same orientation.

The question remains: do the insects intelligently orient themselves toward the direction of the wind, or does the wind, when they are languid, mechanically swing them around to the position of least resistance? We have not ascertained whether, if the wind should change its direction during the night, it would forcibly turn the butterflies about in their sleep or cause

them to waken and shift their position. The helplessness of the drowsy butterflies when thrown up into the breeze, and the fact that about half of them tried but failed to go against the wind would lead us to conclude that this habitual position is the result merely of mechanical force upon the languid insects.

Minot points out that the allied species, *Colias philodice* and *Pieris rapae*, begin to alight on the grass and before twilight is ended they creep down to the roots of the grass-stalks and there spend the night in sleep. The difference in habits of those and our species may be due to meteorological conditions. Minot's observations were probably made at Boston, where the temperature and the breezes would probably be more trying in unprotected spots than at St. Louis.

***Pieris rapæ* Linn.**

At 8:30 p. m. on August 17 this white butterfly was asleep on a pig-weed, sitting on the top of a leaf.

***Nathalis iole*, Boisduval [G. T. Hosenfelt].**

At dusk during the early days of September hundreds of these little yellow butterflies may be found at rest or asleep on the grass or on the low twigs of weeds. If one walks through the vegetation while it is still light, they fly up in great numbers; if one attempts to take them he will have difficulty in doing so for they fly away without much provocation. But as darkness falls they become lethargic and may be picked up like blossoms.

They show to some extent the same anemotropism as do *P. protodice*; they always creep down to a sheltered twig near the ground, quite ignoring the many taller plants, as iron-weed and snakeroot, which abound near by.

***Phyciodes tharos* Drury [G. T. Hosenfelt].**

We have a number of records of this species, noted during August and September, and each case differs from the others. Two were found asleep at 10 o'clock in a vertical position on the twigs of a dead willow five feet from the ground; another rested horizontally on the low branches of a cocklebur; another was found drowsily feeding at twilight on the disk florets of a sunflower, and still others were on the ground and on the tops of iron-weeds. They became drowsy and sluggish in the early

evening, near 6 o'clock, but they do not fall into deep slumber until 9 or 10 o'clock, but even then they retain enough self-control and vigor to teasingly wriggle away from one when caught.

***Pyrameis cordui* Linn.** [G. T. Hosenfelt].

This butterfly was found asleep just above my head on a cedar tree in Kansas, August 13. It was so languid that it was easily taken with the fingers.

Thecla melinus [G. T. Hosenfelt].

This red spotted butterfly was found asleep at 5:45 a. m., August 18, on the under side of a leaf of horse-weed, three feet from the ground.

***Anosia plexippus* Linn.**

This milkweed butterfly is a rapid flyer during the day. That it actually sleeps at night I have no doubt after having observed a large number of them in eastern Kansas between August 8 and 18. They usually select the apex of some tall plant, like *Erigeron*, corn or horse-weed, or choose a twig of a tree at the same height, always about six feet from the ground. many are to be seen still on the wing at 6 o'clock in the evening, but by 6:30 they are settling down on their chosen roost for the night, and an hour later they are sleeping so soundly that they are powerless to escape when disturbed. They cling tenaciously to the support in their sleep, and are not aroused by a strong light falling full upon them. Even when handled they show no response, and when dropped, only flutter aimlessly and fall. They are commonly to be seen mating on the wing during the day, but sometimes spend the night in copulo and are very slow to separate when disturbed. They are early risers, and are actively flitting about long before most other insects. On three different mornings in August, many were to be seen flying about at 5:30 and 5:45 o'clock.

***Argynnis cybele* Fab.** [G. T. Hosenfelt].

Lake View, Kansas, August 19. At 6:10 p. m. this silver-spotted butterfly was asleep on the under side of a red-haw leaf twelve feet from the ground. After vigorous and prolonged shaking of the bough it awoke and flew away; the next morning at 7 o'clock it or another of the same species was again fast asleep on the identical spot.

Atalopedes huron Edwards [G. T. Hosenfelt].

A good many of these butterflies were at rest on cedar and other trees at 8:30 p. m. and still the following morning at 6 a. m. At both times they would promptly fly away when touched, but they did not appear in the least disturbed by my carbide light. On two nights, August 19 and 20, they behaved in the same manner, so I do not know whether they were sleeping lightly or only resting.

MOTHS.

Hyphantria cunea Drury [G. T. Hosenfelt].

This species seems to sleep, or at least relax for a night's rest, in any spot convenient at the moment and without any regular manner or formality. We have found them resting after 7 or 8 o'clock upon a variety of vegetation—grass, sunflowers or weeds. However, they may not confine their rest to the night hours, for we came suddenly upon one which seemed to be asleep in the middle of an afternoon in September.

On September 24 I found seven of this species asleep on various plants in a field on a hill-side. It is interesting to note that every one of the seven rested directly facing the wind.

When picked up at night they often struggle clumsily to free themselves.

Hæmorrhagia tenuis Grote [G. T. Hosenfelt].

Only one specimen of this species has been taken while asleep. At Lake View, Kansas, on August 20, at 8:10 p. m. one was found sleeping on a cedar twig five feet from the ground. Neither the strong light nor my carrying it about on my finger disturbed it in the least or aroused its resistance.

Hæmatopsis grataria Fab. [G. T. Hosenfelt].

On the evening of August 19 many of these small yellow Lepidoptera were on the plants, some in copulo, but they were evidently only resting for they were agile in making their escape when we tried to take them.

***Apantesis arge* Dru. [G. T. Hosenfelt].**

This species was noticed only in the latter part of August and early September. They seemed to go to rest for the night on the ground or on the first convenient stem at hand from six inches to three feet above the ground. Sometimes several occurred near to each other, but seldom more than one on a stem. At that time of year they usually rested, head up, on dead or dried stems.

***Utetheisa bella* Linn. [G. T. Hosenfelt].**

This red mottled moth shows the same behavior night and day; when picked up it slowly opens its wings and so remains motionless.

BEETLES

***Diabrotica 12-punctata*.**

Like the striped pumpkin beetle, these spotted cucumber beetles apparently behave at night very nearly the same as during the day. The two insects are often associated together; where you find one you have not far to seek for the other.

On June 10 at 9:30 p. m. several were at rest on the blossoms of the elderberry. I could not discern whether or not they were asleep. At the same hour on August 30 they certainly were wide awake, walking about on sunflowers and feeding on the petals. On August 15 at the same hour and at 6 o'clock the next morning they were in the flowers of the jimson-weed. When the cucumber blossoms were examined at 5:50 a. m. none were found in the newly opened blossoms, but in the old flowers of the day before which had already closed there were several of these spotted beetles. This shows that at least they are not active enough at that hour to migrate speedily.

