

# PROTOZOAN PARASITES OF THE ORTHOPTERA, WITH SPECIAL REFERENCE TO THOSE OF OHIO

## III.<sup>1</sup> PROTOZOAN PARASITES IN RELATION TO THE HOST AND TO HOST ECOLOGY

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From July, 1932, to October, 1933, a total of 1287 orthopteran individuals were examined, representing 6 families and 99 species. Of these, 34 species and 244 individuals were found to be infected with protozoan parasites, and 33 species and 192 individuals with gregarines. Of 706 males, 131 or 19% were infected with protozoan parasites, and 96, or 14% with gregarines. Of these males, 116 were in nymphal stages and showed 26% infection with protozoan parasites and 8% infection with gregarines. The 590 adult males showed 17% infection with protozoan parasites, 15% with gregarines. Of 581 females, 113 or 19% were infected with protozoan parasites and 96, or 17% with gregarines. Of these females, 123 were nymphs, with 11% infection with protozoan parasites and 11% with gregarines. The 458 adult females showed 22% infection with protozoan parasites and 18% with gregarines.

All nymphs examined (239) showed 18% infection with protozoan parasites, 9% with gregarines. Total adults examined (1048) showed 19% infection with protozoan parasites, 16% with gregarines.

The discrepancies between the numbers of nymph and adult Orthoptera examined were considerable; however, the percentages of gregarine infection indicate that the adults were infected almost twice as often as nymphs. This does not apply to flagellate infection, where the infection of nymphs was close to that of adults.

Female Orthoptera presented a 3% higher degree of gregarine infection than the male. This is not a significant difference, the percentages of infection by all protozoan parasites being

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practically the same in the two sexes. In a study of the parasites of *Blatta orientalis* Linnaeus, R. Kudo (1926) found a far greater infection by *Lophomonas blattarum* Stein and *L. striata* Bütschli in females than in males. In this study, conversely, the flagellate infection of male Blattidae ran considerably higher than that of females.

The Orthoptera examined are given by family and subfamily. They are classified according to Thomas (1933). References: Mead, 1904; Kirby, 1904, 1906, 1910; Kostir, 1914; Blatchley, 1920.

#### BLATTIDAE

Five species of Blattidae were examined. *Ischnoptera deropeltiformis* (Brunner) was without parasites; *Parcoblatta virginica* (Brunner), a new host, harbored *Leptomonas* sp. and *Gregarina ohioensis* n. sp. in large numbers; *P. uhleriana* (Saussure), also a new host, harbored *G. parcoblattae* n. sp.; *P. lata* (Brunner), new host, harbored *Leptomonas* sp.; *P. pennsylvanica* (DeGeer) harbored *Leptomonas* sp., *Gregarina thomasi* n. sp., *G. parcoblattae* n. sp., and *Nyctotherus ovalis* Leidy, variety.

Of 70 specimens of Blattidae examined, 60, or 86%, were infected with *Leptomonas* sp. in contrast to 15 individuals, or 21%, infected with gregarines. Thirty-eight out of 39 males (97%) were parasitized—all of the 21 nymphs, and 17 of the 18 (94%) adults. Of 31 females, 22 (71%) were infected, all of which were adults. Total nymph infection was 21 out of 23 examined (91%); total adult infection, 39 out of 47 examined (83%).

The flagellate infection of the Blattidae considerably exceeded the gregarine, which is conceivably the result of a difference in the concentration of digestive enzymes in the respective seats of infection, namely, the hind-intestine and the mid-intestine. H. S. Swingle (1925) shows that enzymes are not secreted by the hind-intestine of *Blatta orientalis* Linnaeus but may be found in that section of the alimentary canal near the mid-intestine, having been secreted in the latter. The gregarines are limited to the mid-intestine in their early development, inasmuch as that section of the alimentary canal is the only one where they have access to the epithelial layer, that of the other sections being protected by a chitinous layer; and the adult gregarines tend to remain in the mid-intestine.

