The Insects of Virginia No. 11

THE BLOW FLIES OF VIRGINIA (DIPTERA: CALLIPHORIDAE)

by

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A CALL FOR HELP TO OUR READERS REQUESTING INSECT MATERIAL ON LOAN OR AS A DONATION

Our next issues in this series, now in preparation, will include the following insect groups from Virginia:

1. A revision and updating of our No. 3 (44) bulletin on the genus *Culicoides* (Diptera: Ceratopogonidae), by E. Craig Turner, Jr.;
2. The Longhorned Beetles (Coleoptera: Cerambycidae), by Robert H. Perry;
3. The Damselflies (Odonata: Zygoptera), by J. Reese Voshell, Jr. and James H. Kennedy;
4. The Dragonflies (Odonata: Anisoptera), by Frank Carle and E. Craig Turner, Jr.;
5. The Lygaeid Bugs (Hemiptera: Lygaeoidea), by Richard L. Hoffman;
6. The Armored Scale Insects (Homoptera: Diaspididae), by Michael Kosztarab;
7. The Flower Flies (Diptera: Syrphidae), by F. Christian Thompson;
8. The Ticks of Virginia, with notes on their biology and ecology (Acari: Metastigmata), by Daniel E. Sonenshine;
9. The Trichoptera of Virginia, by Oliver S. Flint.

Each of the authors listed above could fully utilize more material from Virginia for their studies. There are definite gaps in the geographical distribution of most insect species, usually because of lack of collecting in certain areas of the state. The Board of Review and the authors encourage our readers to intensify their collecting efforts for these groups and lend or donate available insects (in their personal possession, or in the public collection under their supervision) to the Department of Entomology at Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, (Dr. Michael Kosztarab, Curator). If donated, the commercial value of the collections will be appraised and acknowledged by letter to the donors for use in claiming possible tax deductions. In each bulletin we also acknowledge the loans and/or donations for that project. The donated or loaned material will be forwarded to authors of future bulletins for processing and for inclusion of new distribution records in manuscripts they are preparing. Only with such joint effort in the inventorying of our insect fauna can we achieve our goal of a better understanding of the living environment in Virginia.

PUBLICATIONS in this series are intended to serve as scientific contributions for a better understanding of the **living environment** in Virginia.

Recognizing the basic economic importance of faunistic studies, our goal is to survey methodically the local insect fauna through preparation of inventories designed to show the geographic and seasonal occurrence of insects in the Commonwealth, and to provide keys, descriptions, and illustrations to facilitate their recognition.

Insofar as possible, these studies will include data on biology and life cycles to aid in the formulation of control recommendations and information on ecological interactions—including host relationships, parasites, and predators—and the potential of various species as possible biological control agents. Knowledge gained from such studies will be used to evaluate the impact of future changes in our environment.

CONTENTS

* Not known from Virginia.

COMPOSITION AND PRESSWORK BY
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ABSTRACT

Fourteen species of Calliphoridae collected in Virginia, plus an additional genus known to be represented in the state, are discussed. A key is presented which is applicable to the species of Calliphoridae known to occur in Virginia and to most of those found in the eastern United States. Original citations, diagnostic characters, known distribution, Virginia records, seasonal abundance in the state, and pertinent biological data are given for each species. Sections dealing with the medical and economic importance of blow flies emphasize contributions to the literature subsequent to 1948.

A synopsis of terminology applicable to muscoid flies, and appropriate illustrations, are included to aid in the use of the key and the diagnoses.

ACKNOWLEDGMENTS

The authors are indebted to Mr. David G. Hall for advice and encouragement throughout the course of this study. His knowledge of collection procedures appropriate for the species studied is gratefully acknowledged. Most of the plates illustrating salient morphological features of muscoid flies were redrawn from unpublished originals prepared by Mr. Hall for his own use while assigned to the U. S. National Museum (USNM) by USDA during the late 1930's.

Drs. Curtis W. Sabrosky, Raymond J. Gagné, and Lloyd V. Knutson were extremely hospitable to us during our visits to the USNM. They gave freely of their time and expertise to enable us to study the extensive USNM collection of Calliphoridae. A large number of specimens from this collection were lent to us for more intensive study.

Dr. Michael Kosztarab, Virginia Polytechnic Institute and State University (VPI&SU), has provided advice and assistance since the nucleus of this project took shape as an offshoot of an assignment in his course in Systematic Entomology. To him we are grateful for the stimulus to proceed with this design.

The authors wish to thank the following for their advice and/or loan of specimens: Dr. W. A. Allen, VPI&SU; A. F. Buckman, VPI&SU; S. W. Bullington, VPI&SU; Dr. R. L. Hoffman, Radford College. J. W. Jenkins, VPI&SU; W. I. Knausenberger, VPI &SU; S. G. McCausland, Virginia Beach Mosquito Control Association; Dr. R. R. Mills, Virginia Commonwealth Univeristy; P. B. Schultz, VPI&SU; Dr. J. C. Shaffer, George Mason University; Dr. E. C. Turner Jr., VPI&SU; and Dr. J. R. Voshell Jr., VPI&SU.

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Mr. Frank Rock aided the authors in constructing the numerous Bishopp traps used in this project.

INTRODUCTION

Blow flies are insects found commonly throughout the state of Virginia and over much of the world. They are the bright green and blue "bottle flies" of summer and are encountered most frequently as they congregate near decomposing animal matter or droppings. Many species are associated with man and have been incriminated in the transmission of various human diseases; others may cause human or veterinary medical problems when larvae invade living tissue as obligatory or facultative parasites.

The Calliphoridae are medium to large calypterate muscoid flies. Most species display a metallic sheen which may be somewhat dulled by surface pollen. The longitudinal seam on the second antennal segment, the presence of hypopleural bristles, an undivided metanotum and undeveloped postscutellum, two notopleural bristles (with an adventitious third possible), and the presence of intrapostocular cilia distinguish the species belonging to the family Calliphoridae from all other Diptera currently known.

Hall's (1948) monograph of the calliphorid fauna of North America is the basic reference available to those working in this area. James (1955) treated the species common to the western U. S. and revised the status of three genera, based on the greater number of specimens available to him for study. Additional references include Shannon (1926) and James (1947). Furman and Catts (1970) provide an abbreviated key; however, omissions limit its usefulness. Cole (1969) presents an entertaining look at calliphorid genera. The keys of Greenberg (1971) and Zumpt (1965) include too few U. S. species of Calliphoridae to be useful in extensive survey work. The review of blow fly bionomics by Norris (1965) is an excellent point of departure for reviewing pertinent literature.

The present study was undertaken to provide an assessment of the economic damage caused by blow flies, their relative abundance, and distribution in Virginia and to present for the first time a localized treatment of those species common to the state. In addition, we have attempted to cite some of the more significant advances in the study of blow flies published since 1948. Our list is by no means complete, but the diverse amount of material available indicates the importance of the Calliphoridae to mankind.

During the course of several years, we have collected extensively throughout the Appalachian region of the western section of Vir-

ginia; in addition, various trips made have included numerous eastern sectors. The examination of collections from other institutions and entomologists has provided data from locations and seasons we were unable to personally exploit. We were unable to add materially to the descriptions of the immature forms provided by Hall (1948); consequently, we have not included them.

It is hoped that the present work will permit rapid, accurate identification of adult blow flies by workers previously hesitant to undertake this task. Competent use of Hall's keys requires complete familiarity with muscoid flies; therefore, we have included illustrations of salient morphological features. It is expected that these, along with the explanations provided in the text, will permit students to identify the blow flies before them without referral to additional, and possibly confusing, texts.

This study was completed while we were graduate students in the Department of Entomology, VPI&SU. The experience was both interesting and rewarding. It demonstrates the feasibility of undertaking a project of this scope in addition to the assigned research problems and other numerous duties attendant upon a student immersed in graduate studies. We hope the results of this effort will provide a stimulus to those students who follow us.

MEDICAL IMPORTANCE OF BLOW FLIES

Disease Transmission

The propensity for many species of blow flies to feed upon a wide range of material, coupled with their ready and facile movement. makes them potential vectors of many human diseases. The list of enteric infections spread by blow flies is nearly identical to that of the common house fly (Hall, 1948).

Several examples, with respect to Salmonellae, involve calliphorid species occurring widely in Virginia. Greenberg et al. (1963) studied flies attracted to carrion and manure at a Mexican slaughterhouse. *Phormia regina* (Meigen), *Cochliomyia macellaria* (Fabricius), and *Phaenicia sericata* (Meigen) were netted exclusively over carrion. Twelve *Salmonella* types were isolated from groups of these flies. Further investigation (Greenberg and Bornstein, 1964) emphasized this situation as a health hazard. Specimens of infective *P. sericata* were recovered at residential sites a mile from the slaughterhouse where they had been marked and released.

Ojala and Nuorteva (1966) isolated *Salmonella typhimurium* (Loeffler) Castellani and Chalmers from groups of flies, including *Lucilia illustris* (Meigen), *Protophormia terraenovae* (Robineau-Desvoidy), and *P. sericata*. Fobert (1971) suggested that *Calliphora vicina* Robineau-Desvoidy, and possibly other species, may act as true vectors of the *Salmonella* bacillus besides being merely mechanical carriers. It is interesting to note that *P. sericata* showed more resistance than the house fly to establishment and multiplication of *S. typhimurium* (Greenberg et al., 1970).

The exact role of blow flies in transmission of poliomyelitis is unclear, as noted by Hall (1948). Fluctuations of urban fly populations have been studied with respect to possible transmission of poliomyelitis virus (Power and Melnick, 1945; Melnick, 1949; Schoof et al., 1954; Schoof and Savage, 1955, and Nuorteva, 1963b) with the general conclusion that, although certain blow flies can harbor the virus, their role in epidemiologic transmission may be only incidental. Research in this field waned with the advent of effective polio vaccines.

Swine influenza, of current concern in the United States, was mentioned by Hall (1948) in connection with *Pollenia rudis* (Fabricius). It is possible that earthworms may be the animal reservoir of the virus, with the swine lungworm the vector to hogs and the cluster fly the vector to man. We have been able to find no reports of research on this subject other than those reviewed by Hall. The present attention this subject is receiving may stimulate further research efforts.

The involvement of flies, including *C. vicina* and *Cynomyopsis cadaverina* (Robineau-Desvoidy), in the transmission of helminth and ascarid parasites of humans was investigated by Nadzhafov (1972), and hydatids via *Phormia regina* by Schiller (1954). While direct contamination of new hosts is of primary importance in the epidemiology of many diseases, the role of flies must also be considered seriously.

Mihályi (1967) presented a formula for assessing the relative significance of a fly species with respect to its potential for transmitting enteric diseases. Such an approach, in concert with investigations of synanthropy of blow flies (Nuorteva, 1963a; Nuorteva and Vesikari, 1966) allows quantification of their impact on public health.

Myiasis

Myiasis is the infestation of living human and other vertebrate animals with dipterous larvae which, at least for some period, feed on the host's living or necrotic tissue, liquid body substances, or ingested food (Zumpt, 1965). Myiasis may be classified anatomically according to the portion of the body affected. Flies may be categorized with respect to the time of larval occurrence in wounds (Hall, 1948).

The primary screwworm fly, *Cochliomyia hominivorax* (Coquerel) is the most important producer of human and animal myiasis—traumatic or otherwise — in the New World. The larvae of these flies are obligate tissue parasites of warm-blooded animals. Strongly attracted to sores and wounds, even a lesion such as a tick bite may be sufficiently attractive to induce oviposition (Dove, 1935).

Perhaps a less familiar but no less intriguing group is that of the bird's nest screwworm flies (*Protocalliphora* spp.). The larvae are obligate bloodsucking parasites of nestling birds. A list of hosts compiled by Hall (1948) indicates that almost every family of Passeriformes is affected.

Several calliphorid species which usually oviposit on carrion may become involved in facultative myiasis by "blowing" malodorous sores or wounds of animals. *Cochliomyia macellaria* larvae were reported as the cause of death of sheep in Montgomery County (1957) and Washington County (1956), Virginia (Va. Coop. Ext. Ser., unpublished). *Phormia regina* was noted in these records as infesting lambs in southwest Virginia during 1959. *Phaenicia sericata, Protophormia terraenovae, Lucilia illustris, Cynomyopsis cadaverina. Calliphora vicina,* and *Calliphora vomitoria* (Linnaeus) have been observed in relation to sheep strike (James, 1955). Losses caused by these parasites in the U. S. were estimated to be $5 to $7 million per year (Morris, 1966).

Myiasis involving livestock and other animals may be compiled as statistics of economic loss — and the cost is impressive. Human myiasis, although not particularly common today, can be extremely detrimental to those afflicted (Merritt, 1969) and a cost figure cannot be estimated. As is the case concerning disease transmission, several species of blow flies occurring in Virginia have been involved in human myiasis. These include *Calliphora vicina,* intestinal myiasis (Leclercq, 1963) ; *Lucilia illustris,* wound myiasis (Laitinen et al. 1970) and *Cochliomyia macellaria* (Waldron, 1968).

In Virginia, reports of human myiasis are infrequent, doubtless a tribute to the standard of living we enjoy. Three recent reports concern *Phaenicia sericata*: infestation in the navel of an infant (Pratt, 1956), a case of aural myiasis (Norris, 1957) and the infestation of an ulcer on a woman's upper thigh with subsequent migration of larvae into the vagina (Townsend and Hall, 1976).

Medical and Legal Utility of Myiasis

While instances of myiasis are unfortunate for those afflicted, knowledge of the species and instar of larvae recovered from a sore or wound may provide pertinent information for estimating the length of exposure period of persons found unconscious as a result of accidents or unknown maladies. Merritt (1969) discussed factors stemming from uncontrolled diabetes mellitus which may predispose individuals toward myiasis under certain circumstances.