On September 14 at 8:30 p. m. two spotted beetles were to all appearances asleep on the radial florets of a sunflower, but when the carbide light was thrown on them they gave a slight response in the form of movement of the antennæ.

From these observations I assume that this species has no regular hours or conditions to sleep.

Diabrotica vittata Fab.

I hardly think that these striped pumpkin beetles sleep during the night; at least many of them were active in the jimson blossom at 9:30 p. m. on August 15 at Lake View, Kansas. The next morning at 6 o'clock many of them were still in the blossoms, but I can offer no guarantee that they were the same individuals. Again at 5:50 a. m. on August 16 and 17 I found from two to seven individuals of this species in each of twenty pumpkin blossoms. Many of them were in copulo. Since these flowers do not open until early morning, this is evidence that they must have been awake and migrated during the night.

Copris carolina Linn.

Just after dark July 29, we followed the sound of a heavy, buzzing insect and turned our light upon a flying *Copris carolina*. It was hovering in the road above a pile of fresh horse-dung.

Canthon lævis [E. A. Schwarz].

This dung roller was often seen during the day buried under soft dung; sometimes it was abroad at night, up to 11:30 p. m., rolling and burying its ball. The periods of rest are very irregular, but since the animal goes into the burrow with its food ball and sits at table until all is eaten, perhaps sufficient periods of rest occur at these times.

Harpalus ruficornis [E. A. Schwarz].**Harpalus pennsylvanicus** [E. A. Schwarz].**Harpalus caliginosus** [E. A. Schwarz].

One can scarcely stroll out over a pasture field on a summer evening after dark without being greeted by these active beetles on the wing or ambling along the path or scrambling through the grass. But on a cold, damp September evening we have found *H. ruficornis* in their holes. Perhaps they all sleep in their holes at one time or another, just as it suits their convenience.

Limonius agonus Say. [E. A. Schwarz].

June 10, at 10 p. m. two of the small brown click beetles so common here at St. Louis were calmly at rest on a leaf of poison ivy. I could not discern whether they were asleep.

Lachnosterna.

Several of these may-beetles were found, when the light was flashed upon them, to be feeding on the leaves of the elderberry and grape on early June evenings between the hours of 9 and 10 o'clock, an hour when all honest insects are abed. We know they are abroad even later than this by the thousands which come to the lights.

Nemognatha lutea [E. A. Schwarz].

These yellow sunflower beetles inhabit the blossoms of sunflowers during the day, occasionally flying from one disk to another. They do not drop to the ground, as do some insects when disturbed, but they feign death for a short time by stretching out and stiffening the legs. They spend the night in the sunflowers in the same way, and if they really sleep one cannot discern it; the head and mouth-parts are usually covered with pollen, and the head is often buried in the flower, as are also the legs. When disturbed at night they feign death in precisely the same manner as during the day; from this I conclude that they are not really asleep, but perhaps only resting in the midst of their food supply.

Chauliognathus pennsylvanicus [E. A. Schwarz].

These beetles which are so common where flowers abound seem to sleep right in their day-time quarters, on the disks of sunflowers or daisies, or on the clusters of elderberry or white snakeroot flowers, etc. We have found them in great numbers, both singly and in copulo, resting on these flowers at night, from midsummer to autumn.

Epicauta pennsylvanica DeG. [E. A. Schwarz].

At dusk on August 7 about fifty small black blister beetles were clustered in the crannies of the inflorescences of a group of six goldenrods; none occupied positions on the plant below the flower-heads. They were apparently ready to spend the night, and many were readily taken. They did not drop to the ground upon slight disturbance as usual during the day, and one had to poke them persistently with a pencil to induce them to fall, but they did not cling so tenaciously to the plant as did

their larger cousins. This may be due to the fact that the larger ones were visited later in the evening when they were more sleepy.

As late as September 11, on a cold damp morning a few of these beetles were still to be seen asleep on the goldenrod. Even later in the season, September 28, a few were still occupying the goldenrod, a number of them in copulo.

Macrobasis longicollis Lec. [E. A. Schwarz].

The larger blister beetle is a very agile, sensitive creature. They have the habit, developed to a remarkable degree, of dropping from their plant to the ground immediately upon the approach of the least provocation. In fact this dropping reaction is so pronounced in the blister beetles that when taking them we customarily place the cyanide bottle beneath them and merely touch them to cause them to tumble in.

On July 24 I found eight of these asleep on the iron weed. They showed no consciousness of the light, and did not respond to the disturbance by falling as usual. Here at night we found that they could be tapped repeatedly with a pencil and their only reaction was to walk a little distance and rest again—perhaps sleeping, we could not tell, sometimes on a stem and sometimes on the under side of a leaf. When the insect was forcibly thrown to the ground it would not feign death as usual but would immediately creep up the nearest stem and rest. This sometimes happened to be only a short blade of grass; in that case the insect would climb to the top of that but immediately come down when it found its altitude insufficient, try several others perhaps with the same result, until it would finally find a tall weed up which it would scramble in apparent glee, perfectly happy when it had reached the top. The insects sleep upon their food plants and have an aversion to spending the night on low plants or upon the earth.

A typical case of the behavior of an individual under experimentation is the following:

I awakened a beetle by hitting it hard with a pencil six times; it walked slowly to another leaf without the expected dropping. I pushed it from its support and forced it to fall to the earth; it immediately climbed to the top of its weed again.

Another beetle was at rest six inches from the apex of its food plant. I gave it twenty raps with the pencil when, instead

of dropping, it crawled to the apex of the plant. When I left it in peace again it crept down to its own chosen spot on the plant. I then gave it six more hard licks, whereupon it sought shelter under a leaf near by. With sixteen more blows the insect walked to the under side of another leaf, and even with twenty more hard licks it could not be induced to perform the daylight drop. Becoming impatient, I carried the insect bodily to a nearby path. It walked about eighteen inches to a small plot of short grass, climbed to the top of one blade and tried to look out, and at once meekly came down and tried another. I took it up and carried it to an iron weed near by. Here it plodded its way faithfully to the top where it wearily settled itself. By this time my curiosity was fully aroused as to how much the beetle would endure without fully waking, but at this point the urchin who was holding the lantern exclaimed: "Aw! pick on somebody your own size!"

CONCLUDING REMARKS.

Scudder in 1889, in speaking of the butterflies at rest and asleep, says: "Up to the present time no proper investigation has been made in regard to the sleep of insects. A wide and open field lies before the enquirer, and it is for his use that I have tried to bring together a few facts concerning the postures and behavior of butterflies in different circumstances. The facts however are too few whereon to base any general statements likely to require no important modification on future investigations, and I leave them for the present barren of results in the hope of enticing some one to enter a promising field and perchance relieve these facts of their present stupidity."