*Nyctotherus ovalis* Leidy, variety ?, was taken from only one specimen (*Parcoblatta pennsylvanica* (DeGeer), male nymph), which was surprising, considering the comparatively large number of Blattidae examined. However, this is the only case in which a ciliate has been reported for identified Blattidae other than the domestic cockroaches.

#### PHASMIDAE

Only one species of Phasmidae was examined—25 specimens of *Diapheromera femorata* (Say), and none of these had protozoan parasites.

This is the only orthopteran family for which no parasites have been reported and for which none were observed in this study.

#### ACRIDIDAE

Of the Acrididae, 39 species, representing four subfamilies, were examined. Those of the subfamily Acrydiinae are as follows: *Nemotettix cristatus compressus* Morse, unparasitized; *Acrydium ornatum* (Say), unparasitized; *A. arenosum angustum* (Hancock), a new host, harboring *Gregarina acrydiinarum* n. sp.; *Paratettix cucullatus cucullatus* (Burmeister), a new host, harboring *G. acrydiinarum* n. sp.; and *Tettigidea lateralis* (Say), unparasitized.

The species of the subfamily Acridinae are as follows: *Syrbula admirabilis* (Uhler), unparasitized; *Orphulella speciosa* (Scudder), unparasitized; *Dichromorpha viridis* (Scudder), a new host, harboring *Actinocephalus elongatus* n. sp.; *Chloealtis conspersa* Harris, unparasitized; *Chorthippus curtippennis curtippennis* (Harris), a new host, harboring *Gregarina rigida rigida* (Hall), and *G. indianensis* n. sp.

Species of the subfamily Oedipodinae examined are as follows: *Arphia sulphurea* (Fabricius), a new host, harboring *Gregarina rigida columna* n. subsp., *G. r. rigida* (Hall), and *Actinocephalus elongatus* n. sp.; *A. xanthoptera*, unparasitized; *Chortophaga viridifasciata* (DeGeer), a new host, harboring *Gregarina rigida columna* n. subsp. and *Actinocephalus elongatus* n. sp.; *Encoptolophus sordidus* (Burmeister), harboring a new parasite, *Gregarina rigida columna* n. subsp.; *Hippiscus rugosus* (Scudder), unparasitized; *Pardalophora apiculata* (Harris), a new host, harboring *G. rigida columna* n. subsp. and *Actinocephalus* sp.; *P. phoenicoptera* (Burmeister), unparasitized; *Dissosteira carolina* (Linnaeus), harboring a new parasite, *Gregarina rigida columna* n. subsp., in addition to *G. r. rigida* (Hall) and *G. locustae* Lankester; *Spharagemon bolli* Scudder, a new host, harboring *G. rigida columna* n. subsp. and *G. r. rigida* (Hall); *S. planum* Morse, unparasitized; *S. collare collare* (Scudder), a new host, harboring *G. rigida columna* n. subsp.; and *Trachyrachis kiowa thomasi* (Caudell), unparasitized.

Species of the subfamily Cyrtacanthacrinae examined are as follows: *Schistocerca americana americana* (Drury), harboring a new parasite, *Actinocephalus elongatus* n. sp. (?); *S. alutacea* (Harris), unparasitized; *Melanoplus gracilis* (Brunner), unparasitized; *M. facetus* Hubbell, unparasitized; *M. hinei* (Thomas), unparasitized; *M. obovatipennis* (Blatchley), a new host, harboring *Gregarina rigida columna* n. subsp. and *G. r. rigida* (Hall); *M. scudderi scudderi* (Uhler), a new host, harboring *G. rigida columna* n. subsp.; *M. walshii* Scudder, unparasitized; *M. differentialis* (Thomas), harboring *G. rigida columna* n. subsp., *G. r. rigida* (Hall), and *G. indianensis* n. sp.; *M. bivittatus* (Say), harboring *G. rigida columna* n. subsp., *G. r. rigida* (Hall), and *G. indianensis* n. sp.; *M. confusus* Scudder, unparasitized; *M. femur-rubrum femur-rubrum* (DeGeer), harboring *G. r. rigida* (Hall), *G. nigra* Watson, and *G. locustae* Lankester; *M. fasciatus* (F. Walker), unparasitized; *M. mexicanus mexicanus* (Saussure), harboring *G. rigida columna* n. subsp., *G. r. rigida* (Hall), *G. indianensis* n. sp., and *Actinocephalus elongatus* n. sp. (?); *M. keeleri luridus* (Dodge), harboring *Gregarina rigida columna* n. subsp.