The importance of the dipterous fauna of cadavers as medicolegal indicators developed from the work of Megnin (1894) and now includes case studies (Nuorteva et al., 1967 and 1974) as well as a review by Leclercq (1969). Lane (1975) investigated blow fly succession on corpses in England. Identification of blow fly larvae has become of major interest to criminologists. Time of death of persons killed either by accident or intent can often be readily established by this method. R. J. Gagné (USDA) indicates (personal communication) that he deals with an average of two such cases per week during warm weather. D. G. Hall, in response to our query, supplied the following information: "Persons with knowledge of blow fly biology can estimate time of egg deposition to the stage submitted within a matter of relatively few hours. Questions such as, 'How long has the person been dead?' or, 'Was the person killed here in the woods or somewhere over in town and then dumped where we found him?' asked by FBI and Metropolitan Police officials were the genesis in 1938 of the study resulting in the book *The Blowflies of North America.* The rearing of the immature stages of the various species and the knowledge of how the species can be identified from larval specimens was the direct contribution to police work, and information produced by such means is readily acepted in forensic circles."

Scientific Utility of Blow Flies

The fact that many calliphorid species can be reared easily in large numbers (see Hall, 1948) has prompted many physiologists

to select these insects as ideal test animals. Their hardiness and size make them useful in various laboratory procedures and insecticide screening studies.

The discovery that larvae of some species can be reared upon sterile media permitted physicians to employ them in quasi-surgical routines. Though not often used today, the ability of these larvae to rid wounds of necrotic tissue has been responsible for the preservation of many lives. A resurgence in their successful use has occurred in recent years in instances where sophisticated medical science failed (Anon., 1976).

Effect of Blow Flies on Wildlife

The actual economic impact of blow flies on wildlife in Virginia is difficult to assess in contrast to southwestern states such as Texas where screwworms alone are estimated to cause considerable damage to game, especially deer. The wide range of facultative parasites collected during the course of this study indicates that attack of wildlife is probably a common phenomenon in Virginia. Blow flies do not appear to be a major factor in wildlife population regulation in Virginia. The role of saprophagous species in hastening decomposition of carcasses is undoubtedly their major contribution to ecological succession.

Mason (1944) reviewed the role of *Protocalliphora* spp. in population reduction among cavity-nesting birds, and Hall (1948) stated that the effect of these flies on populations of certain birds may be significant. Our examination of numerous bird nests discloses the northern fowl mite, *Ornithonyssus sylviarum* (Canestrini and Fanzago), to be the nestling parasite most frequently encountered in southwestern Virginia.

Of more direct concern to many hunters and fishermen is the problem of protecting game and fish from being "blown" by oviposing flies. This may be avoided easily by placing the fish catch in the water on stringers and carrying small game in suitable pouches. The task is more difficult during the early fall deer season when the weather is often warm. Prompt field dressing, removal of the carcass from the vicinity of entrails, and conveyance to a suitable meat locker is the best course of action. If transportation must be delayed, screening of the carcass with netting or cheesecloth

will provide temporary protection. Often recommended is sprinkling the body cavity liberally with ground black pepper; we have had no experience with this method.

CONTROL OF BLOW FLIES

Sanitation via removal and proper disposal of garbage, carcasses, and similar breeding media is probably the most satisfactory method of limiting blow fly populations. Studies of fly propagation in residential refuse containers (Magy and Black, 1962; Walsh et al., 1968) emphasize the value of proper trash wrappings and the importance of frequent garbage collection. Alvarez et al. (1972) investigated fly control at a municipal compost plant in Florida and found the major source of flies to be from larvae-infested incoming refuse. They estimated that 45,000 adult flies, primarily *Phaenicia cuprina*, were produced per week at this one site alone during the summer and they indicated that procedural changes and good housekeeping might reduce the population 60% to 80%. Application of chemicals to nocturnal resting sites and dichlorvos-sugar bait were evaluated during the study.

We also had excellent results using sugar baits containing small amounts of dichlorvos and ronnel, when used in small, closed rooms. In early summer, large numbers of blow flies (mainly *Phormia regina*) enter poultry quarters in the Veterinary Science Disease Research Area at VPI&SU. Residual wall sprays cannot be applied in these quarters because of ongoing ectoparasite evaluations in the rooms.

Quarterman et al. (1954a, 1954b) discuss fly dispersal in urban and rural areas. Although flies tend to congregate at favorable breeding and feeding sites, many individuals depart freely. The investigators concluded that movement over a relatively large area is normal in fly activity. Therefore, municipal fly-control efforts should include the most important of the immediate outlying breeding sites. The success of community programs depends largely upon adequate and accurate appraisals of the situation. This allows the most effective use of control operations (Schoof, 1955).

Municipal ordinances and increased community services have greatly improved general sanitary conditions. As new life styles emerge, it is necessary to anticipate potential problems related to fly production and respond to them. Increased use of recreation areas requires

the cooperation of campers to deal properly with refuse. Sanitary facilities must be provided and their use encouraged (Mathis et al., 1969).

The judicious use of insecticides can reduce fly populations while sanitary measures are planned and put into effect. Insecticides should not be considered a replacement for sound waste management practices. Chemical control of filth-breeding flies may be vital in situations where rapid and often unforseen strain may be put on existing sanitary facilities, such as in times of disaster and warfare. It might be well at this time to point out that geographic location is an extremely important factor in any insect control program. Islands are most effectively treated by any large-scale measure because chances of reinfestation are minimized. Localized control measures on a continent are almost invariably temporary. This consideration was emphasized during fly control programs on Pacific islands during the Second World War (Hall, 1948).

The on-going USDA screwworm eradication program results have been largely successful in combating this pest (Eddy and DeVaney, 1970). The effectiveness of the sterile-male technique in this program has stimulated similar research dealing with *Phaenicia sericata* and *P. cuprina* (Whitten and Taylor, 1970). Approaches such as chemosterilants (Yeoman and Warren, 1965) and sterile female techniques are being investigated currently. Factors including pheremonal stimulation of sexual activity (Bartell et al., 1969) and group oviposition (Browne et al., 1969) may provide information on the more subtle biological facets of various blow fly species.

Legner and Bay (1970) stated that large numbers of parasites and predators of noxious flies, including the Calliphoridae, are present in California. Many of these species are distributed widely. Only the species of parasitic Coleoptera and Hymenoptera showed high host specificity. Generally, they attack the later stages of their hosts and are regarded as being more effective than egg parasites.

The fauna which develops in carcasses, manure, and wastes is varied and dynamic. Successions of species have been classified according to the age and condition of the substrate in which they are located. The effects of some of these organisms have been studied with respect to their potential for destruction of fly larvae as Ratcliffe (1972) did with the silphid *Necrodes surinamensis* (Fabric-

ius). Oviposition on carrion is a trait which renders species with this habit less susceptible to many agents possibly important in the natural control of fly populations. Kinn (1966) noted that the mite *Macrocheles muscaedomesticae* (Scopoli) destroyed eggs of the black blow fly, *Phormia regina*, in the laboratory. He further stated, however, that these mites are seldom found on carrion and it was doubtful that the mite is important as a blow fly predator under most circumstances.

The effects on calliphorid populations of organisms, including the microsporidian *Octospora muscaedomestica* (see Kramer, 1964, 1973) and the fungus *Entomophthora muscae* (Cohn) (Kramer, 1971) have received some attention. Greenwood (1964) showed that *Bacillus thuringiensis* Berliner toxins were lethal to larvae of *Phaenicia sericata* and could adversely affect fecundity of adults surviving sublethal doses. Some of these approaches, or offshoots thereof, may prove important to the overall control of blow fly pests in the future.

COLLECTING BLOW FLIES

A short-handled aerial net equipped with a sharp-pointed cotton voile or nylon net bag is best used by collectors with a knowledge of the habits and distribution of the blow fly target species. Some species are known only from net collections. It is fortunate, however, that most calliphorid flies are caught easily in baited traps. Trapping methods are productive and efficient with regard to time invested. Most specimens collected by the authors in the course of this study were taken in a device first described by Bishopp (1916).

The Bishopp trap's operating principle is based on the fact that calliphorid adults are positively phototrophic; therefore, it uses an inverted wire cone placed over a suitable bait. A hole at the apex of the cone allows specimens arising from the bait to enter a larger wire holding cage constructed around the funnel. In using this trap we fitted a length of elasticized sleeving over the top of the holding cage to permit light to enter from above and allow easy access for extraction of specimens.

Trapped flies may damage some of their taxonomically important structures while flying against the wire screen. Thus, it is desirable to treat the entire structure at intervals with a residual insecticide. This procedure immobilizes the flies and simplifies the problem of removing the catch.

Rotting beef liver, ground beef, or decomposing animal carcasses with intestines exposed, can be used as bait with an astonishing degree of success. Because baits in various stages of decay attract different species of flies, it is important to visit the traps to collect specimens during the entire useful life of the bait. If necessary, scavenging mammals may be kept at bay via a large wire-mesh enclosure. During the course of the study, we used large numbers of chicken carcasses and achieved gratifying results. Rotting fruit may also prove useful as a bait, and certain species may gravitate primarily to cold-blooded animals.

Substances such as some mercaptans, ammonium carbonate, butyric acid, lactic acid and valeric acid have been tested in both the field and the laboratory as attractants for synanthropic flies. These materials exhibited limited usefulness in the pure form but attracted greater numbers of flies when mixed with baits (Volccik and Groth, 1972). Our experience with indole and skatole corraborated this, and we discontinued the use of these substances early in the project. There are occasions when it may be undesirable to transport natural baits on long summer trips but yet the prospect of finding suitable material at a site cannot be relied upon. There are, however, artificial baits (see Pickens et al., 1973) which may be useful on these occasions.

The McPhail trap is a glass device employing an enclosed dome and a bottom entrance around which a channel of fluid bait is located. Used primarily in fruit fly surveys, insects entering the trap are drowned in the liquid medium. Several bait formulations have been described (Anon., 1965). We did not use the McPhail trap but did receive calliphorids collected in this manner.

A comprehensive program of blow fly trapping should encompass the entire season that adults are active. Certain species in Virginia can be collected only during the cooler months of the year, while others are present mainly during the heat of mid-summer.

A wide variety of niches and biotypes should be sampled. Our basic approach to the Virginia fauna was developed to encompass the various biotic regions of the state (Hoffman, 1969). Careful planning and placement of traps with respect to factors such as sunlight and terrain is important. F. C. Bishopp studied this concept while a student at Ohio State University and employed it throughout his career; E. W. Laake and his associates followed

Bishopp's lead during studies of screwworm populations near Menard, Texas, in the late 1920's (D. G. Hall, personal communication) (see also MacLeod, 1956; MacLeod and Donnelly, 1956a, 1956b, 1957, 1962 and Norris, 1966).

Rigorous studies associating immature forms with adults can be accomplished only by establishing pure-line laboratory colonies. Such colonies may be useful in gauging the extent of intraspecific variation of selected characters. For additional information the reader is referred to Hall (1948).

Another method frequently employed for collecting is to bring fly-blown material into the laboratory and permit adults to emerge. Placement of the collected material upon clean sand under suitable environmental conditions in a screened enclosure will enable larvae to locate a satisfactory site for pupation. Such studies will demonstrate which species have developed in the substrate. The presence of adults in a baited trap is not positive evidence that oviposition has occurred.

From the foregoing text it should be apparent that anyone undertaking emergence studies should be prepared to tolerate the odors associated with blow fly breeding material.

PRESERVATION OF SPECIMENS

Whenever possible, adult blow flies should be pinned immediately upon return from the field. Standard number 2 insect pins are suitable and should be inserted through the mesothorax caudad of the transverse suture and to the right of the midline. Carding, pointing, or use of minuten pins is not generally necessary and, in fact, renders the specimens undesirably fragile. Proper spreading of the fly's legs while the specimen is fresh will facilitate later identification. Dried flies may be softened easily in standard relaxing chambers.

The calliphorid fauna of Virginia and the surrounding states may be determined largely without relying upon characters of the male genitalia. In certain instances, though, it may be desirable to observe these structures. We found this necessary while examining specimens displaying variation in chaetotaxy. Hall (1948) described his technique for preparing genitalia dissections and included descriptions and figures for comparison.

Collection data must accompany each insect or its scientific value is lost. Thus, specimens pinned and kept in properly maintained collections will retain their color and pollinosity for indefinite periods. Alcohol, or other fluids, are usually unsatisfactory for preservation of museum-quality muscoid adult specimens. The use of such liquids unavoidably affects surface bloom.

It should be noted that competent personnel can rapidly identify many calliphorid species without pinning, thus examining large quantities of material with the greatest economy of time. Indeed, expert taxonomists are often able to identify a specimen without capturing it. They accomplish this through an uncanny familiarity with the specimen's behavior, flight pattern, sound of its flight, or general habitus.

MEASUREMENTS

Microscopic examination of muscoid flies is best carried out with a binocular microscope having objectives permitting 10X to 60X magnification. An ocular micrometer is essential to the examination, and the light employed should be cool yet sufficiently bright so that all important external characters can be seen with ease.

Measurements required for use of the key should be made in micrometer units. As described by Hall (1948), these measurements are to be used as a basis of comparison between parts of the same specimen or as a basis of comparison between species.

Length of head at antenna. Number of micrometer units from visible posterior margin of head (most often just behind postocular cilia) to antennal base. Profile view.

Length of head at vibrissa. Number of micrometer units from lower rear margin of metacephalon to vibrissal angle. Profile view.

Head height. Number of micrometer units from lowest margin of head to upper ocellus. Profile view.

Head width. Entire width of head in micrometer units. Anterior view.

Front width. Number of micrometer units between eyes. Anterior view.