Despite these suggestive remarks, twenty-six years have elapsed without an investigator making a study of the ecology of sleeping insects solely. But here and there are recorded or more often buried under some far-away title some casual notes on the sleeping habits of insects.

The foremost among these are on the most interesting insects from a psychological point of view, the Aculeate Hymenoptera, bees and wasps. Peckhams tell us that the wasp *Astata bicolor*, when she turns in for the night, closes the door behind her until 7:30 o'clock the next morning; then she finishes, fills and seals this nest and begins another which by evening is

far enough along to furnish her good shelter for the night, and so on she always plans and executes her day's work so that each evening she has her lodging-place ready for the night.

They also noted that the male *Philanthus punctatus*, which is without a sting and does not assist in nest building, excavates for himself holes to shelter him for the night, covers the opening with loose soil, and returns to the same abode for several nights. They also mention *Pompilus scelestus* hanging to a leaf of a plant four inches from her burrow and there falling asleep until after eight the next morning, and the wonderful industry of *Crabro stirpicola* working at nest-building for forty-two consecutive hours with only a ten minute interruption.

Hartman finds that a day's work of *Odynerus dorsalis* consists of storing a cell, closing it and building another to be used as a sleeping apartment for the night.

Fabre records finding on a mountain some hundreds of *Ammophila hirsuta* assembled under the shelter of a stone. He has speculated much in attempting to account for this gregarious condition of solitary wasps, but in view of the fact that we have recorded similar phenomena in the sleep of *Ammophila pictipennis*, *Chalybion caruleum* and *Elis 5-cincta*, we cannot interpret his observations other than that the wasps had come together for the purpose of sleep.

These mentions will indicate that the subject is pregnant with possibilities from an ecological point of view, and probably more so from a physiological view-point. The sleep of an organism signifies more than a mere pause in its activity while darkness covers it; while we have not in the present paper touched upon the physiological phenomena of their sleep, we have found many interesting associations of this with the other activities of the insects. For instance, it is of marked biological interest that a few species certainly seem to choose protectively colored situations, and others select sites which are in various ways protective; that some which are solitary by day are gregarious at night, that some insects sleep with all the regularity of a theoretical modern infant, while others of a more unsystematic life snatch a wink when they can. We do not know whether the anemotropism evident in the behavior of some insects is a physiological or psychological phenomenon, or merely mechanical in its origin.

There are many other larger problems that should emanate from a study of sleep, such as the effect of regular or irregular sleep on longevity, the correlation of food habits with the sleeping habits of insects (vegetable feeders more frequently regular sleepers, while carnivorous species are irregular); the correlation of sleep and hibernation, the physiological differences and similarities; the habits of rest of animals in the higher or lower planes of evolution, or the correlation of sleep with the degree of nervous development (*e. g.*, the wasp must provide its own food, build the nest and provision it—a hard life of high mental exertion—while the *Dermestes* or the bed-bug has no such tasks; hence is the same rest needed for both?)

The sleep of animals in the immature stages, larval, pupal or even egg stage, is something untouched upon, and observation on the sleep of insects that can be kept in confinement, such as roaches, *dermestes*, meal-worms, etc., offers to the investigator the comfort of the laboratory for his investigation.

In closing let us again say with Scudder: "Only a few of the most patent of tricks and ways of butterflies [insects] have been noted. * * * These are however still too few whereon to base any general statement, * * * and I leave them in the hope of enticing some one to enter a promising field and perchance relieve these facts of their present stupidity."

ANNOTATED BIBLIOGRAPHY.

- Adams, C. C.** Bull. St. Lab. Nat. Hist. **11**: 110, 119, 140, 193. 1915. Even Noctuid caterpillars such as *Peridroma saucea* and its allies, which live on the ground during the day, climb trees at night. Mentions sleeping habits as recorded by Banks, Brues and Bradley: *Scepsis*, *Chlorion atratum*, *Polistes variatus* and *P. pallipes* sleeping on goldenrod flowers.
- Annandale, N.** Proc. Roy. Phys. Soc. Edinb. **29**: 439-444. 1900. *vide* Longstaff. He thinks the majority of Malayan Phasmidae are active in the intense heat of midday, when most of their enemies of the jungle are at rest, but remain well concealed in the early morning and late afternoon.
- Ashmead, W. H.** (Discussion.) Proc. Ent. Soc. Washington **4**: 26. 1896. Noticed wasps in N. Carolina in early morning, but had never seen them asleep.
- Banks, N.** Sleeping habit of a bee. Ent. News **19**: 340. 1908. A little black bee, *Panurginus illinoiensis* Robt., ♂'s only, have been found asleep; they rest with wings folded close to the body, upon the yellow center of the daisy. They first fell asleep about 6:30 P. M., and by 7:00 many were so soundly asleep that one could frequently pick up a flower containing them and carry it some distance without disturbing them.