and *G. r. rigida* (Hall); *Paroxya hooseri* Blatchley, unparasitized; and *P. atlantica atlantica* Scudder, unparasitized.

A total of 499 specimens of Acrididae were examined, and 87 of these (17%) were infected, the infected specimens representing 19 of the 39 species.

#### TETTIGONIIDAE

In this study, no protozoan parasites were taken from the Tettigoniidae, although 285 specimens, representing 29 species, were examined. Only one protozoan parasite has been reported from the Tettigoniidae, namely, *Gregarina chagasi* Pinto (from *Neoconocephalus fratellus* (Griffini)). An adequate description of this gregarine is not available, and there is no illustration of it, hence its relation to the other gregarines cannot be determined.

The Tettigoniidae examined were as follows: *Scudderia curvicauda curvicauda* (DeGeer); *S. texensis* (Saussure and Pictet); *S. furcata furcata* Brunner; *Amblycorypha oblongifolia* (DeGeer); *A. uhleri* Stal; *A. rotundifolia rotundifolia* (Scudder); *Microcentrum rhombifolium* (Saussure); *M. retinerve* (Burmeister); *Pterophylla camellifolia* (Fabricius); *Neoconocephalus exiliscanorus* (Davis); *N. nebrascensis* (Bruner); *N. lyristes* (Rehn and Hebard); *N. robustus crepitans* (Scudder); *N. ensiger* (Harris); *N. palustris* (Blatchley); *N. retusus* (Scudder); *Orchelimum vulgare* Harris; *O. sylvaticum* McNeill; *O. nigripes* Scudder; *O. concinnum* Scudder; *O. campestre* Blatchley; *Conocephalus fasciatus fasciatus* (DeGeer); *C. brevipennis* (Scudder); *C. nemoralis* (Scudder); *C. strictus* (Scudder); *C. nigropleurum* (Bruner); *Atlanticus testaceus* (Scudder); *A. davisii* (Rehn and Hebard); and *A. americanus* (Saussure).

#### GRYLLACRIDAE

Eleven species of Gryllacridae were examined. These were as follows: *Tachycines asinamorus* (Adelung), a new host, harboring *Pileocephalus tachycines* n. sp.; *Hadenoecus puteanus* Scudder, a new host, harboring *Gregarina hadenoeci* n. sp.; *Ceuthophilus pallidipes* E. M. Walker, unparasitized; *C. latens* Scudder, unparasitized; *C. gracilipes* (Haldeman), a new host, harboring *G. proteocephala* n. sp. and *G. ceuthophili* n. sp.; *C. meridionalis* Scudder, unparasitized; *C. brevipes* Scudder, harboring a new parasite, *G. ceuthophili* n. sp.; *C. divergens* Scudder, a new host, harboring *G. sp.* and *G. ceuthophili* n. sp.; *C. uhleri* Scudder, a new host, harboring *G. prima* n. sp.; *C. nigricans nigricans* Scudder, unparasitized; and *C. thomasi* Hubbell, unparasitized.

Of a total of 145 specimens of Gryllacridae, 38, or 26%, of the individuals, and 6 of the 11 species, were infected.