The width of the front in relation to head width is the fraction obtained by dividing the number of micrometer units between the

eyes by the number of micrometer units in the entire head width. The width of the front at the narrowest portion is obtained similarly.

TERMINOLOGY

Classification of muscoid flies is simplified by paying attention to various stout bristles—termed macrochaetae—the number and pattern of which are remarkably constant within a given species. Dipterists have evolved a somewhat loose set of terminology to distinguish these setae, and the beginning student may be misled by apparent and real inconsistencies within the taxonomic literature. The chaetotaxic terminology described below is essentially identical to that presently employed by muscoid dipterists.

Terms used to describe the outward appearance of sclerites may initially prove confusing. *Setulae* are sometimes difficult to distinguish from macrochaetae; however, the setulae are not as stout as and lack the regular placement of the latter. *Pile* is a soft, dense hairlike covering, coarser than *pubescence*—an inconspicuous nap which may escape superficial detection. *Pollen*, or surface bloom, is often present in definite patterns and may affect the metallic sheen characteristic of many calliphorids.

It should be borne in mind that the age of specimens when caught, as well as the conditions to which they have been exposed, can affect the appearance of various taxonomic characters. Newly emerged (teneral) adults may lack the striking coloration and pollinosity of specimens a day or so old. Still older adults may become worn, i.e., bristles may be lost and areas once pilose, pubescent, or pollinose may be rubbed bare. It is fortunate that the presence of macrochaetae may be confirmed by the *scar*—the point of insertion which remains even if the bristle itself is broken away.

Cephalic Regions and Bristles

Plates 1-3 illustrate the terms used in this paper with respect to the regions and arrangement of bristles on the head.

Arista. The thin, wiry structure (Pls. 2 and 3, AR) projecting cephalad from the third antennal segment (Pl. 2, AN3). The arista bears hairlike setae called cilia; whether these cilia are long or short, or extend all the way from the base of the arista to its tip can be of taxonomic value.

Beard. The profusion of fine, hairlike setae sometimes apparent on the lower buccae and occiput.

Bucca. The wall of the head on each side below the eye, caudad of the vibrissal ridge and continuing to the caudal margin of the head (Pl. 3, BUC).

Cheek grooves. An impression on each side below the eye (Pl. 3, CHG).

Facial bristles. A row of bristles borne on the vibrissal ridge above the vibrissae (Pl. 1, FCL).

Frontal bristles. A row of bristles on the mesal boundary of the parafrontals (Pls. 1 and 2, FRS). The most dorsal are termed the ascending frontal bristles; the lower are often called the transfrontals.

Fronto-orbital bristles. Bristles borne on the parafrontals ventrad of the verticals. The *proclinate fronto-orbitals* (Pl. 1, PFRO) are so named because they project cephalad; the *reclinate fronto-orbitals* (Pls. 1 and 2, RFRO) project caudad.

Labella. The fleshy lobes in which the haustellum terminates (Pl. 3, LAB).

Lunule. A small sclerite directly above the antennae (Pl. 3, LUN).

Occiput. The caudal aspect of the head (Pl. 3, OO.)

Ocellar bristles. The greater ocellars are a pair of bristles with insertion just caudad to the median ocellus (Pls. 1 and 2, OCS). The *lesser ocellars,* sometimes termed the *postverticals,* are situated directly caudad of the ocellar triangle (Pl. 2, LOCS, PVRS).

Ocellar triangle. A roughly triangular plate situated near the vertex and bearing the ocelli (Pl. 2, OCTR).

Palpi. Two elongated structures projecting cephalad from the haustellum and generally visible below the oral margin (Pl. 3, PLP).

Parafacials. The area laterad of the frontal suture and mesad of the eye, often termed genae (Pl. 3, PFCL).

Parafrontals. Often called the front, or genovertical plate, this area is situated dorsad of the lunule and mesad of the eyes (Pl. 3, PFRL).

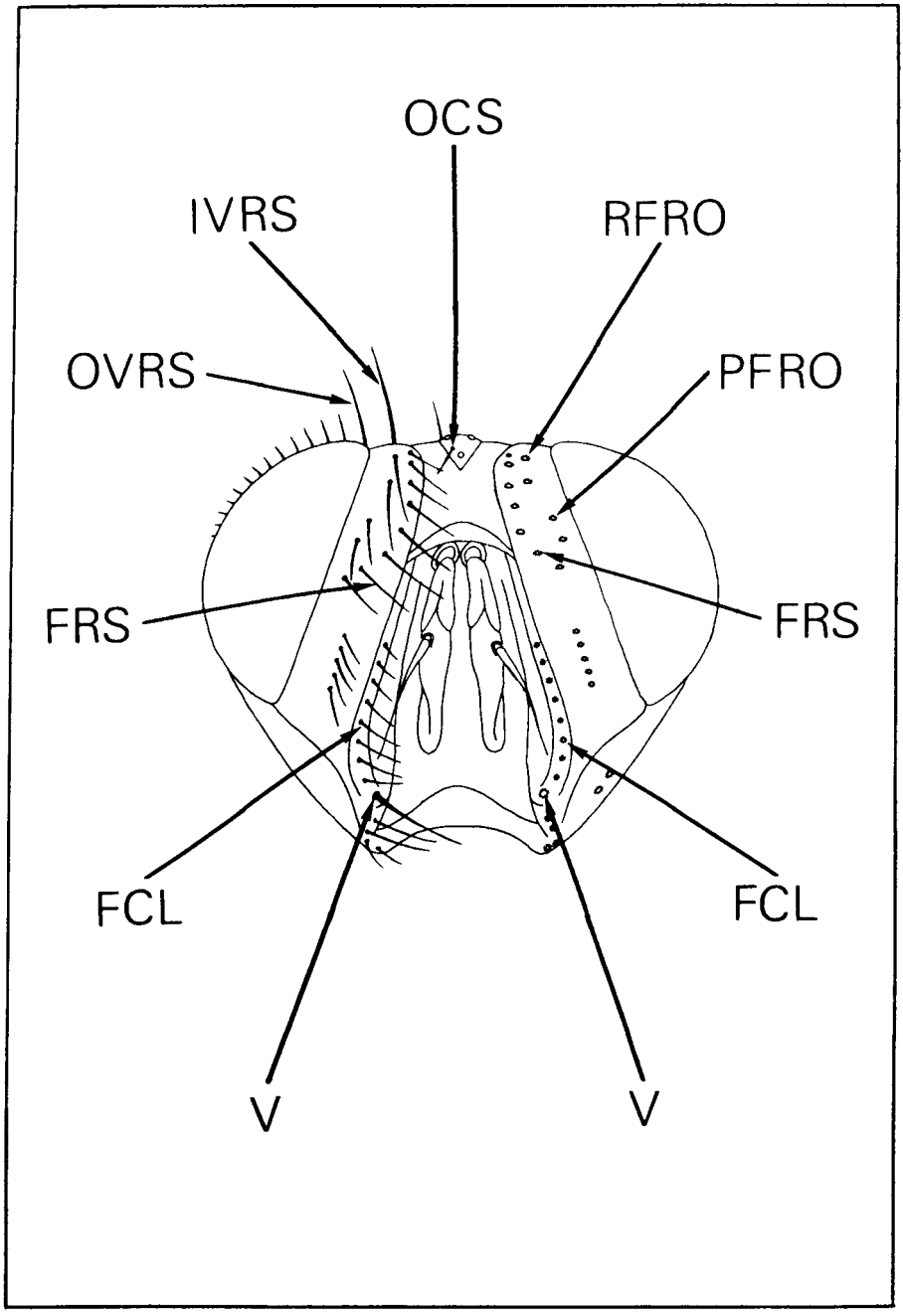


Plate 1. Muscoid Head - Front

Postocular cilia. A very even row of "eyewinkerlike" cilia situated along the posterior orbit of the eye (Pl. 2, POC). *Postocular setae* are located below and behind the row of cilia.

Second antennal segment. A short and typically conical segment apparent ventrad of the lunule. In the calypterate muscoid flies, this segment is partially divided by a longitudinal seam on the outer dorsal side (Pl. 3, AN2).

Vertex. The top of the head (Pl. 3, V).

Vertical bristles. Two pairs of stout bristles inserted above the dorso-mesal corners of the eyes. The median pair, called the *inner verticals* (Pls. 1 and 2, IVRS), is generally the largest. The *outer verticals* (Pls. 1 and 2, OVRS) are located laterad of the inner pair.

Vibrissae. These large bristles, one on each side of the face, are located on, or slightly above, the oral margin (Pl. 1, V).

Thoracic Regions and Bristles

The chaetotaxy of bristles situated on the thorax is extremely important in calliphorid taxonomy. Plates 4 and 5 illustrate the particular bristles to which references are made in this paper.

Acrostichal bristles. The two rows of bristles nearest the midline (Pl. 4, A). Those cephalad of the transverse suture are termed *preacrostichals,* those caudad, *postacrostichals.*

Dorsocentral bristles. Two rows of bristles parallel to and laterad of the acrostichals (Pl. 4, DC).

Humeral bristles. Those bristles borne on the humeral callus (Pl. 4, HM).

Humeral callus. The anterior lateral angles of the prescutum (Pl. 5, HC).

Hypopleural bristles. A somewhat vertical row of bristles inserted on the hypopleuron above the hind coxa (Pl. 4, HYB).

Intraalar bristles. A row of bristles immediately laterad of the dorso-centrals (Pl. 4, IA). Those anterior to the transverse suture are the *preintraalars,* those behind, the *postintraalars.*

Mesonotum. The sclerite which comprises most of the apparent dorsal surface of the thorax (Pl. 5, MSN). It is divided by the transverse suture.

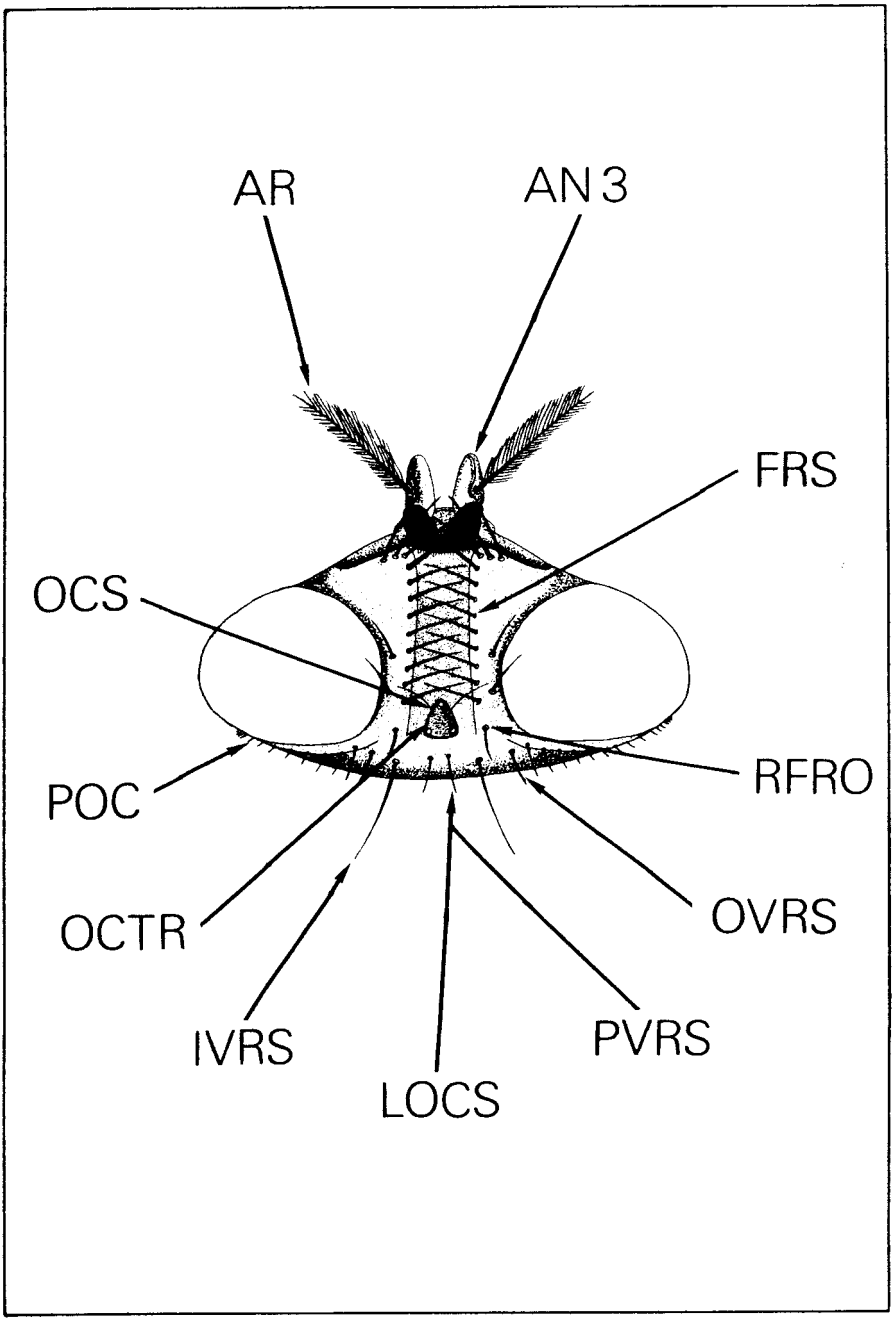


Plate 2. Muscoid Head - Dorsum

Mesothoracic spiracle. Situated between the humeral callus and mesopleuron (Pl. 5, MSP).

Metasternum. A small, curved sclerite slightly anterior to the hindmost coxae (Pl. 5, MS). The structure is best seen on specimens the legs of which have been properly spread and pinned.