- Banks, N.** Sleeping habits of certain Hymenoptera. Journ. N. Y. Ent. Soc. **10**: 209-214. 1902. Notes on sleeping habits of *Ammophila pictipennis* Walsh, *A. vulgaris* Cress., *Epeolus remigatus*, *A. urnaria* Klug, *Melissodes bimaculata* St. Farg., and *Myzine sexcincta* Fab. ♂'s.
In a field near by a few *Bombus americanorum* were found clinging to the under side of a wild carrot flower, back downward; they did not grasp with their mandibles. *Cerceris kennicotti* was resting under a loose piece of rail. *Halictus lignotus* and *Odynerus conformis* were on grass heads. In New Mexico six *Amegilla smithii* Cress. were asleep, clinging by mandibles to grass stems.
- Barrand, —.** Resting Attitudes of Rhopalocera. Entomologist **1906**: 160.
- Barth, G. P.** Bull. Wisc. Nat. Hist. Soc. **6**: 150. 1908. *Anacrabro ocellatus* Pack. still working at 7:45 P. M.
- Bate, D. M. A.** Notes on the resting attitude of *Zamacra flabellaria*. Entomologist **36**: 106. 1903. *Fig.* Assumes a peculiar position when at rest, forewings erect above the thorax and at the same time folded like a closed fan. The under wings are also folded, but to a smaller extent and are only slightly raised; the hinder end of the body is also raised. The antennae lie close along the sides of the body. Quotes Sir George Hampton, Fauna Brit. Ind.: Moths of genus *Gathynia* repose in the form of a cross, with the forewings rolled up at right angles to the body, the hind wings folded close to the body.
- Bolle, J., and M. Richter.** Studien über die Ursache der Schlafzucht der Seidenraupen. Zeits. Landw. Versuchs Oest. **1903**: 287. Abstract, Zool. Zentralbl. **1903**: 911.
- Brischke, G. A.** Ent. Monatsber. **1**: 11. *Psammophila viatica* associated in numbers at the end of September; apparently all females. Fact verified by reviewer in Zool. Rec. **13**: 130.
- Benton, —.** (Discussion). Proc. Ent. Soc. Washington. **4**: 26. 1896. The honey-bees when asleep hold to each other in a cluster; the upper ones grasp any projection with the mandibles while the lower ones grasp also with the mandibles and forefeet the legs of those above.
- Beutel-Reepen.** Die Stammengeschichtliche Entstehung des Bienenstaates. Ein-familienstaat. Leben und Wesen der Bienen, 45-66. The ♂'s of several species of solitary bees spend the night congregated in large clusters. *vide* Turner.
- Biro Lajos.** Szabadban alva mehek es darazok. Ravartani Lapok. **2**: 169-172. 1885. Observations on about twenty species of Hymenoptera while asleep upon *Centaurea urenaria*. *vide* Psyche.
- Bradley, J. C.** Gregarious sleeping habits among aculeate Hymenoptera. Ann. Ent. Soc. Amer. **1**: 127-130. In California, June, 1907, a bunch of black wasps, *Priononyx atrata*, were asleep on dried stems of wild oats, in groups of from 2 to 25; 490 were taken in one hour. A week later they were less abundant. (Naturally when 490 were taken). Also *Priononyx biveloleatum*, *Sphex* (*Ammophila*) two species, *Monedula emarginata*, *Steniola duplicata*, *Stizus uncinatus* and *Sphexius fervidus*, Cr. Associated with them were bees, *Bombus* sp., *Halictus farinosus* and *Melissodes agilis*. He thinks they had previously been scattered over the large field, but had been driven together thus by the recent cutting of the field.
- Brues, C. T.** On the Sleeping Habits of Some Aculeate Hymenoptera. Journ. N. Y. Ent. Soc. **11**: 228-230. 1903. *Priononyx atrata* along shores of Lake Michigan at Chicago; large number asleep on a large sweet clover. In McHenry Co., Illinois, several species were commingled upon the same plants, viz.: *Epeolus lunatus* a parasitic bee, *Scolia bicincta*, *Nysson plagiatus*, *Tachytes* sp. The Texan *Scolia lecontei* chooses a species of Umbelliferae as its sleeping-place and rests, head downward, upon or below the umbels of the plant. The common *Myzine sexcincta* rests not only at night but in the middle of the day also. In southern Illinois and also in Massachusetts the ♂'s of this species occur in abundance on the dry plant of the wild pink.
- Champion, H. G. and R. J.** Observations on the life history of *Methocha ichneumonides*, Latr. Ent. Mon. Mag. **50**: 268. 1914. Spends night and dull weather in an empty hole or any dark hollow.
- Chapman, T. A.** Butterflies at rest. Ent. Rec. **18**: 168-170. 1906.

- Cockerell, T. D. A. Ann. & Mag. Nat. Hist. 1900: 413. Found *Anthidium perpictum* "resting on the stems of grass in dull weather." *Fide* Banks.
- Cresson, E. T. Hymenoptera of Cuba. Proc. Ent. Soc. Phila. 1865: 88. Prof. Poey informs him that *Melissa rufipes* "retires to a bush to sleep, it seizes a branch with its mandibles and places itself in a horizontal position, the back turned toward the ground." *Fide* Banks.
- Cresson, E. T. Hymenoptera Texana. Trans. Amer. Ent. Soc. 4: 201. 1872. Cresson states that Belfrage said that *Scolia lecontei* rests during the night and chilly weather in clusters closely attached to the stems of grass and plants. *Fide* Banks.
- Darwin, C. Power of Movement in Plants. Chap. VI and VII. 1896.
- Dubois, R. Etude sur la Mecanisme de la Thermogenese et du sommeil chez les Mammiferes. Physiologie comparee de la Marmotte. Ann. Univ. Lyon. pp. 268. 125 pls. 119 figs. 1896. Not seen.
- Eaton, A. E. Aculeate Hymenoptera from Burgos, Old Castile, collected during the total eclipse of the sun, August 30, 1905. Ent. Mag. 42: 96-98. 1906. *Bombus* and hive bees ceased to be seen, and ants went to sleep on shoots of a yellow-flowered *Ononis*.
- Fabre, J. H. The hunting wasps. Tr. by A. T. de Mattos. p. 67, 255. 1915. *Sphex flavipennis* retires into her burrow at night, and also seeks shelter there in bad weather or rests for a few moments during the day. The sandy *Ammophila* and the silvery *Ammophila* do not spend their nights or leisure in their holes, but leave the premises altogether after concealing the entrance with a stone.
- Fabre, J. H. The hunting wasps. 1915. Records a single instance of finding on Mont Ventoux, at a height of 6,000 feet, some hundreds of *Ammophila hirsuta* under the shelter of a stone. While Fabre has some difficulty in interpreting this phenomenon, I can only see in it an analogous condition to that recorded for *Ammophila pictipennis* or *Chalybion caruleum*—viz.: congregating for the purpose of sleeping.
- Fabre, J. H. The mason-bees, p. 86, 1914. The mason-bee of the walls, *Chalicodoma muraria* spends the days and nights in one of the cells of her dome, suspended head downwards; the mason-bee of the sheds, *C. siculla*, does very nearly the same as long as there are vacant galleries in her nest, but after these have been used as cells she selects another retreat. The *Chalicodomæ* pass the nights in the stone heaps in the harmas in numerous companies, piled up promiscuously, both sexes together. The most common dormitory is a narrow crevice between two stones; here they all huddle, lying flat on their backs like people asleep. Should bad weather come on, they do not stir.
- Fiebrig, K. Schlafende Insekten. Jenaische Zeits. Naturw. 48: 315-364. 1912. See appendix.
- Fletcher, T. B. Do butterflies migrate by night? Spol. Zeyl. 4: 178-179. 1907.
- Floersheims, —. Tutt Ent. Rec. 18: 36-39. 1906. Description of the great extent to which beetles attack and kill sleeping butterflies. (*Fide* footnote Ent. Soc. Lond. p. cxxi. 1906.)
- Fountaine, —. Roosting habits of *Heliconius charitonia*. Entomologist 44: 403. 1911. They assemble between five and six P. M. and sleep in clusters. One group of a dozen or so noticed every morning always on the same twig of *Phenox hitrus*; sound asleep at six A. M.
- Frohawke, F. W. The Sleeping Attitude of Lycaenidae. Entomologist 47: 212-213. 1914. It is generally supposed that the Lycænidae sleep throughout the night sitting head downward on flower heads and grass stems, in the characteristic attitude they assume in the evening, but later when darkness supersedes the twilight the butterflies (*L. icarus*) turn around and sleep head upward. The author and Mr. W. Holland marked and watched groups of these butterflies and found "they were all head downward from 4 P. M. until darkness; in every case they reversed their position to head upwards at dark," which position they retained for the night.
- Garner, R. L. (Abstract.) Science 42: 843. 1915. The African anthropoid apes sleep on their backs like men, and make their beds eighteen or twenty feet above the ground.

