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An Ecological Study of Coleoptera Succession in Bovine Manure with Emphasis on Natural Enemies of the Face Fly (Musca autumnalis De Geer) in Eastcentral South Dakota

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AN ECOLOGICAL STUDY OF COLEOPTERA SUCCESSION IN BOVINE MANURE WITH EMPHASIS ON NATURAL ENEMIES OF THE FACE FLY (Musca autumnalis DeGeer) IN EASTCENTRAL SOUTH DAKOTA

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Doctor of Philosophy, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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IN EASTCENTRAL SOUTH DAKOTA

Abstract

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Under the supervision of Associate Professor Edward U. Balsbaugh, Jr.

The frequency and succession patterns of coleopterous species in cattle dung were determined for two localities in eastcentral South Dakota during 1969 and 1970. Thirty-nine species of beetles were screened as potential predators of the face fly, *Musca autumnalis* De Geer, a pest of cattle and horses; and 1 Coleoptera, 1 Hymenoptera and 1 nematode were screened as parasites of the same host.

Succession studies of insects inhabiting bovine manure revealed that four families of Coleoptera were recovered from the manure and, in descending order of abundance, were Hydrophilidae, Staphylinidae, Scarabaeidae, and Histeridae. The hydrophilids were first to invade freshly deposited manure, whereas the staphylinids preferred somewhat older and dryer manure, 72 hours or older. Both scarabs and histerids were recovered in constant numbers in all ages of manure.

The mortality of face fly eggs and larvae attributed to natural conditions averaged 21.8%. The staphylinids, *Philonthus cruentatus* Grav., *P. rectangularis* Sharp, and *Aleochara bimaculata*; and the

histerid, *Hister abbreviatus* Fab. were significant predators of face fly eggs and larvae. Only two insect parasites of the face fly were recovered. Experimentally the beetle, *Aleochara bimaculata* Grav., had a parasitism rate of 1.08% while *Aphaereta pallipes* (Say), a wasp, parasitized 7.67% of the face flies to which it was exposed. Natural parasitism of *M. autumnalis* by the nematode *Heterotylenchus autumnalis* Nickle averaged 5.81%.

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INTRODUCTION

Adult face flies, Musca autumnalis De Geer,[1] are facultatively haematophagus. They normally feed on blood from livestock wounds, particularly on cattle, and on mucus secretions around the eyes and muzzles of livestock, but also feed on strings of saliva which cattle throw onto their bodies while trying to dislodge feeding horn flies. Face flies are important pests of cattle because they may cause the cows to produce less milk (Peterson, 1962), and lose weight. Musca autumnalis is also suspected of transmitting bovine conjunctivitis (Thomas, 1967). With 4.5 million cattle, South Dakota ranks sixth in beef production and eighth in total cow and calf numbers in the United States, thus, anything that adversely affects cattle greatly affects the economy of South Dakota. During the summer of 1970, face fly counts were as high as 50 flies per face while the generally accepted economic threshold at which face flies pose a problem is 5 flies per face.

There are 4 known subspecies of the face fly. Musca autumnalis autumnalis, which is native to most of the Palaeartic region, is the subspecies that entered North America, whereas the other three subspecies generally are confined to the Ethiopian region (Teskey, 1969). The first confirmed report of face flies in North America occurred in Nova Scotia, September, 1952 (Vockeroth, 1953). In 1953, face flies were reported in New York State, and by 1960, 26 states,

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[1]Diptera:Muscidae

approximately the northeastern half of the United States, reported the occurrence of face flies (Sabrosky, 1961). By 1967, the USDA reported face flies in 34 states. The first report of face flies occurrence in South Dakota was from Brookings County, July 14, 1961.

Face flies utilize bovine manure for oviposition and larval development. The eggs are laid in fresh manure with the breathing stalk extended above the surface for respiration. Larval ecolsion occurs approximately 24 hours later. The larvae remain in the manure deposits and complete 3 instars in 3 - 4 days. Within 4 - 7 days after hatching, the larvae undergo pupation in soil near the manure pile; however, pupation does rarely occur in manure if the manure is very dry. The pupal stage lasts for 10 - 14 days. New adults are reproductively mature 3 - 4 days after emergence and live approximately 30 days.

Controlling face flies by the use of chemicals has met with only limited success. In South Dakota, where large grazing areas are utilized, it is very time consuming and costly to round up cattle for spraying. Poor results have been obtained using aerial applications of chemicals for face fly control. Current public opinion also opposes the use of any pesticides for fear of environmental contamination. Thus, a study of succession patterns of Coleoptera in bovine manure is ecologically important not only from an empirical, but also from an applied viewpoint, because some Coleoptera are potential predators and parasites of face fly eggs and larvae. By learning succession patterns of beetles in cow dung we can determine

which insects are present in the manure when the eggs and larvae are vulnerable to predators and parasites.

There presently is a movement toward a more naturalistic approach of insect control. Biological control through the use of natural predators and parasites of pest insects is a very important part of the natural control program. If suitable natural enemies of these pests can be found, proper manipulation of populations can afford a safe, effective method in insect control.

With these factors in mind, the possibility of a program for the biological control of the face fly in South Dakota was investigated, and the role of the native, natural insect and nematode enemies of M. autumnalis were studied.

LITERATURE REVIEW

Although there has been much written on the parasites and predators of coprophilous Diptera in general, information concerning parasites and predators of the face fly is scarce.

I. Parasites of Coprophilous Diptera

Insect parasites - Howard (1900) recovered 7 species of hymenopterous parasites which he thought were parasites of Diptera and Coleoptera breeding in human excrement. Two of these species were braconids, Alysia ridibunda Say and Aphaereta pallipes (Say) [=Aphaereta muscae Ashmead]. He reported that the larvae of the sarcophagid fly Ravinia direlecta (Walker) [=Helicobia quadrisetosa Coquillet] were eagerly sought by Alysia ridibunda. In 1901, while investigating the life-history and habits of the horn fly, Haematobia irritans L. in Virginia, Howard reared 6 different parasitic insects from cow dung, but failed to list the species.

Pinkus (1913) found the parasite Spalangia muscidarum Richardson,[2] breeding in the pupae of the stable fly, Stomoxys calcitrans L.,[3] and stated that in nature the stable fly was undoubtedly the principal host, although it could also be reared in the house fly, the horn fly and other dipterous pupae. Lundquist (1936) in Texas, found that Spalangia stomoxysiae Girault [=Nuscidarum stomoxysiae] and S. drosophidae Ashmead, were often found in dry or partly dry cattle

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[2] Hymenoptera:Pteromalidae

[3] Diptera:Muscidae

droppings. During his investigation he found that S. stomoxysiae was not host specific but readily attacked pupae of Orthellia [=Cryptolucilia] spp.,[2] Sarcophaga spp., the horn fly, and the house fly in cattle droppings; S. drosophilae, however, parasitized the small dung - infesting Diptera and the horn fly. As a result of field studies he found that Spalangia spp. accounted for the destruction of 18.7% of the fly pupae that he collected, while a staphylinid pupal parasite, Aleochara bimaculata (Gravenhorst) [=Barydoma bimaculata] destroyed 24.2% of the pupae of Sarcophaga sp. and Orthellia sp. He stated that the newly hatched larva of A. bimaculata gnawed a minute hole in a fly puparium, entered, and consumed the host. The beetle larva passed through a hypermetamorphic development requiring approximately 20 days. He further stated that S. stomoxysiae offered possibilities for biological control of the horn fly.

Mellor (1919) recovered the ichneumonid wasps, Atractodes tenebricosus Gravenhorst and A. exilis Haliday from the puparia of Hydrotaea dentipes (Fabricius)[4] in cow manure.

Roberts (1935) published a list of the hymenopterous parasites recovered from blowflies in Texas, recording 10 species belonging to 5 families. He also discussed the biology of Alysia ridibunda and stated that Aphaereta pallipes [=Aphaereta auripes (Provancher)] and Pachycrepoideus dubius Ashmead[5] were collected over cow dung in Texas.