Notopleural bristles. Stout bristles inserted on the notopleuron (Pl. 4, NPL). The notopleuron is a sclerite situated at the end of the transverse suture. Calliphorids possess two notopleural bristles; however, a weak adventitious third is sometimes present.

Postalar bristles. Borne on the postalar callus caudad of the supraalar bristles (Pl. 4, PA).

Posthumeral bristles. Bristles situated on the prescutum caudad of the humeral callus (Pl. 4, PH).

Presutural bristles. One or more bristles apparent cephalad of the transverse suture, laterad of the preintraalars and dorsad of the notopleuron (Pl. 4, PR).

Propleuron. The pleuron of the prothorax (Pl. 5, PPL).

Pteropleuron. The upper part of the epimeron of the mesothorax (Pl. 5, PTPL).

Scutellar bristles. The *marginal* or *lateral scutellars* are borne on the lateral margin of the scutellum (Pl. 4, MS). The *discal scutellars* are inserted on the dorsal surface of the scutellum (Pl. 4, DS).

Scutellum. The dorso-caudal thoracic sclerite (Pl. 5, SCT).

Sternopleuron. The lower episternum of the mesothorax (Pl. 5, STPL).

Supraalar bristles. One to four bristles apparent above the wing base (Pl. 4, SA).

Transverse suture. The suture separating the prescutum and scutum of the mesothorax (Pl. 5, TS).

Abdominal Regions and Bristles

The abdomen of muscoid flies generally is composed of four apparent segments; the true first and second segments are fused into a single unit. The chaetotaxy of the abdomen is of less taxonomic

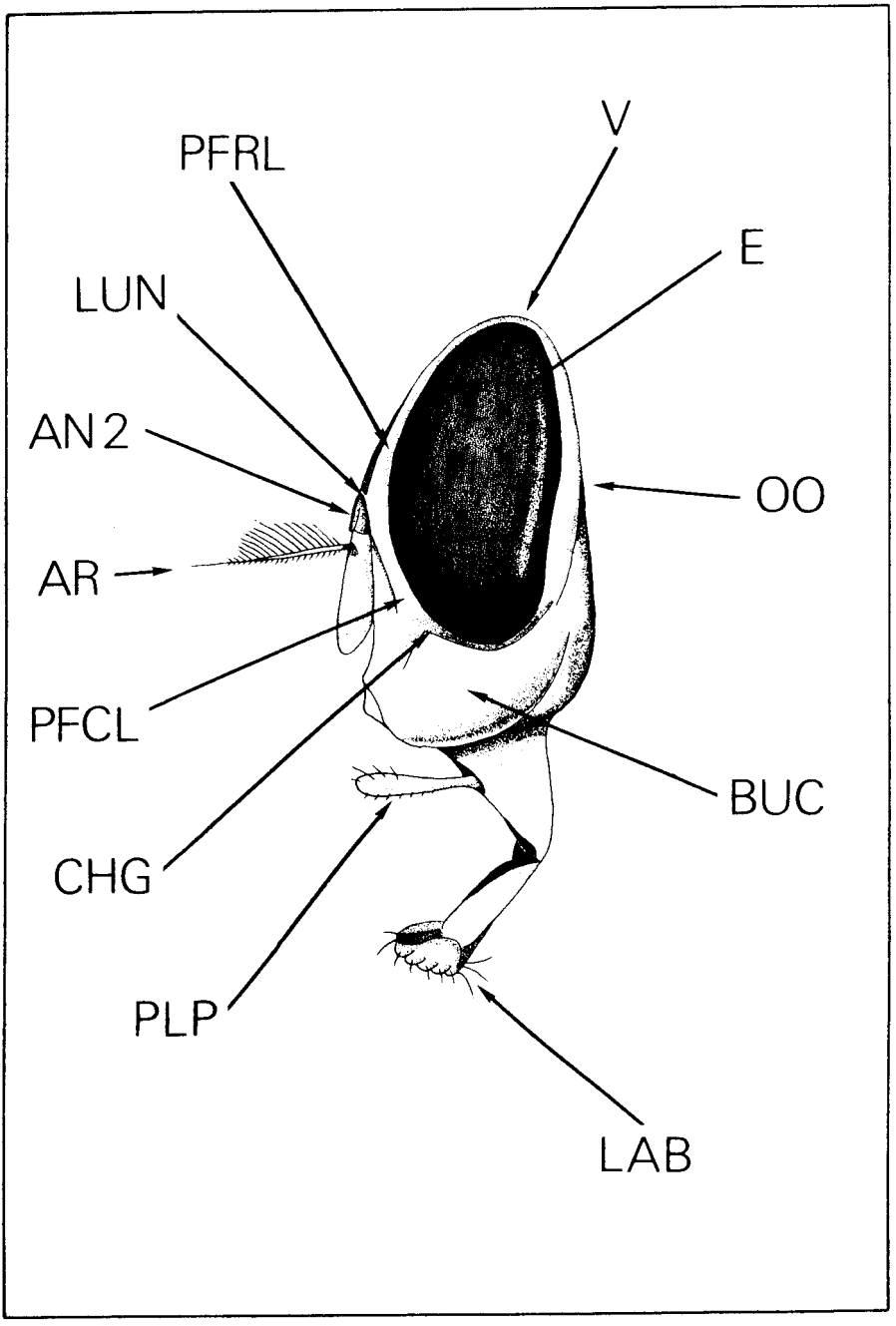


Plate 3. Muscoid Head - Lateral

importance than that of the head, thorax, and legs but the presence of erect median marginal bristles (on the caudal margin of the segment near the midline) may be of significance.

Wing Base

In general, the wings of calliphorid flies follow a typical muscoid pattern and possess various structures of taxonomic value. Two pairs of squamae are evident which may assume distinctive shapes and coloration and may bear hairy setulae on their dorsal surfaces. Additional terms are defined below.

Basicosta. A small, curved sclerite situated directly basad of the costa (Pl. 6A, BC).

Epaulet. A cap-shaped sclerite basad of the basicosta (Pl. 6A, E). Inexperienced students may mistake this structure for the taxonomically more important basicosta.

Remigium. The portion (Pl. 6A, RG) of the large stem vein of the wing basad of the humeral cross vein (Pl. 6A, HC). The presence or absence of distinctive cilia on the dorso-caudal margin of this vein serves to separate two major subfamilies of calliphorid flies.

Subcostal sclerite. A structure situated on the ventral surface of the wingbase (Pl. 6B, SS). Typically covered with a soft, short nap only, it bears wiry bristles in some species.

VARIATION

Probably no subject has aroused more controversy among taxonomists of muscoid flies than that of chaetotaxic and structural variation. The question of the extent of variation within a true species can be settled only by examination of long series of specimens from pure-line cultures. Genetic and developmental anomalies may occur at any time. The fact remains that within the Calliphoridae, members presently considered to be distinct species may exhibit duplication or reduction of taxonomically important bristles, especially on the thorax. In general, small individuals exhibit a tendency toward reduction in numbers of bristle more frequently than do large specimens. In such instances, availability of larval food may place unavoidable obstacles in the path of the taxonomist.

Following Hall's (1948) lead, we have attempted to retain a combination of key characters so that variation in one specimen will

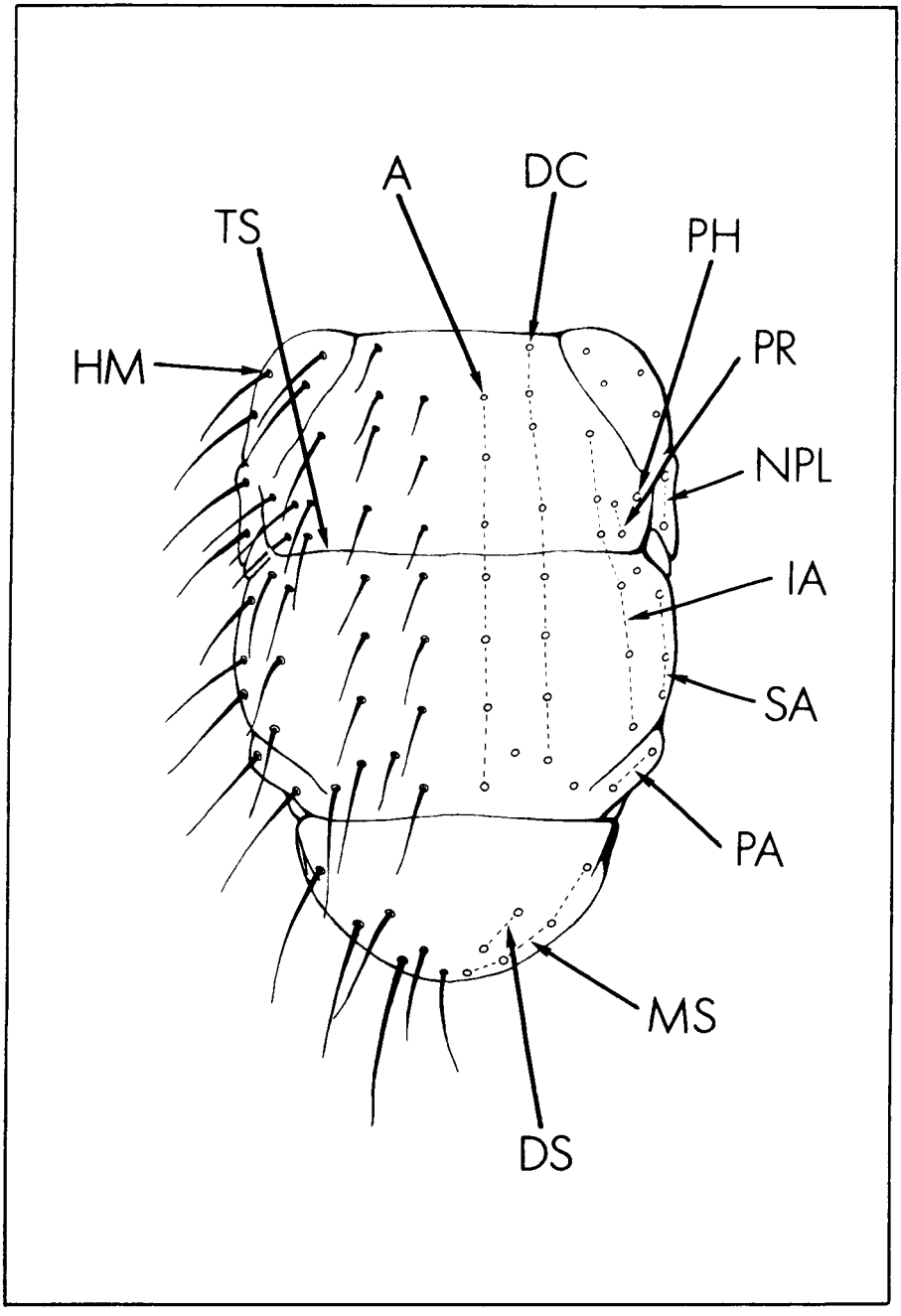


Plate 4. Thoracic Chaetotaxy

be less likely to lead to a wrong determination. Statements concerning number and arrangement of bristles are accompanied, wherever possible, by characters involving proportional measurements and coloration. Male specimens can usually be identified positively by examination of the genitalia; Hall, in his work cited above, provides excellent figures for this purpose. Individual females, however, may sometimes defy all attempts at identification.

Variation is discussed more thoroughly in those sections devoted to species in which it is most frequently noted.

Key to Virginia and Mid-Atlantic Species of Calliphoridae

1. Remigium bare above ---------- 2
   Remigium ciliate above ------- Chrysomyinae (3), p. 28

2(1). Thorax without crinkly yellow setae; prosternum and propleuron setose; body usually with metallic sheen ---------- Calliphorinae (7), p. 31
   Thorax with dense crinkly yellow setae; prosternum and propleuron bare; body subshining only ---- ---------- Polleniinae, p. 43
   (*Pollenia rudis*), p. 43

3(1). Hind coxa pilose posteriorly; mesonotum with distinct longitudinal dark stripes; head yellow below ---------- Chrysomyini (4), p. 28
   Hind coxa bare posteriorly; mesonotum without stripes or with stripes visible only under proper incidence of light; head dark below ---------- ---------- Phormiini (5), p. 29

4(3). Parafrontals with pale setulae anteriorly outside frontal row of bristles; male basicosta yellowish; abdomen with pale lateral pollinose spots ------- ---------- *Cochliomyia macellaria*, p. 28
   Parafrontals with dark setulae anteriorly outside frontal row of bristles; male basicosta black; abdomen with reduced lateral pollinose spots, or none (a species at present confined to the extreme southern U. S. and farther south) ---------- ---------- *Cochliomyia hominivorax*

5(3). Mesonotum flattened; mesothoracic spiracle surrounded by dark pubescence ---------- 6