- Gill, —. (Discussion). Proc. Ent. Soc. Washington **4**: 26. 1896. Fish when supposedly asleep are simply quiescent with their fins waving at intervals or entirely still. African *Dipnoan protopteros*, when streams dry up, goes into the mud, makes a cocoon of slime surrounded by mud, and in this condition has been carried to Europe and revived by placing it in water and dissolving the cocoon.
- Green, E. E. Sleeping Habits of a Bee. Ent. Mon. Mag. **1899**: 214. Not seen.
- Hartman, C. Observations on the Habits of Some Solitary Wasps of Texas. Bull. Univ. Tex. No. 65: 7. 1905. A day's work of *Odynerus dorsalis* consisted of storing a cell, closing it and building another before evening to be first used as a lodging place the following night and filled the next day. (Hartman, in a letter, says he suspects this species has been erroneously identified for him.)
- Hine, J. S. Techn. Ser. U. S. Dep. Agr. Ent. No. 2, pl. ii, p. 24, 1906. The autumn horse-flies, *Tabanus sulcifrons* Macquart, are most active in the strongest sunlight. As evening approaches they become less active and seek a resting-place among the foliage, on some tree-trunk, or on a fence where they remain quiet until sunrise. They have a tendency to collect at evening in certain favorable places in large numbers, ♂'s and ♀'s together.
- Hoffmann, F. Wie und wo nachtigen die Tagfalter? Mitt. Polyxena Wien. **6**: 1. 1911. (Not seen.)
- Ingersoll, E. Life of animals. p. 313. Quotes Perry, on the Wapiti deer: "If there is a stream running through the valley, bordered by a sand bar, the entire band makes this their sleeping place, and the band always assume the same position in sleeping—the calves, cows and yearlings in the center, and the bucks around the outer edge of the circle, so that in case of a night attack by wolves or panthers the strongest will meet the first onset of the foe."
- Isely, D. The Biology of Some Kansas Eumenidae. Kans. Univ. Sci. Bull. **8**: 243, 299. 1913. Quotes Hartman on *O. dorsalis* in reference to its using each newly constructed cell for a night's shelter. Scoliids and *Ammophila* and a solitary *Eumenes bolli* would collect for the night on the tall prairie grass in Ness Co. *Eumenes* did not hold its body rigid as did *Ammophila*, but held itself at right angles to the stem with its abdomen curled under it.
- Jensen-Haarup, A. C. Maerkvaerdig Sovestilling hos hannes af visse Bier. Kobenhavn Flora og Fauna 1909: 65-67. A remarkable position during sleep among the males of certain bees. (Not seen.)
- Kearton, R. The Fairy-Land of Living Things. Where birds sleep. pp. 58-61. 1908. A popular account.
- Kolbe, W. Ueber das Eintreten des Sommerschlafes bei den Chrysomeliden. Zeits. Ent. Breslau **24**: 26-57. 1899. Not seen.
- Longstaff, G. B. Some rest-attitudes of butterflies. Trans. Ent. Soc. Lond. **42**: 97-118. 1906. *Lycena icarus* asleep on the heads of grasses; 12 out of 15 had head down. Most butterflies when asleep usually close their wings over their backs, but some of the larger skippers such as *Caprona* probably sleep with them spread out like geometers. The common skippers *Pamphila sylvanus* and *P. linea* adopt the usual butterfly attitude, but Roland Trimen called attention to the fact that *Nisoniades tages* L. sleeps with the wings inclined so as to form a roof, like many Noctuae, (Barretts Lepid. Brit. Is. 1: 309.) *G. rapa* when settled for the night makes no effort to resist capture. *G. brassicae* goes to sleep on hawkweed, etc., at 7:15 P. M., and remains with wings hanging down and closed over its back.
- Martineau, A. H. Entomologist **29**: 268. 1896. *Sapyga clivicornis* when at rest, "lays its big clubbed antennae between its legs along the under side of its body and quite out of sight, the clubs being turned upwards at the end."
- McCook, H. C. Nature's Craftsmen. pp. 64-67. 1907. The toilet operations of ants usually precede and follow sleep. Their sleepy ways may be illustrated by a group of 25 or 30 agricultural ants. They had been lured by a gas lamp upon the table from underground galleries in a glass formicary. They grouped themselves in little clusters next to the light, on top of corks, clods or pebbles placed for them, for they like slight elevations. Most of them cuddled upon the surface, some squatted upon their abdomens, some lay upon their sides, some stood tiptoe on their hind legs, some crouched upon the earth, piled

high one atop the other. There was constant agitation in the clusters, and frequent changes of position. While the ants of one group were sleeping, others would be at work, and these at times would vigorously jostle the sleepers. New members occasionally joined a group and in their eagerness to get close up to the heat, crowded their drowsy comrades aside. Ants at work in the galleries would drop the pellets they carried, push into a group of sleepers and presently be sound asleep themselves. The longest period during which individuals were observed to sleep was three and a half hours.