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[4]Diptera:Muscidae

[5]Hymenoptera:Pteromalidae

Lundquist (1940) introduced Alysia ridibunda into Texas to control blowflies. He discussed the rearing, release, and establishment of this parasite and found that it would not complete its cycle on Cochiomyia macellaria (Fabricius)[6] or C. hominivorax (Coquerel) /=Cochliomyia americanus Cushing and Patton/,[7] but would mature readily in Sarcophaga spp. and Lucilia spp. larvae. Lundquist also found that Sarcophaga larvae were better hosts than the other species for A. ridibunda.

Hammer (1942) reported that several species of ichneumonids were commonly found as parasites of several species of flies in Denmark, but they were especially prominent in a species of Hydrotaea.[8] He listed the hosts from which the parasites had emerged and stated that as high as 64% of field-collected fly larvae were parasitized. He also reported that only species of the hymenopterous genera Vespa[9] and Mellinus,[10] and the parasitic fungus Entomophthora sp. /=Empusa/[11] were found attacking the face fly.

Mohr (1943), in Illinois, conducted the first ecological study of the entire insect fauna of cattle droppings conducted in the United

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[6]Diptera:Calliphoridae

[7]Diptera:Calliphoridae

[8]Diptera:Calliphoridae

[9]Hymenoptera:Vespidae

[10]Hymenoptera:Sphecidae

[11]Entomophthoralis:Entomophthoraceae

States. He reported 7 species of hymenopterous parasites with a list of their dipterous host. Aphaereta pallipes was reared from Haematobia irritans, Hylemya cinerella (Fallen) /=Pareyle cinerella/,[12] and Sepsis violacea Meigen.[13] Asobara fungiiola (Ashmead) /=Asobara lineata Viereck/[14] was recovered only once from cow dung but the host was not known. Idiasta or Phaenocarpa sp.[15] emerged in numbers from the puparia of H. cinerella. The hosts of Phaenopria sp.[16] were not determined, however, Phaenopria sp. was reared from dung which contained the puparia of H. irritans, H. cinerella, and S. violacea. Xylophora quinquelineata (Say)[17] was reared from Ravinia sueta (Wulp) /=Sarcophaga sueta/ and probably parasitized other sarcophagids in cow dung. Kleidotoma sp.[18] was recovered from the puparia of H. irritans. Figites sp.[19] was reared from dung, but the host was not determined.

Investigations of the dipterous larval, inhabitants of cow dung in England were conducted by Lawrence (1954). He found 16 species of

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[12]Diptera:Anthomyiidae

[13]Diptera:Sepsidae

[14]Hymenoptera:Braconidae

[15]Hymenoptera:Braconidae

[16]Hymenoptera:Diapriidae

[17]Hymenoptera:Figitedae

[18]Hymenoptera:Cynipidae

[19]Hymenoptera:Figitidae

parasitic Hymenoptera attracted to cow manure and discussed the hosts, monthly occurrence, and condition of the piles from which the parasites were collected. Families of Hymenoptera represented in this study were Braconidae, Ichneumonidae, Cynipidae, Practotrupidae, and Diapriidae.

Blickle (1961), in New Hampshire, reported the first parasites recovered from the face fly in the United States: Aphaereta pallipes, Xylophora quinquelineata, and Eucoila sp. These parasites were also recovered from Orthellia caesarion (Meigen),[20] Ravinia latisetosa Parker [=Sarcophaya latisetosa], R. lherminieri (Rabineau - Desvoidy) [=Sarcophaga querula].[21] Of 2,111 dipterous puparia obtained from field collected larvae in this study, 16.3% were parasitized by Hymenoptera. Parasitism of M. autumnalis by Aphaereta for that season varied from 0.3 - 80%, averaging 13%. Average parasitism by Eucoila was 2.2%, with a high parasitism of 24%; and parasitism by Xylophora was 1%, with a high parasitism of 47.8%.

Benson (1962) reported that parasitism of face fly larvae by Aphaereta pallipes in Missouri ranged from 24 - 85%. He stated that although A. pallipes could not emerge from the puparia of the face fly, it did emerge naturally from the puparia of Orthellia caesarion and Ravinia derelicta (Walker) [=Sarcophaya derelicta]. In 1964, Cates conducted ecological investigations of the muscoid flies breeding in cow dung in Missouri. He found 7 hymenopterous and 2 coleopterous

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[20] Diptera:Muscidae

[21] Diptera:Sarcophagidae

parasites of dung-inhabiting flies. The species of Hymenoptera were: Alysia sp., Aphaereta pallipes, Eucolia impatiens (Say),[22] Figites sp. Kleidotoma sp., Neralsia hyalinipennis (Ashmead),[23] and Xylophora quinquelineata. The 2 species of Coleoptera were Aleochara bimaculata and Aleochara bipustulata (L.).[24] Aphaereta pallipes was reared from Ravinia lherminieri, R. derelicta, R. querula, Sepsis sp., Orthellia caesarion, and Musca autumnalis. Neralsia hyalinipennis was recovered only from the puparia of R. lherminieri. Eucolia impatiens was reared from R. querula, R. lherminieri, R. derelicta, and O. caesarion. X. quinquelineata was reared from R. derelicta, R. lherminieri, and R. querula. Aleochara bimaculata was reared from R. querula, R. lherminieri, and R. derelicta. Aleochara bipustulata was recovered from the puparia of R. derelicta and Hylemya cinerella. Although Alysia n. sp., Figites sp., and Kleidotoma sp. were reared from cow manure, the hosts were not determined. Of the 9 species of parasites, only A. pallipes were reared from M. autumnalis.

Houser (1966) concluded that Aphaereta pallipes was a very ineffective parasite of the face fly in Missouri. Sanders and Dobson (1966), while investigating the insects associated with bovine manure in Indiana, recovered A. pallipes, Eucoila sp., and an undetermined species of Pteromalidae from several species of bucoprophilous flies. However, A. pallipes was the only one reared from M. autumnalis.

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[22]Hymenoptera:Cynipidae

[23]Hymenoptera:Figitidae

[24]Coleoptera:Staphylinidae

Similar studies were independently being conducted in the United States in 1966 by Caffey, Poorbaugh, and Anderson. Drea (1966) reported on life history studies of Aleochara tristis Gravenhorst,[25] a pupal parasite of the face fly in France. Aleochara tristis was imported by Jones (ananymous 1967) for the control of the face fly in Nebraska, but obtained limited success.

Wingo et al. (1967) showed that Aleochara bimaculata was found to parasitize less than 1% of face fly puparia and to cause 19.4% reduction of face flies by predation in Missouri. Aleochara tristis yielded an average of 13.5% parasitism in the same study. Thomas (1967 and 1968) in Missouri studied the succession of beetles in bovine manure as well as parasitism. He concluded that Aphaereta pallipes was the most frequent parasite recovered from face flies and parasitism was highest from mid-August through September.

Valiela (1969 a and b) reported on a survey of the arthropods found in cow dung in New York state and the effects of parasitism and predation in that area.

Nematode parasites - Stoffolano and Nickle (1966) reported a nematode parasite, Heteratylenchus autumnalis Nickle,[26] of the face

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[25]Coleoptera:Staphlinidae

[26]Tylenchida:Allantonematidae

fly in New York State. They first found it in a face fly from a laboratory colony, but later discovered it from native face flies in the field population. In a survey of 14 counties in New York State, this nematode was recovered from all samples of face flies. The nematode infections ranged from 8 - 44%. Further investigations of this nematode were made in New England (Stoffolano, 1968); Ohio (Treece and Miller, 1968); Nebraska (Jones and Perdue, 1967); and Missouri (Thomas and Puttler, 1970), revealed that parasitism of *M. autumnalis* by *H. autumnalis* was variable and somewhat unpredictable.

Manure-inhabiting diptera have a variety of parasites. There are several alternate hosts for each parasite and each species of fly may host several species of parasites. In searching for the parasites of the face fly, a consideration of all the parasites from dung-inhabiting dipterous larvae is essential.