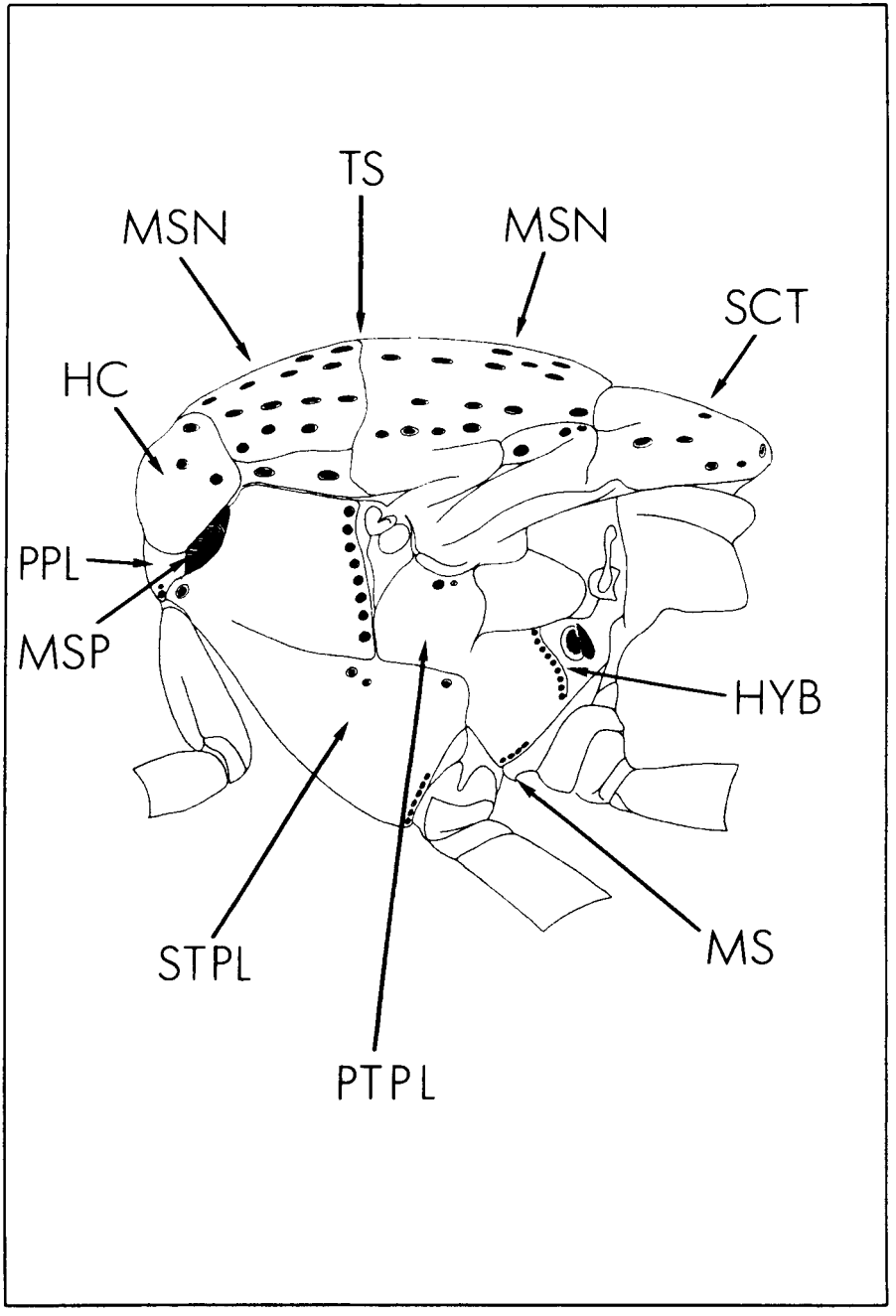


Plate 5. Muscoid Thorax - Lateral

Mesonotum convex; mesothoracic spiracle surrounded by yellow to orange pubescence -- *Phormia regina*, p. 29

6(5). Preacrostichals absent or much reduced; upper squamal lobe with black setae above; head at vibrissae longer than at antennae ---------- *Protophormia terraenovae*, p. 30

Preacrostichals present; upper squamal lobe bare above; head at vibrissae not longer than at antennae ---------- *Protocalliphora*, p. 30

7(2). Lower squamal lobe bare above ----- Luciliini (8), p. 31

Lower squamal lobe with dark setae above ---------- Calliphorini (15), p. 38

8(7). Subcostal sclerite with pubescence only; ocellar triangle small, not reaching halfway to lunule in female ---------- 9

Subcostal sclerite with black wiry setae apically (Pl. 6B); ocellar triangle large and reaching at least half-way to lunule in female ---- *Lucilia illustris*, p. 32

9(8). Length of head at antenna and at vibrissa more than half head height; second abdominal tergite with long and erect median marginal bristles; palpi black or at least dark at apex -------- 10

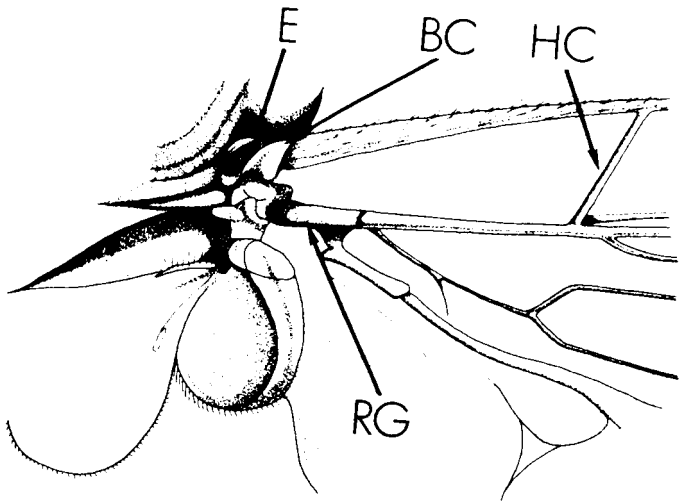
Length of head at antenna and at vibrissa less than half head height (except in some *P. sericata*); second abdominal tergite without median marginal bristles; palpi yellow ---------- 11

10(9). Two postacrostichals; front at narrowest 0.14 head width in male, 0.35 in female; body elongate; costal spine weak (a western U. S. species not recorded thus far from Virginia) ---------- *Bufolucilia elongata*

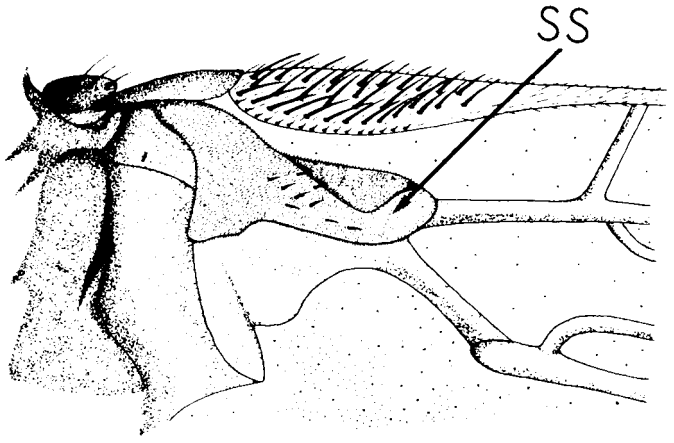
Three postacrostichals; front at narrowest 0.08 head width in male, 0.31 in female; body not elongate; costal spine well developed -- *Bufolucilia silvarum*, p. 31

11(9). Two postacrostichals; abdomen usually uniformly metallic or variously adorned with pollen --- 12

Three postacrostichals; abdomen with apparent mesal division in which one-half is pollinose and the other shining, the character reversible and dependent upon the incidence of light ------ 14



A. Wing Base - Dorsum



B. L. illustris - Venter of Wing Base

Plate 6.

12(11). Basicosta yellow to orange; typically 1 row of black postocular setae (except in some *P. coeruleiviridis*) ; second abdominal tergite with a weak row of marginal bristles; frontal setae ending before reclinate fronto-orbitals ---------- 13

Basicosta black or dark brown; typically 2 rows of black postocular setae; second abdominal tergite without a weak row of marginal bristles; frontal setae ascending through the reclinate fronto-orbitals; front at narrowest 0.05 head width in male, 0.30 in female ---------- *Phaenicia mexicana,* p. 36

13(12). Male with 1 reclinate fronto-orbital bristle slightly anterior to median ocellus; front very narrow with eyes almost contiguous; female with black setulae on parafrontal outside frontal row of bristles; apex of abdomen highly polished and often tinged with red in both sexes--*Phaenicia coeruleiviridis,* p. 33

Male with one reclinate fronto-orbital bristle opposite median ocellus, or none; front wider with eyes separated; female with pale setulae on parafrontal outside frontal row of bristles; apex of abdomen generally not polished more than other tergites and without reddish cast (a southern U. S. species, not recorded thus far from Virginia) ---------- *Phaenicia cluvia*

14(11). Metasternum bare; central occipital area in male with a single seta on each side behind the inner vertical bristle (Pl. 7) ; abdomen usually strongly coppery and dull; male commonly with 2 pairs of ocellar bristles and front at narrowest 0.18 head width; fore femur metallic green ---------- ---------- *Phaenicia cuprina,* p. 34

Metasternum setose; central occipital area in male usually with a group of about 5 setae (sometimes reduced) on each side behind the inner vertical bristle (Pl. 7) ; abdomen bright green to coppery; male with 1 pair of ocellar bristles and front at narrowest 0.11 head width; fore femur black or deep blue ---------- *Phaenicia sericata,* p. 37

15(7). Faciale without strong ascending bristles; accessory ocellar bristles absent ---------- 16
Faciale with strong ascending bristles; accessory ocellar bristles present (a western U. S. genus not yet recorded from Virginia) ------ *Eucalliphora*, p. 38

16(15). Scutellum with 4 or more strong lateral bristles; arista ciliate almost to apex ---------- 17
Scutellum with 3 strong lateral bristles; arista usually ciliate only three-fourths the distance to the apex ---------- 20

17(16). Two postintraalars ---------- 18
Three postintraalars ---------- *Calliphora livida*, p. 39

18(17). Bucca entirely black; basicosta black --------- 19
Bucca reddish on anterior half; basicosta yellowish ---------- *Calliphora vicina*, p. 39

19(18). Bucca with setae entirely black (a northern species not recorded thus far from Virginia) ---------- ---------- *Calliphora terraenovae*
Bucca with reddish or gold hair posteriorly ------ ---------- *Calliphora vomitoria*, p. 40

20(16) Faciofrontal profile protuberant; 1 or 3 postacrostichal bristles ---------- 21
Faciofrontal profile not protuberant; 2 postacrostichal bristles ---------- *Cynomyopsis cadaverina*, p. 41

21(20). One postacrostichal bristle; hindmost preintraalar bristle absent (a northern species, not recorded thus far from Virginia) --- *Cynomya mortuorum*, p. 42
Three postacrostichal bristles; hindmost preintraalar bristle present (a northern species, not recorded thus far from Virginia) *Cyanus elongatus*, p. 42

Family CALLIPHORIDAE

Diagnosis: The Calliphoridae are medium to large calypterate muscoid flies. Most species display a distinct metallic sheen often subdued by a pollinose surface bloom. The longitudinal seam on the second antennal segment, the presence of hypopleural bristles, an undivided metanotum and undeveloped postscutellum, two notopleural bristles (with a possible adventitious third) and the presence of intrapostocular cilia will serve to distinguish the family Calliphoridae from all other currently known Diptera.

Subfamily CHRYSOMYINAE

This subfamily includes those blow flies having cilia posteriorly on the dorsal base of the remigium (stem vein of the wing basad of the humeral cross vein). The "screwworms," "black blow flies," and "bird's nest screwworm flies" belong here.

Tribe CHRYSOMYINI

The species included in this tribe have fine setae present posteriorly on the metathoracic coxae. They are typically metallic blue or green with heads bright orange below. In addition, they possess dark longitudinal stripes dorsad on the thorax. Best known as the "screwworm flies," one species is present in Virginia.

COCHLIOMYIA MACELLARIA (Fabricius)

(Secondary Screwworm)

Musca macellaria Fabricius, 1775, Systema Entomologiae, p. 776.
Callitroga macellaria (Fabricius) ; Brauer, 1883, Akad. der Wiss. Wien, Math.-Nat. Kl. Denkschr. 47:74.

Diagnosis: The following combination of characters will distinguish this species from other North American Chrysomyini. Parafaciale setose, basicosta and legs of male orange to light brown and female with one or two proclinate fronto-orbitals. A green species with the lower head orange, the thorax with three black longitudinal stripes on the dorsum which do not extend beyond the scutellar suture. It may be distinguished from *C. hominivorax* (Coquerel) by the pale setae on the parafrontals outside the frontal bristles and the distinct pollinose areas laterad on the abdomen.

Known Distribution: American tropics northward to the Canadian border.

Virginia Records and Seasonal Abundance: City of Norfolk and City of Virginia Beach; counties of Arlington, Fairfax, King William, Montgomery, Prince George, Spotsylvania, Washington, and York. Dates of collection ranged from June through October, with the greatest incidence in midsummer.

Remarks: *C. macellaria* is probably distributed statewide in Virginia, with the possible exception being the highest elevations in the western sector. The species has been noted in connection with

sheep strike; however, it is not of economic importance in properly managed Virginia sheep flocks. *C. hominivorax* (the primary screwworm) has not been recorded from the state.

We collected *C. macellaria* in traps baited with chicken, frog, and turtle carcasses. Specimens also were taken over human excrement and with a McPhail trap.

Tribe PHORMIINI

The Virginia species of this tribe may be distinguished from those in the Chrysomyini as follows: the metathoracic coxae are bare posteriorly, and the dorsal surface of the thorax lacks stripes, or has faint stripes which depend upon proper light incidence for visibility.

PHORMIA REGINA (Meigen)

(Black Blow Fly)

Musca regina Meigen, 1826, Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten 5:58.

Diagnosis: The following characters will distinguish this species from other North American Phormiini. A slightly elongate, dark olivaceous green species with the mesothoracic spiracle surrounded by orange pubescence. The mesonotum is convex and the legs are black.

Known Distribution: Holarctic; throughout the U. S. during the warmer months.

Virginia Records and Seasonal Abundance: The city of Richmond and City of Virginia Beach; counties of Albemarle, Arlington, Augusta, Craig, Fairfax, Franklin, Giles, Hanover, Louisa, Montgomery, Nelson, New Kent, Roanoke, Smyth, and York. Dates of collection ranged from March through November.

Remarks: This is one of the most numerous blow flies in Virginia. Typically saprophagous, it may become involved in wound myiasis and sheep strike. Knipling and Rainwater (1937) considered this species the most important "secondary" myiasis producing fly in the southeastern U. S.