- Minot, C. S.** Notes on the Flight of New England Butterflies. *Proc. Bost. Soc. Nat. Hist.* **14**: 55-56. 1870. The postures of the butterflies by day are all different from those assumed by night. A little before sundown *Colias philodice* Godt. and *Pieris rapæ* Shrank, begin to alight in the grass. "As it gets later they become more and more inactive until finally they will allow themselves to be trodden upon, pinned and handled in any way. Before twilight is ended they creep down, or descend in some manner, I do not know how, to the very roots of the stalks or blades of grass." They always choose a perpendicular stalk, the wings are raised over the back, the outer edges pressed together, the antennæ are kept nearly perpendicular to the axis of the body and almost concealed by the front edges of the wings.
- Morley, M.** Wasps and Their Ways. p. 120. 1901. Hornets have been known to work by moonlight. Captive wasps are unable to sleep with a light near by.
- Noyes, A. A.** Biology of the nest-spinning Trichoptera. *Ann. Ent. Soc. Amer.* **7**: 269. 1914. Many Trichoptera larvæ build their dwellings chiefly during the night, but *Hydropsyche* build their tubes and nets at all times of the day or night.
- Oudemans, J. T.** Etude sur la position de repos chez les Lepidopteres. *Verhandel. Kon. Akad.* **10**: No. 1. 1904. *Fide* Longstaff. "Lepidoptera have a sleeping dress; this dress forms a harmonious whole. The different parts which contribute to form the whole dress harmonize in their colors and usually in their patterns. The parts of the insect which are concealed during rest are quite frequently strongly contrasted in color or pattern to the exposed parts."
- Peckham, G. W. and E. G. Peckham.** Instincts and Habits of Solitary Wasps. *Bull. Wis. Geol. and Nat. Hist. Surv. Ser. 1.* **2**: 94. 1898. At 4:15 *Astata bicolor* thought she had worked long enough, went into her hole, closed the door behind her and remained there until 7:30 the next morning. She began the work of excavation in the morning, carried it on without haste or pause until 2 or 3 in the afternoon and retired at about 4 o'clock; the next morning she completed the nest in about an hour. They also saw this species make a shallow temporary hole for the night. When the weather was cold or cloudy *Philanthus punctatus* Say remained closely housed within the nest. Two ♂ *P. punctatus* excavated a temporary hole for shelter for the night, covered it with loose soil, remained in it from about 4 o'clock until 10 the next morning, peeping out only once at 8:30 to look around but again retreating and closing the door. ♂'s do not construct a new lodging every night but return to the same spot to sleep. Other wasps creep into crevices; often found in holes in posts. "But we are glad to put it to the credit of one ♂ that he had sufficient foresight and industry to provide a sleeping-place, and sufficient intelligence to return to the spot when the declining sun warns him that evening is approaching." Two *Crabro stirpicola* Pack. worked at nest-building without cessation throughout the night, the second day and second night—a period of forty-two consecutive hours with only one intermission of ten minutes. At 4 o'clock *Pompilus scelestus* Cres. began to investigate very carefully the plants and grasses immediately surrounding her hole; she selected a bunch of clover four inches away, and hanging to a leaf she remained motionless and fast asleep until they left her at sundown. The next morning at 8 o'clock she was still soundly asleep. After they had gently aroused her, she crept up the stem, stretched herself sleepily and slowly made her toilet.
- Peckham, G. W. & E. G.** Wasps, social and solitary. 1905. Female *Crabro* like those of other genera seem to use the galleries of their nests as sleeping places, but the ♂'s stop at any convenient inn. One was entertained in a hole in one of the porch posts for several nights. *Philanthus* ♂'s spend time and care in

- digging a hole in the ground to which they return night after night. In *Agenia* the ♀ keeps one cell ahead of her needs and tucks herself away in it very comfortably, but the *Pelopæi*, instead of making use of their tubes, congregate in the evening about convenient crevices. Quote Banks on *Ammophila* and Brues on *Priononyx*. They also observed a *Pompilus* to take the greatest care in selecting a sheltered spot under some leaves where she afterwards hung herself up and slept soundly until 8 o'clock the next day.
- Pictet, A.** L'instinct et le sommeil chez les insectes. Arch. Sci. Phys. Nat. iv. 17: 447-451. 1904. (Not seen.)
- Poulton, E. B.** Predaceous insects and their prey. Trans. Ent. Soc. Lond. 42: 374, 664. A female *Asilus crabroniformis* asleep on a head of *Centaurea scabiosa*, strongly suggested a crumpled leaf which had fallen upon the flower. This cryptic resemblance was brought about by a remarkable attitude, the insect being in the position formed by a half somersault arrested when the ventral surface was uppermost. *Volucella inanis* readily takes flight in the sun, but in the evening it becomes semi-torpid, and if disturbed then it raises its first leg in a manner clearly mimetic of the warning attitude of its *Bombus* model.
- Rau, P.** The sun-dance of the saw-fly. Ent. News 27: 274-277. 1916. *Macrophya* sp. nov. at rest, apparently settled for sleep, on top of box-elder leaves, before 6 P. M. on an April evening.
- Rau, P., and N. Rau.** The Biology of the Mud-Daubing Wasps. Journ. Anim. Beh. 6: 27-63. 1916. The mothers themselves (*Trypoxylon albitarsis* Fab., *Sceliphron cæmentarium* Drury and *Chalybion cæruleum* Linne) do not use their mud nests for their own shelter but go elsewhere for the night. *Osmia cordata* when removed from its cell prematurely would creep back into its old cell or be happy to get into any crevice.
- Rau, P. & N. Rau.** A sleepy Eumenid. Ent. News 24: 396. 1913. At night the *Ancistrocerus unifasciatus* Saus. would creep into the old cell of the mud-daubers' nest from which they had emerged. In keeping *Pelopoeus cæmentarium* of both sexes in cages with the nests from which they had hatched no such behavior was ever observed.
- Read, C.** Instinct, Especially in the Solitary Wasps. Brit. Journ. Psychol. 4. Pt. 1. Mentions sleeping habits of wasps from Peckhams' account.
- Roubaud, E.** The Natural History of the Solitary Wasps of the Genus *Synagris*. Smithson. Rept. 1910: 507-524. The nests of *Synagris sicheliana* are masses of yellow earth; the most recent cell is always open and serves as a shelter for the builder, which very often dies in it. *S. cornuta* L. during rare moments of rest and at night remains in her cell with her head turned outward, guarding her young.
- Sanborn, F. G.** Proc. Bost. Soc. Nat. Hist. 12: 98. *Ammophila gryphus* clasping small oak twig with mandibles and feet, body elevated one-fourth inch above twig. Fide Scudder and Mann.
- Saunders, —.** Hymenoptera Aculeata of the British Islands. p. 308. The ♂ of *Chilostoma* (a bee) usually spends the night curled up in flowers, but Smith says that at other times he has observed them hanging to blades of grass by their mandibles. Fide Banks.
- Schwarz, E. A.** Sleeping Trees of Hymenoptera. Proc. Ent. Soc. Washington 4: 24-27. 1896. In southwestern Texas *Melissodes pygmaeus* Cress., and *Coloptera wrightii* Cress. were abundant and asleep on *Celtis pallida* on the thinnest and outermost twigs and on the stout thorns, sleeping singly, the tips of the mandibles inserted in the wood and all six legs grasping the twig. Four shrubs near together bore 50 to 70 sleeping bees, and several other shrubs had small numbers. They were on these shrubs every morning. The habit reminds one of the well-known "butterfly-trees" of Monterey, California, and Appalachicola, Florida, the sleeping habitats of *Danaïd archippus* during their winter migration to southern localities. (No reference to the "well known" butterfly trees could be found.)
- Scudder, S. H., and B. P. Mann.** Attitudes in which some Wasps are supposed to Sleep. Psyche 2: 40-41. 1877. *Ammophila gryphus*? rests at night by seizing grass with jaws and holding itself extended with or without use of middle and hind feet. *Odynerus*? seized twig with jaws and supported body in horizontal position.