II. Predators of Coprophilous Diptera

Osten Sacken (1887) reported that Portchinsky was the first person to show that not all insects developing in cow dung were coprophagous. Portchinsky demonstrated that the larvae of *Myiospila meditabunda* (Fabricius)[27] were carnivorous on other fly larvae in the droppings. According to Hammer (1942), Portchinsky found that

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[27]Diptera:Muscidae

the larvae of the flies Mydaea urbana (Meigen) and Polietes albalineata Fallen[28] were also carnivorous.

Howard (1900) first reported on entomophagus insects associated with dung in the United States. He listed 8 species of staphylinid beetles and 4 species of histerid beetles that he found in human dung and that he suspected were predaceous. Pratt (1912) was the first to report on predaceous insects associated with bovine manure in the United States. He found that Hister coenasus Erickson[29] devoured the larvae and pupae of Orthellia caesarion [=Pseudopyrellia cornicina of North American authors, not Fabricius], and stated that it probably attacks other species, including the horn fly. He further reported that the staphylinid beetle Aleochara bimaculata was recovered from three-day-old manure and was probably predaceous.

Portchinsky (1913a) detailed the habits and description of Muscina stabulans (Fallen),[30] which was found in human, cattle, and horse dung. He stated that once M. stabulans reached the third-instar it became carnivorous and would attack the larvae of Musca domestica. In some experiments, the larvae of Orthellia cornicina (Fab.) [=Musca cornicina] were fed to the larvae of M. stabulans taken from bovine

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[28]Diptera:Muscidae

[29]Coleoptera:Histeridae

[30]Diptera:Muscidae

manure. Although the larvae of the latter were fully grown, those of M. stabulans immediately attacked and ate them. Portchinsky (1913b) also reported on the biology of Hydotaea dentipes. In his experiments, there was a total destruction of the larvae of Musca domestica and Stomoxys calcitrans by the larvae of H. dentipes. Portchinsky stated that Palietes albalineata was the most rapacious of all coprophilic larvae, but the former 2 were also important.

Hewitt (1914) found that adult Scatophaga stercoraria (L.)[31] preyed upon adults of M. domestica, S. calcitrans, O. cornicina, Fannia canicularis (L.),[32] Pollenia rudis (Fabricius),[33] and Calliphora vicina Rabineau - Desvoidy [=Calliphora erythracephala Meigen]. Scatophaga spp. showed a definite preference for muscid flies, perhaps because excrement has an attraction for both the predator and its victims. Hewitt also observed that S. stercoraria destroyed a large number of dipterous larvae, especially muscid flies. The life history and habits of S. stercoraria were also investigated by Cotterel (1920) in England. Cotterel found this species breeding in human, poultry, sheep, cattle, and horse excrement, cattle and sheep excrement were the preferred media. Cotterel found that S. stercoraria fed on a large variety of Diptera, but preferred flies of the genera Calliphora and Musca. A series of his experiments with fly traps

[31]Diptera:Anthomyiidae

[32]Diptera:Muscidae

[33]Diptera:Calliphoridae

were seriously interfered with by the abundance of the adult S. stercoraria that fed on the trapped flies.

According to Cates (1964), Leilen, in 1915, listed several species of entomophagous fly larvae, and in 1917 found that carnivorous anthomyiids possessed two mouthhooks, one of which was longer and larger than the other and were used for tearing the tissue of other larvae. Keilen and Tate (1930) found that Polietes lardaria Fallen[34] was a very active predator of the horn fly and that the larvae of Mesembrina mystacea L. and M. meridiana (L.)[35] were carnivorous.

Thomsen and Hammer (1936) found that Myiospila meditabunda was one of the most constantly occurring members of the fly fauna of cow dung in Denmark, however, only two to three adults were usually found on a single pile. They also found that the larvae of Hydrotaea dentipes devoured the larvae of Musca domestica, S. calcitrans and Lucilia, but in turn succumbed to the more vigorous larvae of Muscina stabulans and Palietes albolineata. In field studies, they found that a large number of H. dentipes or M. stabulans in a baited container was accompanied by a small number of Musca domestica and S. calcitrans. In 1937, Thomsen described the larvae and habits of Hebecnema umbratica (Meigen), the musical fly; Polietes hirticrura Meade; Mesembrina meridiana; Myiaspila meditabunda; Mydaea urbana; and M. scutellaris Robineau - Desvoidy [=Mydaea pagana Fabricius]. He stated

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[34]Diptera:Anthomyiidae

[35]Diptera:Muscidae

that the larvae of all these species were coprophagous during the first two instars, and were carnivorous in only the third-instar.

In 1942, Hammer published the results of his investigations of the fauna of bovine droppings in Denmark. Several species of gamasid mites were found that preyed upon the eggs and newly hatched larvae of dung flies. Hammer also observed a number of spiders which preyed on adult flies on dung. Attacks by spiders and mites were minor compared to the destruction caused by beetles, particularly those of the families Staphylinidae, Histeridae, and Hydrophilidae. Hammer stated that staphylinids were quite abundant in bovine manure, and that a number of species, especially *Philonthus* spp., attacked only the eggs. Hammer observed a single *Philonthus* sp., which was especially adept at finding and completely destroying egg masses (approximately 35 eggs) of *Orthellia* spp. He also observed a large rove beetle, *Ontholestes tessellatus* Fourcroy [=*Ontholestes nebulosus* Fabricius], which preys on the adult flies on the cow droppings. Hammer thought that these beetles did not attack the fly larvae because the fly larvae developed more rapidly than did beetle larvae, and usually disappeared from the pats before the beetle larvae had reached a considerable size.

Hammer further stated that although *Hister unicolor* L. was not very abundant in bovine manure, it affected the abundance of flies because both its larvae and adults were voracious predators. Although the larvae of this species are much smaller than the developing fly larvae, they can, with their large head and mandibles, overpower a fairly large fly larva. Hammer also reported finding a number of

species of Hydrophilidae in cow droppings. Adults of Sphaeridium scarabaeoides L. are carnivorous and feed on egg masses of Orthellia which they destroyed in large numbers. The larvae of this beetle are also voracious predators of dung fly larvae. Hammer estimated that approximately 25 Orthellia larvae are necessary for the development of 1 Sphaeridium larva. In addition, Hammer observed 2 species of Hymenoptera, Vespa sp. and Mellinus sp., preying on adult face flies and other dung flies. He concluded that mortality in dung flies is quite high because of predation by various entomophagous insects.

The ecosystem of bovine manure in Illinois was studied by Mohr (1943). He found Platysthethus americanus Erickson, other staphylinids, and S. scarabaeoides prey on the larvae of H. irritans, Sarcophaga spp., H. cinerella, O. caesarion, Vialacea spp., Leptocera sp.,[36] and Sargus cuprarius (L.) [=Geasargus cuprarius].[37] Mohr also stated that Sphaeridium bipustulatum Fabricius[38] and Hister abbreviatus[39] prey on the larvae of the stratiomyid fly, Sargus cuprarius, and the scarab beetle Aphodius fimetarius (L.).

Hafez (1948) reported on ecological and biological observations of several species of Sepsidae. The most serious enemies of sepsid flies, according to Hafez are adult and larval histerid and staphylinid beetles which prey on eggs and larvae of these flies. One adult Philonthus beetle consumed 10 eggs of Sepsis thoracica in 5 minutes,

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[36]Diptera:Borboridae

[37]Diptera:Stratiomyidae

[38]Coleoptera:Hydrophilidae

[39]Coleoptera:Hydrophilidae

and a hister larva devoured 30 first-instar larvae of the same fly species in eight hours. Hafez (1949) also reported on the biology of several species Borboridae. The eggs and larvae of these flies are particularly preyed upon by several species of histerid and staphylinid beetles, while the adults are probably attacked by several species of adult empidid flies.

Laurence (1954) reported that 2 specimens of Mesembrina spp. in the British Museum collection were reared from larvae that consumed 30 - 40 Musca autumnalis larvae. Aleochara languinosa Gravenhorst was observed several times feeding on the eggs of Scatophaga sp. and the larvae of Psychoda phalaenoides (L.).[40] Laurence also observed Philonthus marginatus Stroem preying on adults of Psychoda sp. and Sepsis sp. on cow droppings.