P. regina is cultured easily in the laboratory and is often used in various physiological and toxicological procedures. Maggots reared on sterile media have been employed in postoperative surgery.

The authors collected this species in traps baited with a variety of animal carcasses, both warm- and cold-blooded. Adult flies were reared from larvae infesting a dead turtle; specimens were collected from human excrement and the flowers of wild mustard. We have noted large numbers of this species congregating in rooms housing laboratory chickens, and several specimens were reared from manure collected in a commercial chicken house. The latter record probably represents individuals which originated in chicken carcasses and migrated into the manure as mature larvae.

PROTOPHORMIA TERRAENOVAE **(Robineau-Desvoidy)**

Phormia terrae-novae Robineau-Desvoidy, 1830, Essai sur les Myodaires 2:467.

Diagnosis: The following characters will distinguish this species from other North American Phormiini. A robust, dark greenish-blue to deep-blue species with the mesothoracic spiracle surrounded by dark pubescence. The mesonotum is conspicuously flattened, and the acrostichal bristles are only weakly developed.

Known Distribution: Holarctic; most abundant in the northern region. In the U. S. it has been collected as far south as Texas and northern Georgia.

Virginia Records: Montgomery County, 3 March 1976 (Hall and Townsend): one female trapped over a chicken carcass.

Remarks: Hall (1948) indicated this species to be the northern counterpart of *Phormia regina*. Typically saprophagous, it may produce severe myiasis in various large wild and domestic animals.

P. terraenovae is evidently rare along the southern Atlantic coast. It may occur with slightly more frequency on ridge-tops in the northern portion of Virginia, but this habitat has not been thoroughly collected.

PROTOCALLIPHORA **Hough**

Protocalliphora Hough, 1899, Ent. News 10:66. *Apaulina* Hall, 1948, The Blowflies of North America, p. 179.

Diagnosis: The following combination of characters will distinguish the *Protocalliphora* from other North American Phormiini. Preacrostichal bristles strongly developed, upper squamal lobe without black setae on the dorsal surface, mesonotum flattened and the mesothoracic spiracle surrounded by dark pubescence.

Remarks: The "bird's nest screwworm flies" are an interesting group whose larvae evidently are obligatory bloodsucking parasites of nestling birds. Hall (1948) believed the species occurring in North America to be different from European *Protocalliphora* and placed them in *Apaulina*. Subsequent work based on considerably greater numbers of specimens indicates that American and European forms may be congeneric. C. W. Sabrosky (USDA), currently engaged in a revision of the genus, indicates (personal communication) that he has Virginia records of five species, one of them new. The genus appears to be most abundant in the higher portions of western Virginia. Collection efforts are hampered because adults of *Protocalliphora* are not attracted to baited traps. Few have been taken with nets. Most specimens in collections have been reared from larvae or pupae recovered from nests of birds.

Subfamily CALLIPHORINAE

This subfamily contains the common "blue bottle" and "green bottle" flies. All lack cilia dorsally on the remigium, and both the prosternum and propleuron are setulose. The majority of Virginia Calliphoridae belong to this taxon.

Tribe LUCILIINI

The species included in this tribe lack setae dorsally on the lower squamal lobe, and the arista is generally plumose to the tip. Often termed "green bottle" flies, six species were found in Virginia.

BUFOLUCILIA SILVARUM (Meigen)

Musca silvarum Meigen, 1826, Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten 5:53.

Diagnosis: The following characters will distinguish this species from other North American Luciliini. A greenish-blue species with the head width at the antennae and vibrissae equal to more than half the head height. The second abdominal segment bears strongly developed median marginal bristles; there are three postacrostichal bristles and the wing displays a strong costal spine.

Known Distribution: Holarctic; Virginia, Arkansas, and California north to southern Canada.

Virginia Records and Seasonal Abundance: Counties of Arlington, Fairfax, Hanover, Loudoun, Montgomery and Roanoke. Collection dates ranged from May through October.

Remarks: The genus *Bufolucilia* is interesting because of the intriguing life history of the European species *B. bufonivora* (Moniez). The larval stages of the latter are evidently parasitic upon toads. Honig (1969) reported reduction of toad populations as a result of this parasite. Records of toad parasitism from the Palearctic Region are often unreliable because of failure to distinguish between *B. silvarum* and *bufonivora* (Hall, 1948).

Dodge (1952) reported collection of *B. silvarum* from the carcass of a rat and the frequent trapping of this species over decaying meats. He also noted that the numbers of individuals encountered during a three-year trapping program were higher than would be expected for a species requiring a larval stage in toads. Reports by Dicke and Eastwood (1952) and Schoof et al. (1956) indicate the incidence of this species to be higher than accounted for by toad parasitism. Brothers (1970) reported saprophagous activity for *silvarum.*

We collected this species in traps employing chicken, frog, and turtle carcasses and dog food, liver preparations, and human excrement as bait. In addition, specimens were reared from a dead turtle and collected via a McPhail trap.

Hall (1948) stated that he had collected specimens during the last week in March in northern Virginia (Arlington and Fairfax counties).

LUCILIA ILLUSTRIS **(Meigen)**

Musca illustris Meigen, 1826, Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten 5:54. *Lucilia caesar* of many North American authors.

Diagnosis: The presence of wiry bristles on the subcostal sclerite will distinguish this species from other North American Luciliini (see Pl. 6B). Generally shining greenish-blue, the thorax may reflect bronze and purple in certain light. In the female, the ocellar triangle extends halfway to the lunule.

Known Distribution: Holarctic; northern Mexico to southern Canada in North America.

Virginia Records and Seasonal Abundance: The cities of Alexandria, Hampton, and City of Virginia Beach; counties of Arlington, Fairfax, Hanover, Madison, Mathews, Montgomery, Loudoun and York. Dates of collection ranged from April to August.

Remarks: Hall (1948) lists *L. illustris* as an open woodland and meadow species. Dasgupta and Roy (1969) found that females would not oviposit on living animals; however, egg masses artificially transferred to various mammals produced severe myiasis.

L. caesar is an Old World species and to the authors' knowledge has not been recorded from North America.

Specimens of *illustris* appeared readily at freshly exposed carcasses, including those of chickens, rabbits, opossum, frogs, and turtles. Additional adults also were captured over human feces and from the flowers of wild mustard.

PHAENICIA COERULEIVIRIDIS **(Macquart)**

Lucilia coeruleiviridis Macquart, 1855, Diptères Exotiques, sup. 5: 133.

Diagnosis: The following characters will distinguish this species from other North American Luciliini. A robust, shiny blue-green species with the subcostal sclerite bearing downy pubescence only. Two postacrostichal bristles, legs dark brown to black, and with the caudal two abdominal segments highly polished, often to a reddish cast. The male has one reclinate fronto-orbital bristle slightly anterior to the median ocellus and the female has dark setulae on the parafrontal outside the frontal row of bristles.

Known Distribution: Nearctic; common throughout the southeastern U. S. from Maryland to Florida.

Virginia Records and Seasonal Abundance: The cities of Alexandria, Norfolk and City of Virginia Beach; counties of Arlington, Essex, Fairfax, Giles, Goochland, Hanover, Louisa, Middlesex, Montgomery, Henrico, New Kent, Page, Princess Anne, Pulaski, Roanoke, Smythe, Washington, Westmoreland, and York. Dates of collection ranged from April through October.

Remarks: This species is the predominant member of the Luciliini in southwestern Virginia and is evidently attracted to most decaying animal matter. Donohoe (1937) indicated that the species may be economically important in those portions of California where commercial fruits are dried, but James (1955) believed these records should be referred to *P. mexicana.*

The authors collected *coeruleiviridis* over a variety of warm- and cold-blooded animal carcasses, human excrement, and crushed apples.

PHAENICIA CUPRINA **(Wiedemann)**

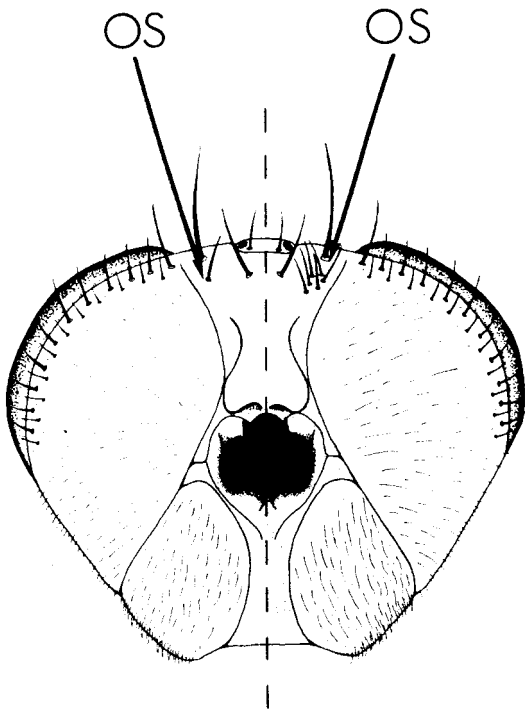
Musca cuprina Wiedemann, 1830, Aussereurop. Zweifl. Insekten 2: 654. *Lucilia pallescens* Shannon, 1924, Insecutor Inscitiae Menstruus 12:78. *Lucilia cuprina* Shannon, 1926, Wash. Ent. Soc. Proc. 28:131.

Diagnosis: The following combination of characters will distinguish this species from other North American Luciliini. Coloration dull coppery, rarely tinged with green, and with the metasternum bare. The thorax bears three postacrostichal bristles. The dorsal surface of the abdomen typically exhibits a median line separating the structure into halves, one pollinose and one metallic. The appearance of the two sides may be reversed by altering the incidence of light. Central occiput as in Pl. 7.

Known Distribution: Oriental and American regions; southern U. S. In its present taxonomic status, considered present also in Australia and Africa.

Virginia Records and Seasonal Abundance: Cities of Alexandria and Norfolk; counties of Arlington, Fairfax, Giles, Henrico, Nelson, Prince George, and Roanoke. Dates of collection ranged from June through October.

Remarks: Waterhouse and Paramonov (1950) considered *Lucilia* Robineau-Desvoidy and *Phaenicia* Robineau-Desvoidy congeneric. They presented extensive data to demonstrate that *cuprina* and *sericata* (Meigen) are distinct speices. In addition, they separated *Lucilia cuprina* (their designation) into two subspecies: *L. cuprina cuprina* (the "typical" subspecies with a dull, bronzy sheen) was considered equivalent to the *pallescens* of Shannon, while *L. cuprina dorsalis* (shining metallic green with copper overtones) was indicated as occupying Africa, India, and Australia.



Phaenicia cuprina Phaenicia sericata

Plate 7. Cerebrale - Caudal View

Despite the absence of currently known morphological dissimilarities between the adults, Waterhouse and Paramonov pointed out that two distinct species may in fact be represented by their *cuprina* complex. We have seen no work elaborating upon the assertion by E. F. Knipling (*in* Hall, 1948) that differences exist between Australian and North American larvae of what currently is considered *P. cuprina*. Furthermore, there is no explanation in Waterhouse and Paramonov (1950) or Zumpt (1965) for the biological differences between the Australian and North American forms. While an important sheep strike fly in Australia, we are not able to find a single record of such behavior for this species in North America. That at least some Virginia sheep are strike susceptible has been shown by our records relating to *Phormia regina* and *Cochliomyia macellaria*. The so-called *cuprina* of North America has been taken in Virginia only in connection with garbage or flowering plants.

We therefore consider it probable that *P. pallescens* will prove to be a distinct species; however, considerable work remains to be done before the exact taxonomic position of the several forms can be clarified.

We have collected this species in Virginia mostly near small garbage dumps and over rotting vegetables. Specimens were netted over goldenrod, and several individuals were captured when they entered buildings in late fall.

PHAENICIA MEXICANA **(Macquart)**

Lucilia mexicana Macquart, 1843, Diptéres Exotiques 2:300.

Diagnosis: A shining blue-green species similar to *P. coeruleiviridis* but with basicosta black and two or more rows of postocular setae.

Known Distribution: Nearctic and Neotropical; in the U. S. most abundant in the southwest; rare in California.

Virginia Records and Seasonal Abundance: Prince George County, 12 July 1938 (D. G. Hall): in USNM.

Remarks: A review of the literature did not reveal any records of significant human or veterinary medical problems attributable to this species. The species is not abundant in Virginia, although the central Piedmont region may support larger populations than our records reflect.

James (1955) indicated that *mexicana* is a sylvan species attracted to excrement, garbage, and freshly-killed carcasses. From an economic aspect, he indicated this species may have been involved in contamination of drying fruit reported by Donohoe (1937.).

PHAENICIA SERICATA **(Meigen)**

Musca sericata Meigen, 1826, Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten 5:53.

Diagnosis: The following characters will distinguish this species from other North American Luciliini. A coppery-green species. palpi yellowish, basicosta yellow to white, three postacrostichal bristles and with the metasternum setose. The central occipital area usually with a cluster of several setae caudad of the inner vertical bristle (Pl. 7); abdominal dorsal pollinose pattern as in *cuprina*.

Known Distribution: Often said to occur worldwide in temperate areas; however, Hall (1948) collected no specimens in Central or South America or on Central or Southwest Pacific Islands during extensive surveys in the early 1940's, and Zumpt (1965) indicated that the species may not be completely cosmopolitan.

Virginia Records and Seasonal Abundance: City of Norfolk; counties of Albemarle, Arlington, Augusta, Chesapeake, Hanover, Henrico, Montgomery, Nelson, Northumberland, Princess Anne, Pulaski, and Roaonke. Dates of collection ranged from May through October.

Remarks: *P. sericata* is one of the first of a series of saprophagous insects attracted to fresh carrion. The species also is attracted to a wide range of decaying substances, especially fruit and meat waste. It is an important factor in sheep strike, primarily in Great Britain (Zumpt, 1965).