#### GRYLLIDAE

Of the Gryllidae, 14 species, representing four subfamilies were examined. Seven species of Gryllinae were as follows: *Gryllus assimilis* Fabricius, for which new parasites were named, harboring *Leidyana gryllorum* (Cuenot), *L. erratica* (Crawley), *Gregarina kingi* Crawley, *G. galliveri* Watson, and *G. oviceps* Dising; *Gryllus domesticus* Linnaeus,

unparasitized; *Miogryllus verticalis* (Serville), unparasitized; *Nemobius fasciatus fasciatus* (DeGeer), a new host, harboring *Leidyana gryllorum* (Cuenot) and *L. erratica* (Crawley); *N. fasciatus tinnulus* Fulton, unparasitized; *N. fasciatus socius* Scudder, a new host, harboring *L. erratica* (Crawley); *N. maculatus* Blatchley, unparasitized.

Three species of the subfamily Oecanthinae were as follows: *Oecanthus nigricornus quadripunctatus* Beutenmüller, unparasitized; *O. nigricornus nigricornus* F. Walker, unparasitized; and *O. latipennis* Riley, unparasitized. It is interesting to note that no protozoan parasites have been reported from the Oecanthinae, although some of the same species of gregarines have been taken from subfamilies of the Gryllidae which are placed taxonomically on either side of the Oecanthinae by the orthopterists. This suggests, perhaps, a closer relationship between such isolated groups than has heretofore been suspected. The granular contents of the oecanthin gut are totally unlike the gut contents of the other Gryllidae examined by the author—a factor which may be correlated with the absence of parasites.

Two species of Trigonidiinae examined were *Anaxipha exigua* (Say), a new host, harboring *Leidyana erratica* (Crawley); and *Phyllopalpus pulchellus* Uhler, unparasitized.

Two species of Eneopterinae examined were *Hapithus agitator agitator* Uhler, a new host, harboring *Leidyana erratica* (Crawley), and *Gregarina galliveri* Watson; and *Orocharis saltator* Uhler, unparasitized.

Of a total of 263 specimens of Gryllidae examined, 52, or 20%, of the individuals, and 5 of the 14 species were infected.

The Orthoptera examined harbored protozoan parasites from three classes of Protozoa, namely, the Mastigophora (*Leptomonas* sp. in the Blattidae), the Sporozoa (many Gregarinida, in four families of Orthoptera), and the Infusoria (*Nyctotherus ovalis* Leidy, variety ? in one species of Blattidae).

#### SEAT OF PROTOZOAN PARASITE INFECTION

The predominating seat of gregarine infection is the extreme anterior end of the mid-intestine at the base of the enteric ceca. The infected region is often in a disintegrated condition—a dark, sticky mass—and for this reason it is often difficult if not impossible to determine to what extent the enteric ceca and the anterior end of the mid-intestine are involved. Occasionally only one or two ceca are infected; and sometimes, on the other hand, nearly the entire mid-intestine, or isolated spots towards the middle or posterior end are infected. It is doubtful that the anterior end is more susceptible to infection than any other part, but the sporozoites are probably liberated in that region by the action of the enzymes on the spores and immediately penetrate the host tissue.

When the gregarine infection becomes well advanced, the sticky mass supplants the normal host tissue, and the gregarines appear on the celomic side, always adhering to the mass.

Gregarine cysts are found throughout the entire length of the mid- and hind-intestines. They are usually in masses along with sporonts and associations in the mid-intestine; in the hind-intestine they may

be found isolated among particles of debris in the gut contents. The largest number of cysts was found in some hosts which had been dead for about twelve hours, and it is likely that the uncontrolled action of the digestive enzymes after the death of the host is responsible for the encystation.

#### HOST ECOLOGY

Ecological factors were recorded for each of the localities in which Orthoptera were collected, and some suggestive correlations were noted.