Cates (1964) investigated the effects of predaceous insects on face fly populations in Missouri, comparing staphylinid, histerid, and Sphaeridium species beetle populations recovered from 48 hour old bovine manure to the muscoid Diptera populations obtained from the same manure. The staphylinid beetle population consisted of Aleochara bimaculata, A. bipustulata (L.), Atheta analis Gravenhorst, Falagria dissecta Erickson, Oxyteles suspectus Casey, Philonthus alumnis Erickson, P. cruentatus Gmelin and Platystethus americanus. He found that muscoid fly populations were independent of the staphylinid populations, but stated that this may have reflected the saprophytic habits of A. analis, F. dissecta, O. suspectus, and P. americanus.

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[40]Diptera:Psychodidae

He studied the histerid beetle populations, consisting of Hister abbreviatus Fabricius, H. americanus Paykull, and H. bimaculata L., but found that the muscoid fly populations were not affected by them. However, in observing populations of S. bipustulatum and S. scarabaeoides, he found that as the Sphaeridium populations increased, the muscoid populations decreased.

Sanders and Dobson (1966) investigated the insect complex associated with bovine manure in Indiana. They reported that both larvae of S. scarabaeoides, and larvae and adults of Hister abbreviatus, were probably predaceous on other insects in manure. Larvae and adults of Philonthus cruentatus were found feeding on dipterous larvae under manure piles. They also stated that the staphylinids, Platystethus americanus and Ontholestes cingulatus (Gravenhorst) are probably predaceous.

Thomas (1967) further investigated predaceous beetles of the face fly in Missouri, and agreed with Cates (1964) that the larvae of Sphaeridium beetles were predators of the face fly. Thomas further demonstrated that Philonthus spp. were predaceous on face fly larvae.

Overwintering arthropods found in South Dakota cow droppings were listed by McDaniel and Balsbaugh (1968), however no known predators or parasites were included.

Bourne and Hays (1968) studied the effects of larval S. scarabaeoides on larval horn flies. They concluded that as temperature increased, the rate of predation also increased.

Valiela (1969) stated that P. cruentatus caused a 37.4% mortality in face fly eggs and larvae if the hydrophilid, S. scarabaeoides was also present. Valiela also speculated that there is highly complex relationship among the species in the bovine manure ecosystem which directly affects predation rates.

MATERIALS AND METHODS

The study areas were located along the Big Sioux River on the Brookings County - Moody County line in the part of the Great Plains known as the Coteau des Prairies. This coteau, which slopes to the south and west, is a highland area between the Minnesota - Red River Lowland and the James River Lowland. Elevations range from 3,000 feet above sea level on the north to about 1,600 feet on the south, where it is drained by the Big Sioux River (Westin et al. 1967).

The cattle herd at test site "A," located in Moody County (Figure 1), was composed of 48 angus and hereford cows with calves and 2 angus bulls. These animals were maintained throughout the summer on pasture grasses; their diet was not supplemented by grain or additives. In previous years these cattle had been sprayed with a non-systemic, short residual insecticide.

Test site "B" (Figure 2) was located in Brookings County, 1 mile north and 1/2 mile west of site A. The herd at site B consisted of 45 predominantly angus cows with calves and 1 shorthorn bull. These animals also grazed on pasture grasses throughout the summer with no grain supplement. Toxaphene had been used in previous years for fly control, however, no attempt was made to control flies on these cattle during 1969 or 1970.

Since there was no record of the use of persistent insecticides on these test sites, it was thought that this area was probably as free of residual toxicants as any site in the test area, and the effect of these chemicals on the insect fauna was minimal.

Figure 1. Test site A: Moody County, South Dakota.

Figure 2. Test site B: Brookings County, South Dakota.

I Succession Studies

Succession studies of Coleoptera in bovine manure were made at both sites. These studies were initiated to establish the numbers and species of Coleoptera present in different conditions of bovine dung. By establishing the succession patterns of Coleoptera, I planned to isolate species which are potential predators of face fly larvae. Manure was collected for the succession study at both sites A and B. Dung, which had been deposited by the cattle within the previous 24 hours, was collected in 37.9 l plastic pails with tightly fitting lids. The pails containing the manure were then put into a freezer for 96 hours at $0^{o}C$. Since the manure was kept frozen for at least 96 hours, it was assumed that all the insects in the manure were killed since no living insects were observed in the manure after it had thawed. The pails of manure were removed from the freezer and allowed to thaw at room temperature. If the manure dried out during the thawing period, distilled water was added so that the consistancy of the manure would be similar to that of freshly deposited dung.

Succession study exclosures at both sites A and B were 9.12 m^2, surrounded by double strand barbed wire. Six depressions, 32.5 x 22.5 x 5.0 cm were dug in each exclosure. A 32.5 x 22.5 x 5.0 cm pan was placed into each of the 6 dugout areas so that the lip of the pan was level with the surface of the ground. Holes, 2.5 cm^2 were punched in each corner and the center of these pans, and covered by a 14/16 mesh galvanized wire fly screening held in place by aluminum

paste which allowed drainage. The pans were painted a flat green color so that they would not reflect sunlight and would blend into their surroundings. Two hundred ml of sand was then placed into the pan to both aid in drainage and yet help retain some moisture in the pan. A 22.5 cm diameter x 5.0 cm deep bovine manure patty was then constructed in the pan from reconstituted manure. A preliminary survey indicated that the same insect species and numbers were attracted to the manure whether the dung was on the ground or in the pans. The pans were used to facilitate handling.

One pan was selected at random, by casting a die, and was removed from the succession study area at intervals of 24, 48, 72, 96 hrs., and 7 and 14 days. Each pan was placed in a plastic bag for return to the laboratory. In the laboratory, 7.5 l of a 25% sucrose/water solution was mixed in a 17.9 l galvanized metal pail. The pan was then removed from the plastic bag and the manure and sand placed into the sugar floatation solution. The material was diluted to allow the insects to float to the surface of the solution. They were collected with a 32/2.5 cm^2 wire mesh sieve and forceps, and placed in 70% ethyl alcohol, identified, counted, and recorded by species and number. The succession studies, which lasted 15 weeks, were conducted from June 18 - September 26, 1969, and 1970.

II Field Mortality

Field studies were conducted during the summer of 1969 and 1970 to determine the effects of the natural enemies of the face fly

in eastcentral South Dakota. A plastic bowl, 13.75 cm diameter x 5.0 cm deep, was filled with reconstituted manure and covered with a layer of cheesecloth. A slury of manure (2 mm thick) was spread evenly over the cheesecloth. The bowls were then placed into the laboratory face fly colony after 6 hours. The face flies oviposited through the manure slury and the cheesecloth and deposited their eggs in the manure in the bowl. When the cheesecloth and manure slury were removed, the face fly eggs in the manure could be easily counted and recorded (Rummel 1970).

One bowl with manure and eggs remained in the laboratory as a control. Two other bowls of manure with eggs were taken to the test site. The field mortality test sites were the same as those used in the succession studies. Mortality tests of the face fly were conducted when the study area was not being used for succession studies so that the sites would not have a high concentration of cattle droppings in a small area. At the study site a bowl of manure with eggs was placed in a cage 30 cm^3 with plywood floors and covered with 32 mesh/2.5 cm^2 nylon screening. This cage served as a field control so that climatological factors causing face fly eggs and larvae mortality could be evaluated. Another bowl of manure and face fly eggs was buried so that the lip of the bowl was even with the surface of the ground. These 2 bowls remained in the field for 4 days, and then were returned to the laboratory. Four replications during 1969 and 5 replications during 1970 were used in these studies.

In the laboratory, the bowls of manure with eggs were each placed on a bed of fine sand in a 20 cm diameter x 3.75 cm deep pan to provide a pupation site for the face fly larvae. After pupation was completed, the pupae were removed by sifting the sand through a 14.16 mesh per 2.5 cm^2 screen and placed into petri dishes and incubated for 2 weeks at 30°C and 55% RH. After 2 weeks, the pupae from which adults did not emerge were idssected to see if they were parasitized. By comparing the mortality rate of the face flies in each test situation, an estimate of the importance of the natural enemies of the face fly was obtained.