James (1967) reported an unusual series of specimens, identified as *P. sericata,* in which marked reduction in dorsal thoracic chaetotaxy was evident, especially among the postacrostichals. We have examined individuals which exhibited unilateral reduction of the postacrostichal bristles; however, the general habitus of the species and various supplementary characters are sufficiently distinctive so that no problems in routine identification should be encountered. Of more frequent occurrence is the bilateral presence of additional, small postacrostichals.

Larvae of *sericata* have been employed in surgical routines for the removal of necrotic tissue. Brumpt (1933) provides a review of this subject.

We trapped this species over chicken and frog carcasses and human excrement. Additional specimens were those reared from putrid liver and those which emerged from chicken manure in a commercial egg-production house. The latter record probably represents individuals which originated in chicken carcasses and then migrated into the manure as mature larvae. Our records indicate that *sericata* is most common in the eastern lowlands of Virginia.

Tribe CALLIPHORINI

Those species placed in the Calliphorini possess dark setulae dorsally on the lower squamal lobe. Often termed the "blue bottle flies," they are robust, with coloration ranging from shining blue to dull black. Most species are northern in distribution. In Virginia they are collected most frequently in early spring and late fall.

EUCALLIPHORA Townsend

Eucalliphora Townsend, 1908, Smithsn. Misc. Coll. 51:118.

Diagnosis: Species of variable size and with the general appearance of *Calliphora* (see Hall, 1948); the thorax black and pollinose, the abdomen generally dark metallic blue. They may be distinguished from other members of the Calliphorini by the presence of strongly developed bristles on the facials and the addition of accessory ocellar bristles.

Known Distribution: Nearctic; western U. S. from northern Mexico to Ontario, Canada.

Virginia Records and Seasonal Abundance: None.

Remarks: Brimley (1938) listed *E. lilaea* (Walker) from North Carolina. We have no records from Virginia, and the specimen reported as collected from North Carolina appears to be out of the normal range of the species. James (1955) lists it from numerous counties in California and notes that it often breeds in the carcasses of small mammals.

CALLIPHORA LIVIDA **Hall**

Calliphora livida Hall, 1948, Blowflies of North America, p. 296. *Calliphora viridescens* of North American authors.

Diagnosis: The following characters will distinguish this species from other North American Calliphorini. Hindmost preintraalar bristle present, four to five lateral scutellar bristles, three postintraalar bristles; the buccae black on mature specimens.

Known Distribution: Nearctic; southern U. S. northward to British Columbia and Ontario.

Virginia Records and Seasonal Abundance: Counties of Arlington, Fairfax, Frederick, Montgomery, Roanoke, and Wythe. Dates of collection ranged from March through April; specimens were noted again in late August.

Remarks: *C. livida* is frequently confused with *vicina* in survey collections. The coloration of the buccae will serve to separate the two; however, teneral specimens must be examined with care.

This species is saprophagous and is attracted to almost all types of carrion. We have taken it in traps baited with the carcasses of chickens, opossum, and rabbits.

CALLIPHORA VICINA **Robineau-Desvoidy**

Calliphora vicina Robineau-Desvoidy, 1830, Essai sur les Myodaires, p. 435. *Musca erythrocephala* Meigen, 1826, Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten 5:62 (preoccupied).

Diagnosis: The following characters will distinguish this species from other North American Calliphorini. Hindmost preintraalar bristle present, four to five lateral scutellar bristles, two postintraalar bristles; the buccae are reddish to yellowish on the anterior half.

Known Distribution: Holarctic; in the U. S. most abundant from Virginia northward to Canada.

Virginia Records and Seasonal Abundance: Counties of Arlington, Augusta, Bedford, Chesterfield, Fairfax, Frederick, Giles, Grayson, Hampton, Montgomery, Pulaski, Roanoke, Rockingham, Smyth, Wise, and Wythe. This species is present during early spring and

late fall; our records indicate collections during the periods March through June and August through October.

Remarks: *C. vicina* appears to be the most widespread bluebottle fly in Virginia. The abundance of this species in insect collections at some universities may be misleading because the meeting of springtime entomology classes (with students collecting) coincides with the appearance of large adult populations.

Sychevskaya (1962) reported *C. vicina* to be active in the temperature range 44.6 to 89.6° F (7.0 to 32.0° C). As temperatures reached 75° F (24° C), the flies withdrew to sheltered areas. Ovarian development was delayed by warmer ambient temperatures (ca. 86° F [30° C]). Eggs representing the second population peak were laid as cooler weather returned.

C. vicina is used extensively in insect physiological research and is often referred to by the preoccupied name *C. erythrocephala* (Meigen).

Hall (1948) indicated that adults of this species are attracted to most ill-smelling products of decay. We trapped this species over a variety of animal carcasses.

CALLIPHORA VOMITORIA **(Linnaeus)**

Musca vomitoria Linnaeus, 1758, Systema Naturae 10:595.

Diagnosis: The following combination of characters will distinguish this species from other North American Calliphorini. A large, robust species with the typical habitus of *Calliphora*, the thorax deep blue-black with dark longitudinal stripes and the abdomen shining blue with whitish pollen. The hindmost preintraalar bristle is present; there are four to five lateral scutellar bristles, two postintraalar bristles; the basicosta is black and the buccae are black with golden to reddish setulae posteriorly.

Known Distribution: Holarctic; in the U. S. from Virginia and California northward to Alaska.

Virginia Records and Seasonal Abundance: Counties of Arlington, Augusta, Bedford, Botetourt, Fairfax, Giles, Grayson, Hanover, Montgomery, and Westmoreland. Like *C. vicina*, the species appears in two population peaks; in Montgomery County from March through July and from September through October.

Remarks: *C. vomitoria* is a woodland species and appears to prefer shady places (Mihályi, 1965). MacLeod and Donnelly (1957) found that it appeared later in the spring than *C. vicina* and *L. illustris.*

Hall (1948) stated that *vomitoria* is not particularly common in the U. S. In Virginia, it appears to be most abundant in the western mountains. A typical saprophage, the species was trapped over a variety of animal carcasses including those of chickens, opossum. rabbits, and squirrels.

CYNOMYOPSIS CADAVERINA **(Robineau-Desvoidy)**

Cynomya cadaverina Robineau-Desvoidy, 1830, Essai sur les Myodaires, p. 365.

Diagnosis: The following characters will distinguish this species from other North American Calliphorini. A robust species with the abdomen shining metallic blue to blue-green and the head greyish-yellow to golden pollinose anteriorly. The scutellum typically bears three strongly developed lateral bristles (rarely an adventitious fourth), the arista is ciliate approximately three-fourths of the distance to the apex, and the thorax bears two postacrostichal bristles.

Known Distribution: Nearctic; from Texas north to Ungava Bay; most abundant along the U. S.-Canadian border.

Virginia Records and Seasonal Abundance: City of Alexandria; counties of Albemarle, Arlington, Augusta, Fairfax, Fauquier, Loudoun, Montgomery, Pulaski, and Roanoke. Dates of collection ranged from February through June and from September through October.

Remarks: Hall (1948) indicated that this species apparently overwinters in the pupal stage. This is consistent with our collections; numerous adult *cadaverina* frequently appear on the first warm days of spring in Virginia. We have obtained adults after soil samples collected in mid-winter were brought into the laboratory.

A number of specimens were seen in which the number of postacrostichal bristles was reduced, most often unilaterally, but occasionally on both sides. Hall (1948) noted that southern specimens frequently have the parafaciale reddish in ground color and this plus the golden pollinosity lends superficial resemblance to *Cyanus elongatus* or *Cynomya mortuorum.* These species, however, have not been taken from southeastern localities.

The adults of *cadaverina* are readily attracted to human feces and various types of carrion.

CYANUS ELONGATUS **(Hough)**

Cynomyia elongata Hough, 1898, Ent. News 9:106.

Diagnosis: The following characters will distinguish this species from other North American Calliphorini. A large black and greyish species similar to *C. cadaverina.* The front and parafacials are bright gold, the abdomen shining bluish-green, the scutellum bears three lateral bristles, the hindmost preintraalar bristle is present, there are three postacrostichal bristles, and the arista is ciliate three-fourths of the distance to the apex.

Known Distribution: Nearctic; from South Dakota northward to Alberta, Canada.

Virginia Records and Seasonal Abundance: None.

Remarks: Specimens of *C. cadaverina* exhibiting chaetotaxic variation may occasionally be mistaken for *elongatus.*

The habitat preferences of this species are generally unknown. Hall (1948) stated that it seldom comes to baited traps.

CYNOMYA MORTUORUM **(Linnaeus)**

Musca mortuorum Linnaeus, 1761, Fauna Suecica, Ed. 2, p. 452.

Diagnosis: The following characters will distinguish this species from other North American Calliphorini. A large black and greyish species with the front golden pollinose and the abdomen metallic bluish-green. It differs from *C. elongatus* in that the hindmost preintraalar bristle is absent and the thorax bears one postacrostichal bristle.

Known Distribution: Holarctic; North America along the Arctic Circle.

Virginia Records and Seasonal Abundance: None.

Remarks: This species may be confused with specimens of *C. cadaverina* in which thoracic chaetotaxic variation is evident. Brimley's (1938) records from North Carolina are considerably out of the normal range of *mortuorum.*

Subfamily POLLENIINAE

The Polleniinae includes species which are dull black, non-metallic, with a slight degree of light pollinosity. They superficially resemble, and are often confused with, members of the genus *Musca*.

Tribe POLLENIINI

Only one genus and a single species of this tribe are known to occur in North America. Members may be separated from the Melanodexiini by the presence of the presutural preintraalar bristle, the posthumeral bristle, and the scutellum and postscutellum flattened discally.

POLLENIA RUDIS **(Fabricius)**

(Cluster Fly)

Musca rudis Fabricius, 1794, Entomologia Systematica 4:314.

Diagnosis: A dull black species, the abdomen tesselated and the thorax with crinkly yellow setulae most abundant laterally. These characters, together with those characteristic of the Polleniini, will distinguish this species from other North American Calliphoridae.

Known Distribution: Holarctic; in the U. S. from the east to the west coast and north to the Canadian border.

Virginia Records and Seasonal Abundance: City of Norfolk; counties of Albemarle, Arlington, Augusta, Bath, Buckingham, Craig, Culpeper, Dinwiddie, Fairfax, Fauquier, Franklin, Goochland, Highland, King George, Lee, Loudoun, Montgomery, Pulaski, Roanoke, Rockbridge, Russell, Scott, Smyth, Spotsylvania, and Stafford. Adults have been taken throughout the entire year; however, midwinter records usually pertain to individuals overwintering in houses.

Remarks: *P. rudis* is a parasite of several species of earthworms, and larvae have not been reared upon substances other than living hosts (Hall, 1948; Thompson and Davies, 1973a, 1973b and 1974). The actual ecological impact of such parasitism is difficult to assess, though it is well known that this species frequently is of concern when large numbers of adults seek shelter inside buildings. Flies of the final generation of the year reach a population peak toward the end of October and attempt to locate suitable protected sites as colder weather approaches. In the wild, such locations are often

under the bark of decaying trees. The flies tend to crawl rather than fly into buildings and are able to negotiate seemingly impenetrable crevices (see also Pimentel and Epstein, 1960; Richards and Morrison, 1972).

Attics are favored wintering sites for *P. rudis*, and relief from large aggregations which tend to wander throughout the rest of the house may be obtained by hanging insecticide-impregnated resin strips on the sunny side of the attic where the heat of midday will assist in vaporization of the chemical.

The authors collected adult *P. rudis* from various houses and rural outbuildings as well as from traps baited with carcasses of rabbits, opossum, turtles, and frogs. Substances such as banana and liver are attractive also. Numerous specimens were netted over alfalfa and wild mustard.

LITERATURE CITED

Alvarez, C. G., F. S. Blanton and H. D. Putnam. 1972. Identification and control of flies associated with a compost plant. Environ. Ent. 1:710-6, illus.

Anonymous. 1965. Mexican Fruit Fly, *Anastrepha ludens*, Survey Manual 803-08.0000. USDA, ARS, Plant Pest Control Division. 19 pp.

Anonymous. 1976. Harnessing maggot power. Medical World News, 23 August, p. 40.

Bartell, R. J., H. H. Shorey and L. Barton Browne. 1969. Pheromonal stimulation of the sexual activity of males of the sheep blow fly *Lucilia cuprina* (Calliphoridae) by the female. Anim. Behav. 17:576-85.

Bishopp, F. C. 1916. Fly traps and their operation. USDA Farmer's Bull. 734: 16 pp.

Brimley, C. S. 1938. The insects of North Carolina. North Carolina Dept. Agric., Raleigh. 560 pp.

Brothers, D. R. 1970. Notes on the saprophagous activity of *Bufolucilia silvarum* (Meigen) (Diptera: Calliphoridae). Pan Pacific Ent. 46:198-200, illus.

Browne, L. B., R. J. Bartell and H. H. Shorey. 1969. Pheromone-mediated behavior leading to group oviposition in the blow fly *Lucilia cuprina*. Jour. Insect Physiol. 15:1003-14, illus.

Brumpt. 1933. Utilisation des larves de certaines mouches pour le traitmont de l'ostéomyélite et de diverses affections chirurgicales chroniques. Ann. Parasitol. Humane et comp. 11:403-20.

Cole, F. R. 1969. The flies of western North America. Univ. Calif. Press. Berkeley and Los Angeles. xi + 693 pp.

Dasgupta, B. and P. Roy. 1969. Studies on the behavior of *Lucilia illustris* Meigen as a parasite of vertebrates under experimental conditions. Parasitol. 59:299-304.