In general, where the vegetation was abundant, the insect gut was distended and more likely to be parasitized. The greatest degree of parasitism was that of the acridid grasshoppers taken in the fairly abundant vegetation of the pockets of the arrested Indiana sand dunes, about a mile from the Lake Michigan shore. These acridids were almost 100% parasitized and their alimentary canals were expanded from feeding. Nowhere else were those particular species of Orthoptera found in such large numbers, and since they are scavengers and often cannibalistic, their prevalence was an additional factor contributing to the presence of many parasites. On the other hand, the acridids of the extremely arid prairie of the Kettle Hills (Fairfield County, Ohio) showed very little parasitism and were small gutted.

It is of interest to note that only those Orthoptera which live in burrows and cracks, or under logs and stones, and are carnivorous, are especially parasitized. (There is a possibility of a light factor as well as the scavenger habits of the host influencing the prevalence of parasites.) Seasonal duration of the subdivisions of the Orthoptera might be considered a factor also, but the duration of the Acrididae, which are parasitized, is not essentially different from that of the Tettigoniidae, which are not parasitized.

In an attempt to correlate the pH of the anterior end of the orthopteran mid-intestine with protozoan prevalence and soil pH, 37 specimens of 4 families were studied. These were: 12 specimens of Acrididae with intestinal pH averaging 6.0; 4 specimens of Gryllacridae with intestinal pH averaging 5.9; 18 specimens of Tettigoniidae with intestinal pH averaging 5.6; 3 specimens of Gryllidae (*Oecanthus* spp.) with intestinal pH averaging 5.6. The degree of anterior mid-intestine acidity may be a factor in excluding parasites from the Tettigoniidae and certain Gryllidae (*Oecanthus* spp.), as the average pH of these groups was somewhat lower than that of the others examined.

Relating intestinal pH to the soil pH of the localities in which the insects were collected, it was found that 7 specimens were from localities with soil pH of 7.0, and their intestinal pH ranged from 5.9 to 6.6, averaging 6.3. The other 30 specimens came from localities where the soil pH was from 4.8 to 6.4, and their intestinal pH ranged from 5.6 to 5.9, averaging 5.7. Hence, intestinal acidity may possibly be correlated with that of the soil.

Each of the ecological factors constitutes a problem in itself, and many further possibilities for research are indicated.

## SUMMARY

Ninety-nine species of Orthoptera were examined, with 34% infection; 1287 individual specimens, with 19% infection.

It is indicated that the protozoan parasites of the Orthoptera are host-specific for families and, to some extent, for subfamilies.

Protozoan parasites were taken from species of all of the major subdivisions of the Orthoptera studied, except the Phasmidae, Tettigoniidae, and Oecanthinae (subfamily of Gryllidae). The distinctive appearance of the gut contents and the gut pH of the latter two were correlated with the absence of parasites in these groups. The number of Phasmidae was too small to justify making a statement concerning the absence of parasites.

Twenty-two (or 24?) new hosts were recognized, and 12 (or 10?) hosts already studied were assigned new parasites. (The exact number is doubtful because of a few inaccurate host determinations made in the past.)

The infection by cephaline Gregarinida of nymph Orthoptera was approximately one-half as frequent as that of adults, but the degree of infection by flagellates (one species) was about the same in nymphs and adults. Female insects were infected by gregarines slightly more often than males; not nearly so often by flagellates. Ciliates (one species) were taken from one host only. No amoebae were observed.

The predominating seat of gregarine infection was the extreme anterior end of the mid-intestine at the base of the enteric ceca. However, other parts of the mid-intestine, including the enteric ceca were sometimes infected. Flagellates and ciliates were taken from the hind-intestine, particularly the colic region.

The average pH of the anterior end of the mid-intestine of Tettigoniidae and *Oecanthus* spp. of the Gryllidae (where there is probably no parasitism) was lower than that of specimens of two other orthopteran subdivisions which are known to be freely parasitized. There was a tendency for the gut pH to correlate with that of the soil of the locality in which the insect lived.

In general, the greatest degree of parasitism was in well-fed Orthoptera which were terrestrial, scavengers, and cannibalistic.

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