- Scudder, S. H.** Butterflies of Eastern United States. 2: 1602-1604. Cambridge. 1889. Postures at rest and asleep. At sleep the wings are packed away into smaller compass, with the exception of some Hesperidi; the wings erect back to back, the forewings slide down behind the hind pair so that only the latter and the apex of the front edge of the former are visible. One observation of a European *Thais* asleep in confinement with spread wings. There is more variety in the position of antennæ; some like Satyrinæ sleep with these spread wide, others tuck them between the wings, and others bring them together beside the front edge of the wings the clubs appearing beyond as if crowded out by the tight shutting of the wings.
- Severin, H. H. P., H. C. Severin and B. S. Hartung.** The ravages, life history, etc., of the melonfly, *Dacus cucurbitæ*. Ann. Ent. Soc. Amer. 7: 191. 1914. Feeds from sunrise to ten o'clock, but during the hottest part of the day thousands may be found at rest under large leaves of plants in or near an infested field of cucurbits.
- Shepherd-Walwyn,** Entomologist 36: 201. pl. 3. 1903. The resting position of the moth, *Plusia moneta* is most striking as it hangs by its two front legs, stretching them out to their fullest extent.
- Sladen, F. W. L.** The humble-bee, p. 63, 267-268. 1912. A humble-bee is usually in an animated state, abdomen pulsating, head held erect and antennæ pointing at attention, but occasionally a queen is found resting on a flower with her head hanging down and antennæ resting on her face, evidently indulging in a nap, for she awakes with a start when disturbed. Before the cares of motherhood have come upon her the queen is very fond of dropping off to sleep in the warm sunshine or in the newly found nest. *Psithyrus*, the usurper-bee, becomes a temporary lodger in the nest of *Bombus*, returning to it for meals and to spend the night.
- Slevogt, —.** Haben Insekten Ortsinn? Soc. Ent. 19: 37. *Aeschna* has permanent night quarters. (Not seen.)
- Soule, C. G.** Sound Sleep of *Lycaena americana*. Psyche 5: 42. 1888. She observed in the vacant lots about Boston "that as one side of the street grew shady toward sunset *L. americana* might be seen clinging to grass blades with wings somewhat drooped, suggesting that the muscles were somewhat relaxed by sleep." One was carried on a grass stem five blocks undisturbed. Later experiments always found the butterfly in the same position more than half way up the grass-blade, head up, wings drooped to an acute instead of a right angle with the body.
- Stiles, C. W.** (Discussion.) Proc. Ent. Soc. Washington 4: 27. 1896. It is difficult to conceive of the sleep of a tape-worm, *Oxyurus*; yet it undoubtedly has long periods of rest and is active in the evening. Many protozoa are still for a long time; *Acalephs* have also a resting period; in necrobiosis sleep may last for eight or ten years.
- Tonge, A. E.** Resting attitudes of Lepidoptera. Proc. S. Lond. Ent. Soc. 1909: 5-8. Pl. 2-3.
- Turner, C. H.** Literature for 1914 on the Behavior of Spiders and Insects. Journ. Anim. Beh. 5: 439. 1915. Reviews Beutel-Reepen on sleep of solitary bees, Williams on *Priononyx thomæ* and Frohawk on butterflies of the family of Lyncænidæ.
- Turner, C. H.** Notes on the Behavior of a Parasitic Bee of the Family Stelliidæ. Journ. Anim. Beh. 1: 374. The bees hatched from a nest of the mud-dauber, and at night or whenever the room was darkened the bees would retire to the mud cells.
- Vavilov, —.** Quoted in Journ. of Hered. 7: 43. 1916. Wild geese "swim to the selected open shore, where they get out, lie down, and fall asleep. The old birds alone do not sleep, but divide the watches, and, if they hear anything suspicious, at once wake the whole flock with a loud cry of warning."
- Watson, J. B.** Behavior, an Introduction to Comparative Psychology. p. 112. 1914. Night and day periods of activity are purely instinctive, since no structural peculiarities account for the differences.

- Watson, J. B.** Journ. Anim. Beh. **2**: 431. 1912. Quotes Werner (Biol. Centralbl. **31**: 41-44.) on sleeping habits of fishes, *Amiurus nebulosus*, *Misgurnus fossilis* and *Cabitus talnia*. The bodily attitudes taken in sleep are quite different for different species, even in nearly related species. In general there is a complete cessation of activity, a certain chosen bodily attitude and almost complete stoppage of breathing. Very light contact is sufficient to awaken the fish.
- Werner, F.** Ueber die Schlafstellungen des Fische. Biol. Centralbl. **31**: 41-44. Reviewed by Watson.
- Westwood, J. O.** Introduction to Modern Classification of Insects **2**: 211. 1840. *Scolia interrupta* and *S. 4-punctata* ♂'s, which are extremely sluggish, are found crowded on the ears of grass near the seaside, in groups or societies of 20 or 30 where they pass the night and make no attempt to escape. The ♂'s of *S. 6-cincta* are found in similar localities. Quotes from Latreille that in night or bad weather *Fænus jacubator* fix themselves by their jaws to the stalks of different plants and are then almost in a perpendicular position.
- Williams, F. X.** Monograph of the Larridae of Kansas. Kans. Univ. Sci. Bull. **8**: 187. 1913. Larridae ♂'s make holes probably as a place of retirement during unfavorable weather and at night. A black species of *Tachysphex*, probably *fuscus* or *terminatus* was observed digging a hole in the sand and closing the retreat from within. *Plenoculus apicalis* and *Niteliopsis affinis* have much the same habits as the above.
- Williams, F. X.** Larridae of Kansas. Kan. Univ. Sci. Bull. **8**: 210. 1913. The males of the Larridae are "frequently seen on flowers or basking in the sun. They were only observed to work when excavating short tunnels, in which they probably passed the night."
- Williams, F. X.** Notes on the Habits of Some Species of Wasps that Occur in Kansas. Kans. Univ. Sci. Bull. **8**: 227. 1913. *Priononyx thomæ* ♂'s in common with many other species of Sphegidae congregate in some numbers on weeds where they pass the night or remain during unfavorable weather. Such "clumps" are common on Russian thistle in western Kansas.
- Wittfield, —.** The southern *Euphoeades palamedes* sleeps with spread wings. Fide Scudder.