Dicke, R. J. and J. P. Eastwood. 1952. The seasonal incidence of blowflies at Madison, Wisconsin (Diptera: Calliphoridae). Wisc. Acad. Arts and Letters 41:207-17.

Dodge, H. R. 1952. A possible case of blow fly myiasis in a rat, with notes on the bionomics of *Bufolucilia silvarum* (Mg.) Ent. News. 63:212-4.

Donohoe, H. C. 1937. Fly damage to drying cut fruits. Proc. Ent. Soc. Wash. 39:283.

Dove, W. E. 1935. Screw worm control. USDA, BEPQ Bull. E356, 10 pp.

Eddy, G. W. and J. A. Devaney. 1970. A brief statistical review of the United States-Mexico screw-worm eradication program. Bull. Ent. Soc. Amer. 16:159-64.

Fobert, L. C. J. 1971. Observations in connection with insects as carriers of *Salmonella* bacteria. Biologisch Jaarboek. 39:221-37.

Furman, D. P. and E. P. Catts. 1970. Manual of medical entomology. Third Edition. National Press Books. Palo Alto, California. 163 pp.

Greenberg, B. 1971. Flies and disease. Vol. 1, Ecology, classification and biotic associations. Princeton University Press. Princeton, New Jersey. 856 pp.

Greenberg, B. and A. Bornstein. 1964. Fly dispersion from a rural Mexican slaughterhouse. Amer. J. Trop. Med. Hyg. 13:881-6.

Greenberg, B., J. A. Kowalski and M. J. Klowden. 1970. Factors affecting the transmission of *Salmonella* by flies: natural resistance to colonization and bacterial interference. Infect. Immun. 2:800-9.

Greenberg, B., G. Varela, A. Bornstein and H. Hernandez. 1963. Salmonellae from flies in a Mexican slaughterhouse. Amer. J. Hyg. 77:177-83.

Greenwood, E. S. 1964. *Bacillus thuringiensis* in the control of *Lucilia sericata* and *Musca domestica*. N. Z. Jour. Sci. 7:221-6.

Hall, D. G. 1948. The blowflies of North America. Thomas Say Found. Washington, D. C. 477 pp.

Hoffman, R. L. 1969. II. The biotic regions of Virginia. *In* The insects of Virginia: No. 1. VPI and SU Research Division Bulletin 48:23-62.

Honig, J. 1969. A fly reduces toad populations. Klein-ter-Praxis. 14:109-10.

James, M. T. 1947. The flies that cause myiasis in man. USDA Misc. Publ. No. 631. 175 pp.

James, M. T. 1955. The blowflies of California (Calliphoridae). Calif. Insect Survey Bull. 4:1-34, illus.

James, M. T. 1967. Variation in chaetotaxy in *Phaenicia sericata* (Diptera: Caliphoridae). Ann. Ent. Soc. Amer. 60:706.

Kinn, D. N. 1966. Predation by the mite, *Macrocheles muscaedomesticae* (Acarina: Macrochelidae), on three species of flies. J. Med. Ent. 3:155-8.

Knipling, E. F. and E. T. Rainwater. 1937. Species and incidence of dipterous larvae concerned in wound myiasis. J. Parasitol. 23:451-5.

Kramer, J. P. 1964. The microsporidian *Octosporea muscaedomesticae* Flu, a parasite of Calypterate Muscoid flies (*Phormia regina* (Mg.) *Callitroga* (*Cochliomyia*) *macellaria* (F.), *Pollenia rudis* (F.), *Musca domestica* (L.) and *Lucilia* (*Phaenicia*) *sericata* (Mg.). Jour. Insect Pathol. 6:331-42.

Kramer, J. P. 1971. Experimental studies on the phycomycosis of Muscoid flies caused by *Entomophthora muscae* (Cohn). Jour. N. Y. Ent. Soc. 79: 52-5.

Kramer, J. P. 1973. Susceptibility of sixteen species of muscoid flies to the microsporidian parasite *Octosporea muscaedomesticae*. J. N. Y. Ent. Soc. 81:50-3, illus.

Laitinen, E., P. Nuorteva and O. V. Renkonen. 1970. A case of wound myiasis in man caused by *Lucilia illustris*. Ann. Ent. Fenn. 36:123.

Lane, R. 1975. An investigation into blowfly (Diptera: Calliphoridae) succession on corpses. J. Nat. Hist. 9:581-8.

Leclercq, M. 1963. Un cas de myiase intestinale à larves de *Calliphora*. Rev. mèd. Liège 18:61-3.

Leclercq, M. 1969. Entomological parasitology — the relations between entomology and the medical sciences. Pergamon Press, Oxford, London. xviii + 158 pp.

Legner, E. F. and E. C. Bay. 1970. The introduction of natural enemies in California for the biological control of noxious flies and gnats. Proceed. 37th Ann. Conf. Calif. Mosq. Control Assoc. Inc. p. 126-9.

MacLeod, J. 1956. A preliminary experiment on the local distribution of blowflies. J. Anim. Ecol. 25:303-18.

MacLeod, J. and J. Donnelly. 1956a. The geographical distribution of blowflies in Great Britian. Bull. Ent. Res. 47:597-616.

MacLeod, J. and J. Donnelly. 1956b. Methods for the study of blowfly populations. II. The use of laboratory bred material. Ann. Appl. Biol. 44: 643-8.

MacLeod, J. and J. Donnelly. 1957. Some ecological relationships of natural populations of Calliphorine blowflies. J. Anim. Ecol. 26:135-70.

MacLeod, J. and J. Donnelly. 1962. Microgeographic aggregations in blowfly populations. J. Anim. Ecol. 31:525-43.

Mason, E. A. 1944. Parasitism by *Protocalliphora* and management of cavity-nesting birds. J. Wildlife Mgmt. 8:232-47.

Magy, H. I. and R. J. Black. 1962. An evaluation of the migration of fly larvae from garbage cans in Pasadena, Calif. Calif. Vector Views. 9:55-9.

Mathis, W., H. F. Schoof and T. L. Mullenix. 1969. Fly production in relation to refuse disposal in recreation areas. Jour. Econ. Ent. 62:1288-91.

Megnin, P. 1894. La faune des cadavres. Application de l'Entomologie à la Medicine Légale. Encycl. Leautun., Paris.

Melnick, J. L. 1949. Isolation of poliomyelitis virus from single species of flies collected during an urban epidemic. Amer. J. Hyg. 49:8-16.

Merritt, R. W. 1969. A severe case of human cutaneous myiasis caused by *Phaenicia sericata* (Diptera: Calliphoridae). Calif. Vector Views. 16: 24-6, illus.

Mihályi, F. 1965. Rearing flies from faeces and meat, infected under natural condition. Acta. Zool. Hung. 11:153-64.

Mihályi, F. 1967. The danger index of synanthropic flies. Acta. Zool. Hung. 13:373-7, illus.

Morris, R. F. 1966. The sheep blowfly and its control in Newfoundland. Can. Dept. Agr. Publ. 1273: 10 pp.

Nadzhafov, I. G. 1972. The role of flies in the epidemiology of human helminthic diseases in the Azerbaijan SSR. Meditsinskaya Parazitol. i Parazitarnye Bolezni. 41:168-72.

Norris, D. 1957. Coop. Econ. Insect Report 7:607.

Norris, K. R. 1965. The bionomics of blowflies. Ann. Rev. Ent. 10:47-68.

Norris, K. R. 1966. Daily patterns of flight activity of blowflies (Calliphoridae: Diptera) in the Canberra district as indicated by trap catches. Aust. Jour. Zool. 14:835-53.

Nuorteva, P. 1963a. Synanthropy of blowflies (Dipt., Calliphoridae) in Finland. Ann. Ent. Fenn. 29:1-49.

Nuorteva, P. 1963b. The role of flies in the epidemiology of poliomyelitis. Anz. Schädlingsk. 36:149-55.

Nuorteva, P. and T. Vesikari. 1966. The synanthropy of blowflies (Diptera: Calliphoridae) on the coast of the Arctic Ocean. Ann. Med. Exp. Biol. Fenn. 44:544-8.

Nuorteva, P., M. Isokoski and K. Laiho. 1967. Studies on the possibility of using blowflies (Dipt.) as medico-legal indicators in Finland. I. Report of four indoor cases from the city of Helsinki. Suom. Hyont. Aikak. 33: 217-25.

Nuorteva, P., H. Schumann, M. Isokoski and K. Laiho. 1974. Studies on the possibility of using blowflies (Diptera: Calliphoridae) as medico-legal indicators in Finland. Ann. Ent. Fenn. 40:70-4.

Ojala, O. and P. Nuorteva. 1966. Isolation of *Salmonella* bacteria from flies in southern Finland. 10th Nordic Vet. Congr. 2:622-7.

Pickens, L. G., R. W. Miller and G. R. Mowry. 1973. An improved bait for flies (Dipt. Muscidae, Calliphoridae). Jour. Med. Ent. 10:84-8.

Pimentel, D. and B. Epstein. 1960. The cluster fly, *Pollenia rudis* (Diptera: Calliphoridae) Ann. Ent. Soc. Amer. 53:553-4.

Power, M. E. and J. L. Melnick. 1945. A three-year survey of the fly population in New Haven during epidemic and non-epidemic years for poliomyelitis. Yale Jour. Biol. and Med. 18:55-69.

Pratt, H. F. 1956. Human myiasis due to *Phaenicia sericata* (Meigen) in Virginia. Proc. Ent. Soc. Wash. 58:14.

Quarterman, K. D., J. W. Kilpatrick and W. Mathis. 1954a. Fly dispersal in a rural area near Savannah, Ga. Jour. Econ. Ent. 47:413-19.

Quarterman, K. D., W. Mathis and J. W. Kilpatrick. 1954b. Urban fly dispersal in the area of Savannah, Ga. Jour. Econ. Ent. 47:405-12.

Ratcliffe, B. C. 1972. The natural history of *Necrodes surinamensis* (Fabr.) (Coleoptera, Silphidae) Trans. Amer. Ent. Soc. (Phil.) 98:359-410, illus.

Richards, P. G. and F. O. Morrison. 1972. A summary of published information on the cluster fly, *P. rudis* Fabricius (Diptera: Calliphoridae). Phytoprotection. 53:103-11.

Schiller, E. L. 1954. Studies on the helminth fauna of Alaska. XIX. An experimental study on blowfly (*Phormia regina*) transmission of hydatid disease. Exper. Parasitol. 3:161-6.

Schoof, H. F. 1955. Survey and appraisal methods for community fly control programs. Publ. Hlth. Monogr. 33: iv + 18 pp.

Schoof, H. F., G. A. Mail and E. P. Savage. 1954. Fly production sources in urban communities. Jour. Econ. Ent. 47:245-53.

Schoof, H. F. and E. P. Savage. 1955. Comparative studies of urban fly populations in Arizona, Kansas, Michigan, New York and West Virginia. Ann. Ent. Soc. Amer. 48:1-13, illus.

Schoof, H. F., E. P. Savage and H. R. Dodge. 1956. Comparative studies of urban fly populations in Arizona, Kansas, Michigan, New York and West Virginia. II. Seasonal abundance of minor species. Ann. Ent. Soc. Amer. 49:59-66.

Shannon, R. C. 1926. Synopsis of the American Calliphoridae (Diptera). Proc. Ent. Soc. Wash. 28:115-39.

Sychevskaya, V. I. 1962. On changes in the daily dynamics of the specific composition of flies associated with man in the course of the season. Rev. Ent. URSS 41:545-53.

Thompson, A. J. and D. M. Davies. 1973a. The biology of *Pollenia rudis*, the cluster fly (Diptera: Calliphoridae). I. Host location by first-instar larvae. Can. Ent. 105:335-41.

Thompson, A. J. and D. M. Davies. 1973b. The biology of *Pollenia rudis*, the cluster fly (Diptera: Calliphoridae). II. Larval feeding behaviour and host specificity. Can. Ent. 105:985-90.

Thompson, A. J. and D. M. Davies. 1974. The biology of *Pollenia rudis*, the cluster fly (Diptera: Calliphoridae). III. The effect of soil conditions on the host-parasite relationship. Can. Ent. 106:107-10.

Townsend, L. H. Jr. and R. D. Hall. 1976. Human myiasis in Virginia caused by *Phaenicia sericata* (Meigen) (Diptera: Calliphoridae). Proc. Ent. Soc. Wash. 78:113.

Volcčik, R. and U. Groth. 1972. Studies on action of attractants on synanthropic flies. Sektion Biol. (FG Allgemeine, Zoologie and Tierphysiologie EM Arndt Universität, Greifswald, E. Germ. (Abstract only, Rev. App. Ent. (B)60:61.

Waldron, W. G. 1968. A report on four recent cases of human myiasis (in California, including two caused by *Phaenicia* spp. and one caused by *Cochliomyia macellaria* (F.). Calif. Vector Views. 15:41.

Walsh, J. D., D. D. Linsdale, K. E. White and R. E. Bergstrom. 1968. Fly larval migration from residential refuse containers in the city of Fresno, Calif. Calif. Vector Views. 15:55-62.

Waterhouse, D. F. and S. J. Paramonov. 1950. The status of the two species of *Lucilia* (Diptera: Calliphoridae) attacking sheep in Australia. Austral. Jour. Sci. Res., (B) 3:310-336.

Whitten, M. J. and W. C. Taylor. 1970. A role for sterile females in insect control. Jour. Econ. Ent. 63:269-72.

Yeoman, G. H. and B. C. Warren. 1965. The chemosterilization of the sheep blow fly *Lucilia sericata* (Meigen) with apholate. Vet. Rec. 77:922-8.

Zumpt, F. 1965. Myiasis in man and animals in the Old World. A textbook for physicians, veterinarians and zoologists. London, Butterworth and Co. xv + 267 pp.