III Parasitism Studies

INSECT PARASITISM - Parasitism of the face fly by other insects was studied in 1969 and 1970 to determine which insect parasites were present in eastcentral South Dakota and to establish their rates of face fly parasitism. In order to obtain eggs, a pleated souffle cup (118 1/4 ml) was filled with reconstituted manure and covered with cheesecloth and a manure slury as described previously. After the cups were exposed to the face fly colony for 4 hours, the eggs in each cup were counted and the cup was alternately taken to the study area at site A or B. Sites A and B showed no difference in insect populations thus each site was used for every other replication. A 20 cm diameter x 3.75 cm deep pan was filled with reconstituted manure leaving an area in the middle for the contents of the souffle cup to be placed. The pleats of the souffle cup were opened and the

contents removed and placed in the hole left in the manure. The area between the insert and the rest of the manure was then smoothed to make the surface of the pan look uniform and like naturally deposited manure. This pan of manure was then placed on a bed of sand in a 32.5 x 22.5 x 5.0 cm pan and left in the field for 7 days. The pans were returned to the laboratory along with their sand beds. The sand containing the face fly pupae was sifted through a 14/16 mesh screen so that the pupae could be separated. The pupae were then placed in a labled petri dish and kept at 30°C and 50-55% RH for 2 weeks. Pupae from which no flies emerged were kept for an additional 2 week period, and then dissected and examined for parasitism. All parasites were identified and counted. The data from these sites for 1969 and 1970 were combined for analysis since no significance was shown between the 2 years as determined by Bartlett's test for homogeniety of variances.

NEMATODE PARASITISM - Adult face flies are parasitized by a nematode, *Heterotylenchus autumnalis*, which may not cause death, but can cause sterility or at least a decline in face fly fecundity. Wild adult face flies, both male and female, were collected in 4 dram snap top vials from the face of cattle, on manure piles, and from resting places on fences and trees. These flies were returned to the laboratory and anesthetized with ethyl acetate and dissected in 70% ethyl alcohol under a dissection microscope to determine the rate of nematode infestation.

IV Predation Studies

The predation rates of several species of Coleoptera on immature face flies were investigated under laboratory conditions. Potential predators were collected from naturally deposited bovine dung by collecting the excrement in the field at site "A," returning the manure with its insect inhabitants to the lab and removing the insects by the floatation method mentioned previously. The species being tested was put into a 17.95 l cylindrical cardboard ice cream carton that contained a 2.5 cm sand bedding and 113.4 g of reconstituted manure. The manure provided a source of moisture and a place for the beetles to burrow. A piece of cheesecloth, placed over the open end of the cylinder, was held in place by rubber bands. The potential predators were fed on crushed face fly pupae for two days, not fed on the third day, and tested for predation on the fourth day after capture. This routine was used to equilibrate the appetite and behavior of the beetles. To determine the predation rate of these coleopterous species, 25 face fly eggs were manually implanted using a size 0 camel hair brush into each of 2-12-5 cm diameter x 2.5 cm deep reconstituted manure patty. Each manure patty was then placed on 2.5 cm of sand in a 17.95 l ice cream cylinder. Five individuals of each species being screened were introduced into one of the ice cream cylinders. The open end of the cylinders were covered with cheesecloth held in place by rubber bands. The potential predators were allowed to remain in the cylinder for 5

days. The fly pupae were then counted in both the test and the control cylinders and compared to the number of eggs originally exposed. The means of each of 4 replications were compared using Duncan's new multiple range test.

RESULTS AND DISCUSSION

I Succession Studies

It was the purpose of this study (1) to determine the species, abundance, and seasonal occurrence of adult insects of the families Histeridae, Hydrophilidae, Scarabaeidae, and Staphylinidae in bovine manure in eastcentral South Dakota, and (2) to determine in which condition of manure (24-96 hr.) each of the species was most abundant.

Since face fly larvae migrate from manure patties within 4-5 days after egg deposition, a knowledge of the species and abundance of insects occurring in the manure during this period is essential. Only species of the 4 previously mentioned families of beetles were studied because a consideration of the entire fauna would have been impossible in a limited time period, and because the members of these 4 families constituted 99+% of the insects recovered from bovine manure.

Thirty-eight species of adult Coleoptera were recovered from cow dung in these studies. There were 3 species of Histeridae, 9 species of Hydrophilidae, 14 species of Scarabaeidae, and 12 species of Staphylinidae. The frequency of recovery of each insect species from bovine manure and the per cent of the total population are shown in Table 1. The total number of each species of insects collected from the 4 ages of manure throughout the period of investigation is shown on Table 2. The weekly occurrence and abundance of each of the species of insects collected in cow dung from June 18 to September 10, 1969, and 1970, are shown in Table 3.

HISTERIDAE

Three species, representing the genera Hister and Phelister, were found in bovine manure. Both H. abbreviatus and P. subrotundus were equally abundant during the months of August and September. There were averages of 0.65 H. abbreviatus and 0.57 P. subrotundus adults per manure dropping for the study. The greatest number of Hister adults recovered from a single pile of manure was 5, and in most cases the number of larvae was less than 7. However, since both the adults and larvae are voracious predators, the histerids are considered important in the reduction of the dipterous populations in dung in South Dakota.

HYDROPHILIDAE

Nine species, representing the genera Cercyon, Sphaeridium, and Cryptopleurum, were found associated with bovine manure. Of the 5 species of Cercyon, both C. pygmaeus and C. quisquilius were very abundant. The other species, in decreasing order of abundance, were C. lateralis, C. unipunctatus, and C. praetestatus. All of the species of Cercyon, except C. praetestatus, were common throughout the course of this investigation. Cercyon praetestatus was present only during the months of July and August.

Of the three species of Sphaeridium found in this study, all were abundant. Sphaeridium lunatum was most abundant with 1139 adults collected in 1969 and 1970. Sphaeridium scarabaeoides and S. bipustulatum were represented by 966 and 603 adults respectively.

The adult *Cercyon* occurred in such abundance at certain times that it is possible that they competed with the fly larvae for nutrients. For example, on September 11, 1969, 218 adult *Cercyon* spp. were recovered from one manure dropping. Adults of *Cryptopleurum* species were not present in sufficient numbers to affect the development of face fly eggs or larvae in bovine manure during this study.

SCARABAEIDAE

Fourteen species, representing the genera *Aphodius*, *Ataenius*, *Copris*, and *Onthophagous*, were recovered from bovine manure. Only 6 species were abundant. *Aphodius haemorrhoidalis* was the most abundant species, and the other 5, in decreasing order of abundance, were: *Onthophagus hecate*, *Aphodius granarius*, *A. fimetarius*, *Ataenius spretulus*, and *Aphodius vittatus*.

This investigation supported the work of Portchinsky (1913a) and Hammer (1942) and it was found that adult scarabs were abundant enough at certain times to compete with the fly larvae for space and nutrients, both by feeding in the manure and removal of areas of it for egg deposition. For example, 122 adult scarabaeids were recovered from one dropping on July 23, 1969, and 186 were collected from one dropping on August 4, 1970.

STAPHYLINIDAE

Twelve species, representing the genera *Falagria*, *Platystethus*, *Oxpoda*, *Ontholestes*, *Philonthus*, *Aleochara*, *Gyrophypnus*, and *Oxytelus*

were found associated with bovine dung in eastcentral South Dakota. Platystethus americanus was the most abundant species. All the other species, except Ontholestes cingulatus, Philonthus varians, Gyrohypnus obsidianus and Oxytelus suspectus, were recovered regularly from cow manure. These species in the decreasing order of abundance, were; Falagria dissecta, Oxypoda sagulata, Philonthus creuntatus, P. rectangularis, Aleochara bipustulata, Philonthus umbrinus, and Aleochara bimaculata.

II Field Mortality Studies

The purpose of these studies, conducted during the summer of 1969 and 1970, was to determine the mortality of face fly eggs and larvae in the field due to the action of natural enemies. The puparia recovered from the test manure patties were recorded, and the results are shown in Table 4.