APPENDIX

From a physiological point of view the concluding remarks by Fiebrig are suggestive, and we here append an English translation of that part of his paper, pp. 347-354.

Those characteristics, which are manifested in the true sleep of vertebrates, are also present in the sleep of insects, especially of the Hymenoptera. These characteristics are principally:

Relative immovability,

Unconsciousness,

The same or similar behavior under various external influences (light, approach, contact),

Similar behavior when going to sleep and on awaking,

Adjusting of the periods of sleep to the changing periods of day and night,

in short, very often, manifestations which lead to the conclusion that the habits of sleep are protective. But, while most of the

remaining accompanying manifestations, as, for instance, the response to external stimuli, seem to correspond to those well-known and familiar forerunners of sleep, the specific rigidity among insects of the (cataleptic) muscular strain is just the opposite of our usual conceptions of sleep. To be sure, we recognize certain sleep-like manifestations, which at present are causing much discussion, resulting from hypnotism, often bringing about most surprising results, and, just as among bees, showing the strangest departures from normal rest positions. We also speak of an hypnotic sleep, a rigidity brought on by hypnotism. We do not understand as yet the physiological processes of these cataleptic conditions observed among vertebrates. Do similar physiological processes exist in the sleep of insects, in the clinging colonies of bees and wasps, as take place in the hypnotic sleep of vertebrates? It is a well known fact that not only man is susceptible to this form of sleep, but also many, psychologically poorly developed, vertebrates, as, for example, the hen. Is perhaps this hypnotic-like sleep of insects the forerunner of our present fully developed form of sleep, in which, because of the high development of the psychological, i. e., the nervous system, the assimilating and reviving processes are more complete and radically more intensive? Such cataleptic or hypnotic sleep in the higher vertebrates could be regarded as an atavic form of sleep. This view would receive considerable support if we were to assume that such a sleep was the rule among cold blooded animals of the present day and particularly among the giant lizards and amphibians of prehistoric ages. The fact that this so-called "hypnotic" sleep is of a decidedly passive nature and only brought about through the influence of an external organism need be regarded of only secondary importance for our comparison, in which the cataleptic manifestations accompanying sleep are the vital considerations; it can readily be assumed that among insects instead of a person an object, i. e., any external factor, to a certain extent could act as hypnotizer (for example, light or its absence.)

Although we may compare the manifestations of sleep among insects with a known form of sleep, we have not advanced very much further in knowing its nature, particularly so, since the physiological nature of hypnotic sleep is, I believe, still unknown. It would be carrying me too far were I to consider—even

speculatively—these apparently most complicated manifestations further. One thing I should like to call attention to particularly, however, and that is the significance of the organs of sight. Sight seems to be the sense which is most intensely affected by sleep, judging from the susceptibility of a sleeping organism to light stimuli, particularly the dependence of sleep on the amount of light. We are forced to the conclusion that it is the optic nerves which usher in sleep, which perceive and transmit the first intimation of sleepiness, which give the body the signal that it is time to retire. (Just think of the drooping eyelids of tired persons.) The same is true, as we have seen, of the sleep of insects. On comparing the organs which bring this about—the eyes—which transmit the sleep producing sensations, we find a very material difference. On the one side we have the one lens eye (closed by means of a lid) of the vertebrates, and on the other the facet eye of the insects. Are these differently constructed organs of sight in any way connected with the variations in sleep manifested by these two widely separated groups? Picture the effect of light, positive or negative, on insects, and its effect on the nervous system of the articulates with relatively few ganglia: many eyes and few nerve cells opposed to one pair of eyes and a single nerve center with a highly diversified nervous system among mammals and birds. Would it not be conceivable that, since sleep manifestations are so closely connected with the eyes (the optic nerves), they would assume certain definite forms according to the kind and construction of the organs of sight? According to my judgment all the great variations in the organization* of the widely differing groups of animals which are expressed in various forms of sleep, also cause the various uses of the limbs, especially of the muscles; we have only to call to mind the great difference in the sleep of warm and cold blooded vertebrates, which, undoubtedly, is caused primarily by a difference in respiration, i. e., conditions of blood circulation. The manifestations, which among cold blooded vertebrates have a certain resemblance to sleep, are so different from those conditions among mammals and birds, not even a sensitiveness to light seeming to be present, that it is doubtful whether among cold blooded animals conditions occur which can be designated as “sleep” at all.

*It would perhaps be simplest to ascribe the specific manifestations of sleep among insects to the little developed circulatory system.

It must seem very peculiar, indeed, that, while we are unable in general to recognize an ability to sleep among cold blooded vertebrates, the nearest relatives of the sleep-demanding mammals and birds, we should have for so large a number of the much lower articulates such convincing evidence of a sleep similar to that of the highest organized animals. As far as my investigations have gone this seems to be the case, the sleep of insects appearing to be real sleep, while those sleep-like conditions which are found among cold-blooded vertebrates, can hardly be admitted into the catagory of actual sleep manifestations. Startling as these conditions may seem at first glance, upon reflection some of their surprising effects become clearer when we recall how totally different is the distribution of the physical and the psychological qualities in these widely separated groups.

In conclusion I wish to call particularly to mind that among warm blooded animals those seem to have the most pronounced form of sleep which have the intensest manifestations of life (particularly again the birds). With such intensive living the busy workers certainly deserve a few hours of rest; we can surely appreciate their intensive desire for rest, and that insects also "get tired and sleep."

Sleep is a reflex of life, indeed, of the active manifestations of life, the reflected image of the physical and psychological activity of an organism. From this point of view we shall be able to understand more clearly certain forms of sleep. In the same way we shall be helped in explaining also the sleep of insects, the richest group in genera in the animal kingdom, which we meet at every step and whose existence, whose lives are still so little known to us.



Rau, Philip and Rau, N . 1916. "The Sleep of Insects; an Ecological Study." *Annals of the Entomological Society of America* 9, 227-274.
<https://doi.org/10.1093/aesa/9.3.227>.

View This Item Online: <https://www.biodiversitylibrary.org/item/43630>

DOI: <https://doi.org/10.1093/aesa/9.3.227>

Permalink: <https://www.biodiversitylibrary.org/partpdf/193728>

Holding Institution

Smithsonian Libraries and Archives

Sponsored by

Smithsonian

Copyright & Reuse

Copyright Status: NOT_IN_COPYRIGHT

This document was created from content at the **Biodiversity Heritage Library**, the world's largest open access digital library for biodiversity literature and archives. Visit BHL at <https://www.biodiversitylibrary.org>.