The data in Table 4 shows that a 21.8% average mortality rate of the face fly eggs and larvae in manure can be attributed to natural enemies under the conditions of this test. The climatological factors were responsible for a 13.9% mortality and the mortality in the laboratory control was 16.2%. This mortality due to natural enemies may be attributed in part to the presence of hymenopterous and coleopterous parasites, predation of the eggs and larvae by coleopterous insects and competition for space and nutrients in the manure droppings.

Results from studies in other areas of the United States have indicated a higher face fly egg and larva mortality due to natural enemies (Thomas 1967, Valiela 1969b), however, it is felt that the environmental conditions, especially temperature, which exist in South Dakota play an important role in limiting the action of some natural enemies. The climate in South Dakota is characterized by cool summer evenings and short growing seasons which has the effect of reducing the activity and searching time of predators as well as parasites.

III Parasitism Studies

It was the purpose of this investigation to determine the species of parasites attacking the face fly in eastcentral South Dakota and their effectiveness as natural control agents of this pest.

Two species of parasites were recovered from the face fly. These were *Aphaereta pallipes* and *Aleochara bimaculata*. Rate of parasitism of the face fly by these two species is shown in Table 5.

PARASITISM BY *APHAERETA PALLIPES*

This small braconid is a gregarious parasite with 20 reported species of dipterous hosts (Houser 1966). During this investigation, the parasite was not able to emerge from face fly puparia but still killed the host. Therefore, all instances of parasitism of the face fly by *A. pallipes* were confirmed by dissection of the puparia. This

phenomenon was also reported by Bickle (1961), Benson and Wingo (1963), and Thomas (1967).

Seasonal parasitism of M. autumnalis averaged 7.67% with the highest parasitism occurring on August 26, 1970 when 20.2% of the face fly puparia contained A. pallipes. During both 1969 and 1970 the highest rate of parasitism by A. pallipes occurred in late August and early September, when the native face fly population reached its peak population. Parasitism in late August and September is important since it could reduce the overwintering populations of adult face flies as the hibernating flies develop in the field during the last 20 - 30 days before frost occurs in late September and early October (Benson and Wingo, 1963).

PARASITISM BY ALEOCHARA BIMACULATA

This staphylinid insect is a solitary pupal parasite which undergoes a hypermetamorphic development. This parasite usually escaped from the puparium by gnawing a hole at the anterior end. Parasitism by A. bimaculata averaged 1.08% and a rate of no more than 2.05% parasitism was noted at any time during this study.

PARASITISM BY HETEROTYLENCHUS AUTUMNALIS

This nematode parasite of adult face flies was first reported by Stoffolano and Nickle (1966) to invade the ovaries of adult female M. autumnalis causing female sterility. The rates of infestation by this nematode has varied from 23.1% in New York (Stoffolano and Nickle, 1966) to 50.4% in laboratory colonies (Treece and Miller,

968), and to 30% in Nebraska (Jones and Perdue, 1967) to as high
84% in Missouri (Thomas and Puttler, 1970). In this study
rasitism rates of 5.01% and 6.62% for 1969 and 1970 respectively
re noted as shown in Tables 6 and 7. The highest parasitism rate
any sample above 10 flies was 18.18%, even though the nematodes
re present in relatively constant numbers from mid-June to mid-
ptember.

IV Predation Studies

The purpose of these investigations was to determine in the
oratory the predatory effect of nine species of adult Coleoptera
the eggs and larvae of the face fly. These species were;
eridium scarabaeoides, S. lunatum, S. bipustulatum, Aleochara
culata, Philonthus cruentatus, P. rectangularis, P. umbrinus,
er abbreviatus, and Phelister subrotundus.

TION BY SPAERIDIUM

This genus of hydrophilid was abundant in bovine manure in South
ta. Counts as high as 50 per dropping were common. Hammer (1942)
ted that the adults were carnivorous, however, Sanders and
n (1966) stated that adult Sphaeridium were scavengers.

A laboratory experiment was initiated to determine if adults of the
eridium species preyed on face fly eggs and larvae, and to quan-
tively measure this predation. The results are shown in Table 8.
an be seen that none of the treatment means differed significantly
each other or from the mean of the control. Therefore, it was

concluded that adults of the Sphaeridium species do not prey on face fly eggs or larvae under conditions of the test, and were never observed preying on the eggs or larvae of any dung inhabiting species of Diptera in the field. They, therefore, are probably scavengers in the adult stage. Since the adult Sphaeridium inhabited the manure soon after it was deposited, and tunneled incessantly in the manure, they were responsible for much of the early aeration, and the predacious and parasitic insects used these tunnels to search out their prey (Thomas 1967).

PREDATION BY STAPHYLINIDAE

Staphylinids were abundant in bovine manure throughout the larval face fly development period, and were observed feeding on the eggs and larvae of several species of dung-breeding flies. This supports the reports of Howard (1900), Hammer (1942), Mohr (1943), Hafez (1948 and 1949), and Laurence (1954).

Experiments were initiated to determine if adult staphylinids preyed on face fly eggs and larvae, and to quantitatively measure this predation. The results are shown in Table 9.

From the data shown in Table 9, the following can be concluded:

1) Philonthus cruentatus was the most effective predator of the face fly since the mean number of puparia recovered from eggs exposed to this species was significantly less than the mean number recovered after exposure to the other staphylinids or the control.

2) Philonthus rectangularis and Aleochara bimaculata were predaceous on the face fly, but to a lesser extent than P. cruentatus.

3) Philonthus umbrinus was not a predator of the face fly.

PREDATION BY HISTERIDAE

Histerids were not numerous in bovine manure in South Dakota, but were observed feeding on face fly eggs in the field. Several authors have studied the role of histerids as predators of dung inhabiting flies (Hammer 1942, Mohr 1943, Hafez 1948, Cates 1964, and Sanders and Dobson 1966), however, there was a difference of opinion as to the actual predaceous capability of these beetles.

Experiments were initiated to determine if some adult histerids preyed on face fly eggs and larvae, and to what extent. The results are shown in Table 10.

From the data shown in Table 10, the following may be concluded:

1) Hister abbreviatus was predaceous on face flies since the mean number of puparia recovered from the eggs exposed to H. abbreviatus was significantly less than the mean of the control.

2) Phelister subrotundus was not predaceous on face flies.

SUMMARY AND CONCLUSIONS

The succession of Coleoptera in bovine manure and incidence of natural enemies of the face fly in South Dakota were determined from June to October in 1969 and 1970.

Two parasitic insect species were recovered from the face fly. Aphaereta pallipes, although not abundant, appeared in greatest numbers during late August and September. A large population of A. pallipes could reduce overwintering populations of adult face flies since the hibernating flies develop in the field during the last 20 - 30 days before frost occurs in September. However, in my study this parasite was not abundant on bovine manure, and it is questionable if this species is important by itself in the natural control of the face fly.

Aleochara bimaculata, a second parasite of the face fly, was recovered less frequently than Aphaereta pallipes.

Heterotylenchus autumnalis, a nematode parasite of adult face flies, was present throughout the summer season. However, the rate of parasitism during 1969 and 1970 was too low in this study to be considered as important in controlling the wild face fly population.

Of the 4 families of adult Coleoptera found associated with bovine manure, the staphylinids and histerids were the most significant predators of face fly eggs and/or larvae. Adults of the genus Sphaeridium were not predaceous on the face fly. Adults of the Cercyon species could have been important at times, because they occurred in such abundance that they may compete with the face fly larvae for nutrients.

During periods of abundance, adult scarabaeids could adversely affect face fly populations by competing with the face fly larvae for space and nutrients or by removal of portions of manure for egg deposition.

The biotic mortality of face fly eggs and larvae in the field can be attributed to specific factors. Biotic mortality noted in this study can be partitioned into three elements: (1) face fly mortality due to parasites, (2) predation on face fly eggs and larvae by coleopterous species, and (3) possible competition between face fly larvae and other dipterous and coleopterous species.

A combination of these factors could limit the native face fly population. It is apparent, however, that the supression of the face fly by biological means as determined in this study is not a feasible way in itself of controlling this pest in South Dakota.

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APPENDIX

Table 1. Frequency of Coleoptera recovered in bovine manure in eastcentral South Dakota for 1969 and 1970.

Species	1969		1970	
	Total No.	Percent	Total No.	Percent
Platystethus americanus Er.	2466	22.00	2931	21.52
Cercyon pygmaeus (Illig.)	2262	20.22	2833	20.80
Cercyon quisquilius L.	1278	11.42	1626	11.93
Aphodius haemorrhoidalis (L.)	824	7.37	878	6.44
Falagria dissecta Er.	797	7.12	932	6.84
Sphaeridium lunatum Fab.	521	4.66	618	4.53
Sphaeridium scarabaeoides L.	428	3.80	538	3.95
Oxypoda saqulata Er.	412	3.70	530	3.89
Onthophaqus hecate Panz.	315	2.82	314	2.30
Aphodius granarius (L.)	297	2.65	328	2.40
Sphaeridium bipustulatum Fab.	294	2.63	309	2.26
Cryptopleurum minutum (Fab.)	247	2.21	301	2.20
Philonthus cruentatus Grav.	162	1.45	221	1.62
Aphodius fimetarius (L.)	139	1.24	143	1.04
Cercyon lateralis (Marsh.)	136	1.22	156	1.14
Aleocharainae	103	.92	158	1.16
Ataenius spretulus (Hald.)	103	.92	110	.81
Aphodius vittatus Say	45	.40	64	.47
Onthophaqus pennsylvanicus Harold	43	.38	56	.41
Aleochara bipustulata L.	40	.36	65	.48
Philonthus rectanqularis Sharp	40	.36	52	.38
Phelister subrotundus Say	31	.28	28	.21
Philonthus umbrinus Grav.	25	.22	65	.48
Aphodius ruricola Melsh.	24	.21	25	.18
Hister abbreviatus Fab.	20	.18	60	.44
Aphodius coloradensis Horn	19	.17	23	.16
Cercyon unipunctatus (L.)	19	.17	43	.32
Adhodius distinctus (Muller)	18	.16	50	.37
Aleochara bimaculata Grav.	17	.15	63	.46
Philonthus varians (Payk.)	13	.12	14	.10
Aphodius sterocorosa Melsh.	11	.10	15	.11
Aphodius fossor (L.)	10	.09	18	.13
Glischrochilus quadrisiqnatus (Say)	7	.06	8	.07

Table 1. (Continued)

Species	1969 Total No.	1969 Percent	1970 Total No.	1970 Percent
Copris tullius Oliv.	7	.06	10	.07
Carabidae sp.	5	.04	4	.03
Oxytelus suspectus Casey	5	.04	7	.05
Xantholinini	2	.02	4	.03
Gyrohypnus obsidianus (Melsh.)	1	.01	0	.00
Ontholestes cinquatus Grav.	1	.01	6	.04
Cercyon praetestatus (Say)	1	.01	3	.02
Aphodius prodromus (Brahm.)	1	.01	1	.01
Hister americanus Payk.	1	.01	17	.12
Total	11,190	99.97	13,627	99.97

Table 2. Occurrence of thirty-eight species of Coleoptera in 4 ages of bovine manure in eastcentral South Dakota, 1969 and 1970.

Species	Age of Manure Pile in Hrs.				Total No. Recovered	Ave. No. Per Pile
	24	48	72	96		
Histeridae						
Hister abbreviatus	20	19	23	10	72	.69
Phelister subrotundus	0	2	7	50	59	.57
Hister americanus	0	3	7	9	19	.18
Hydrophilidae						
Sphaeridium lunatum	468	339	275	69	1151	11.07
S. scarabaeoides	607	187	114	52	960	9.23
S. bipustulatum	298	172	105	28	603	5.80
Cercyon quisquilius	974	775	692	382	2823	27.14
C. pygmaeus	1228	1809	1092	795	4924	47.35
C. lateralis	51	48	69	72	240	2.31
C. unipunctatus	12	23	13	13	61	.59
C. praetestatus	4	0	0	0	4	.04
Cryptopleurum minutum	60	187	136	114	497	4.78
Scarabaeidae						
Onthophagus hecate	222	182	168	58	630	6.06
O. pennsylvanicus	50	22	14	13	99	.95
Aphodius haemorrhoidalis	155	325	344	411	1235	11.86
A. vittatus	17	28	25	37	107	1.03
A. coloradensis	13	12	12	5	42	.40
A. fossor	3	4	14	6	27	.26
A. distinctus	11	10	20	27	68	.65
A. fimetarius	19	51	59	79	208	2.00
A. ruricola	7	7	8	21	42	.40
A. graniarius	87	125	120	177	509	4.89

Table 2. (Continued)

Species	Age of Manure Pile in Hrs. 24	48	72	96	Total No. Recovered	Ave. No. Per Pile
A. prodromus	0	1	1	0	2	.02
A. sterocorosa	9	4	12	1	26	.25
Copris tullius	3	5	3	5	16	.15
Ataenius spretulus	16	74	47	50	187	1.80
Staphylinidae						
Falagria dissecta	65	350	398	540	1353	13.01
Platystethus americanus	781	1360	1430	1210	4781	45.97
Oxpoda sagulata	56	124	198	309	687	6.61
Ontholestes cingulatus	4	2	0	0	6	.06
Philonthus cruentatus	95	98	121	54	368	3.54
P. varians	9	4	11	3	27	.26
P. umbrinus	28	20	16	18	82	.79
P. rectanularis	8	17	38	25	88	.85
Aleochara bimaculata	37	14	14	6	71	.68
A. bipustulata	35	14	17	18	84	.81
Gryohypnus obsidianus	0	1	0	0	1	.01
Oxytelus suspectus	5	3	1	2	11	.11

Table 3. Frequency of thirty-eight species of Coleoptera recovered from bovine manure in eastcentral South Dakota from June 18 to September 10, 1969 and 1970.

Species	Total Number Recovered from 104 Manure Pats												
	June		July					August				September	
	18	25	2	9	16	23	30	6	13	20	27	3	10
Histeridae													
H. abbreviatus	1	0	4	0	5	0	2	1	3	7	12	20	25
P. subrotundus	0	0	0	0	0	0	2	1	8	6	12	14	15
A. americanus	5	1	1	0	0	0	0	1	3	4	2	1	0
Hydrophilidae													
S. lunatum	26	15	10	34	53	91	92	97	177	238	126	126	68
S. scarabaeoides	44	17	12	81	51	123	43	68	119	146	102	107	58
S. bipustulatum	13	6	9	89	32	123	40	36	47	54	69	59	16
C. quisquilias	167	81	222	179	255	149	169	138	278	188	269	393	416
C. pygmaeus	88	87	114	386	147	285	194	351	597	446	497	935	968
C. lateralis	0	0	8	17	10	10	20	13	80	16	16	51	51
C. unipunctatus	0	0	0	0	1	0	1	0	9	8	13	12	17
C. praetestatus	0	0	0	0	2	1	0	1	0	0	0	0	0
C. minutum	7	7	32	27	19	35	30	20	95	44	58	77	67
Scarabaeidae													
O. hecate	81	33	33	2	3	2	3	0	59	137	142	105	29
O. pennsylvanicus	33	10	16	7	1	1	1	1	8	5	11	3	2
A. haemorrhoidalis	57	42	111	204	112	325	284	150	159	73	47	28	20
A. vittatus	59	11	24	4	2	2	7	0	0	0	0	0	0
A. coloradensis	16	10	14	2	1	0	0	0	0	0	0	0	0
A. fossor	7	3	3	4	2	0	1	3	3	1	1	0	0
A. distinctus	10	6	8	8	0	0	0	0	1	4	5	5	10
A. fimetarius	3	5	10	9	43	19	10	0	1	15	26	62	79
A. ruricola	5	6	3	4	5	5	3	2	7	3	2	3	1

Table 3. (Continued)

Species	Total Number Recovered from 104 Manure Pats												
	June		July					August				September	
	18	25	2	9	16	23	30	6	13	20	27	3	10
Scarabaeidae													
A. granarius	47	53	59	68	69	38	41	20	66	121	26	9	8
A. prodromus	1	0	1	0	0	0	0	0	0	0	0	0	0
A. sterocorosa	0	0	0	2	0	2	4	4	11	1	1	1	0
C. tullius	5	1	1	3	2	0	0	0	0	0	2	1	2
A. spretulus	0	0	0	0	0	0	1	14	20	51	89	20	18
Staphylinidae													
F. dissecta	34	30	71	59	176	254	131	87	195	194	185	232	81
P. americanus	378	208	179	271	953	917	1021	149	410	265	191	206	149
O. sagulata	19	14	52	34	95	67	43	72	132	158	106	87	63
O. cingulatus	0	0	0	0	0	0	0	1	4	1	0	0	0
P. cruentatus	7	2	4	14	20	35	17	29	59	63	58	38	37
P. varians	0	0	0	3	4	1	1	1	2	10	3	1	1
P. umbrinus	0	0	0	2	2	3	6	10	8	12	29	15	2
P. rectanularis	0	0	0	3	6	8	0	8	23	21	13	9	0
A. bimaculata	0	0	6	15	23	4	0	3	7	6	11	2	3
A. bipustulata	0	1	3	13	23	2	5	9	7	9	0	26	7
G. obsillianus	0	0	0	0	0	1	0	0	0	0	0	0	0
O. suspectus	0	0	0	0	0	0	0	0	5	1	1	3	2

Table 4. Field mortality of eggs and larvae of <u>Musca autumnalis</u> DeGeer, due to natural conditions.

Date	Situation	No. Eggs Exposed	No. Pupae Recovered	Mortality in Lab. Control	Mortality Due to Environmental Conditions	Mortality Due to Action of Natural Enemies
7/3/69	Lab. Control	100	86	14.0	----	----
	Field Control (eggs caged)	100	42	28.0	14.0	----
	Field Test (eggs exposed)	100	47	53.0	39.0	25.0
7/27/69	Lab. Control	100	80	20.0	----	----
	Field Control (eggs caged)	100	54	40.0	20.0	----
	Field Test (eggs exposed)	100	38	62.0	42.0	22.0
8/17/69	Lab. Control	100	90	10.0	----	----
	Field Control (eggs caged)	100	70	30.0	20.0	----
	Field Test (eggs exposed)	100	57	42.0	33.0	13.0
8/30/69	Lab. Control	100	83	17.0	----	----
	Field Control (eggs caged)	100	54	26.0	9.0	----
	Field Test (eggs exposed)	100	49	51.0	34.0	25.0

Table 4. (Continued)

Date	Situation	No. Eggs Exposed	No. Pupae Recovered	Mortality in Lab. Control	Mortality Due to Environmental Conditions	Mortality Due to Action of Natural Enemies
6/20/70	Lab. Control	100	85	15.0	----	----
	Field Control (eggs caged)	100	57	23.0	8.0	----
	Field Test (eggs exposed)	100	49	51.0	36.0	26.0
7/2/70	Lab Control	200	171	14.5	----	----
	Field Control (eggs caged)	200	136	32.0	17.5	----
	Field Test (eggs exposed)	200	101	49.5	35.0	17.5
7/20/70	Lab. Control	100	80	20.0	----	----
	Field Control (eggs caged)	100	52	28.0	8.0	----
	Field Test (eggs exposed)	100	51	49.0	29.0	21.0
8/5/70	Lab. Control	100	83	17.0	----	----
	Field Control (eggs caged)	100	65	35.0	18.0	----
	Field Test (eggs exposed)	100	48	62.0	45.0	27.0
8/20/70	Lab. Control	100	82	18.0	----	----
	Field Control (eggs caged)	100	71	29.0	11.0	----
	Field Test (eggs exposed)	100	51	49.0	31.0	20.0

Table 5. Parasitism of face flies in eastcentral South Dakota 1969 and 1970.

Species of Parasite	No. Pupae Recovered	No. Parasites	% Parasitism
Aleochara bimaculata	1278	14	1.08
Aphaereta pallipes	1278	97	7.67

Table 6. Parasitism of *Musca autumnalis* DeGeer, by the Nematode *Heterotylenchus autumnalis* Nickle, in eastcentral South Dakota, 1969.

Date	No. of Flies Dissected		Total No. of Face Flies Found Parasitized by Nematodes[1]
6/25	5♀		0
6/30	8	1♂	0
7/3	24		1
7/4	18		1
7/10	19		0
7/13	25	2	1
7/20	32	1	1
7/25	18		0
7/28	10		0
8/1	23		1
8/4	16		2
8/13	28	6	1
8/14	15		2
8/15	19		2
8/20	13		1
8/27	34	12	2
8/30	18	1	1
9/11	10		1
9/15	14	1	2
9/21	6		0
Total	355	24	19

Percent Parasitism 5.01%

[1]All Nematodes found in female flies.

Table 7. Parasitism of Musca autumnalis DeGeer, by the Nematode Heterotylenchus autumnalis Nickle, to eastcentral South Dakota, 1970.

Date	No. of Flies Dissected		Total No. of Face Flies Found Parasitized by Nematodes[1]
5/20	1♀		0
5/23	3		0
5/28	1		0
6/4	6	1♂	0
6/10	3		0
6/11	10		0
6/14	12		0
6/18	16		1
6/21	4		0
6/27	27		1
7/1	19	1	2
7/3	34	1	1
7/14	38		2
7/17	30		2
7/19	24	2	2
7/23	35		2
7/24	16		1
7/27	18	2	2
7/29	22		2
7/30	31		3
8/3	19		2
8/4	6		2
8/7	2		1
8/9	4		2
8/10	10		1
8/12	27	2	4
8/14	42		4
8/16	50	6	3
8/17	35		3
8/18	20	2	4
8/20	23		2

Table 7. (Continued)

Date	No. of Flies Dissected		Total No. of Face Flies Found Parasitized by Nematodes[1]
8/25	72		4
8/30	12	2	1
9/1	21		3
9/6	6		0
9/10	25	5	3
9/11	17	1	2
9/21	12		1
9/29	20		2
10/1	20	10	3
10/14	10		1
10/30	0		0
Total	798	35	69

Percent Parasitism 6.62%

[1] All Nematodes recovered from female flies.

Table 8. Predation of face fly eggs and larvae by adults of three species of *Sphaeridium*.

Replicate	No. of puparia recovered from 25 face fly eggs exposed to 3 species of Sphaeridium for 5 days			
	S. scarabaeoides	*S. lunatum*	*S. bipustulatum*	Control
I	21	18	19	24
II	20	23	19	23
III	18	21	24	19
IV	22	19	22	23
Mean[1]	20.25[a]	20.25[a]	21.0[a]	22.25[a]

[1]Means of the same letter were not significantly different as determined by Duncan's new multiple range test at the 5 percent level.

Table 9. Predation of face fly eggs and larvae by adults of four species of staphylinid beetles.

Replicate	No. of puparia recovered from 25 face fly eggs exposed to 4 adult *Staphylinidae* for 5 days				
	Aleochara bimaculata	*Philonthus umbrinus*	*Philonthus cruentatus*	*Philonthus rectangularis*	Control
I	13	20	6	12	18
II	17	16	6	15	22
III	16	17	4	13	19
IV	14	19	5	14	21
Mean[1]	15.0^{b}	18.0^{ab}	5.25^{c}	14.5^{b}	20.0^{a}

[1]Means having the same superscript are not significantly different as determined by Duncan's new multiple range test at the 5 percent level.

Table 10. Predation of face fly eggs and larvae by two species of Histerid beetles.

Replication	No. of puparia recovered from 25 face fly eggs exposed to 5 adult Histeridae for 5 days: Hister abbreviatus	Phelister subratundus	Control
I	10	18	20
II	7	19	24
III	9	20	21
IV	10	19	22
Mean[1]	9.00[b]	19.00[a]	21.75[a]

[1]Means having the same superscript letter are not significantly different as determined by Duncan's new multiple range test at the 5 percent level.