THE FORENSICALLY IMPORTANT CALLIPHORIDAE (INSECTA: DIPTERA) OF PIG CARRION IN RURAL NORTH-CENTRAL FLORIDA

By

SUSAN V. GRUNER

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2004

For Jack, Rosamond, and Michael

ACKNOWLEDGMENTS

The successful completion of this thesis would not have been possible without the support, encouragement, understanding, guidance, and physical help of many colleagues, friends, and family. My mother, Rosamond, edited my thesis despite her obvious distaste for anything related to maggots. My husband, Michael, cheerfully allowed more than most spouses could bear. And when it got really cold outside, he only complained two or three times when I kept multiple containers of stinking liver and writhing maggots on the kitchen counter. He also took almost all of the fantastic photos presented in this thesis and for my presentation. Finally, Michael had the horrible job of inserting an arrow with twelve temperature probes into pig "E."

I am also indebted to Dan and Jenny Slone, Jon Allen, Debbie Hall, Jane and Buthene Haskell, Dan and Zane Greathouse, owners of Greathouse Butterfly Farm, Aubrey Bailey, and the National Institute of Justice.

My professional colleagues, John Capinera, Marjorie Hoy, and Neal Haskell, guided and encouraged me through my research and writing every step of the way. Although I doubt that John Capinera was greatly interested in maggots, his support and enthusiasm in response to my enthusiasm are very much appreciated. Marjorie Hoy's beneficial advice was always appreciated and on occasion, she offered a shoulder on which to cry. Neal Haskell, as usual, went above and beyond the call of duty in every aspect of my time spent as an M.S. graduate student. I thank them all for their support.

Finally, I thank the pigs which were sacrificed in the name of forensic science.

TABLE OF CONTENTS

page

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

THE FORENSICALLY IMPORTANT CALLIPHORIDAE (INSECTA: DIPTERA) OF PIG CARRION IN RURAL NORTH-CENTRAL FLORIDA

By

Susan V. Gruner

August 2004

Chair: John Capinera
Major Department: Entomology and Nematology

The use of insect life stages in the determination of postmortem intervals in crime scene investigations is an important forensic science tool used by coroners, medical examiners, and police investigators. For estimation of postmortem interval, basic distribution data for the major indicator species of insects are required. It is apparent that the seasonality and species assemblage vary in different geographical areas.

A study to determine possible indicator species of Calliphoridae present in rural north-central Florida was conducted using pig carrion as models representing human bodies. A wooded habitat was used as the site for placement of the pigs. The study involved 19 batches of pigs placed in a wooded site over a period of time including spring, summer, fall, and winter collections from November 16, 2001, to March 2004 (approximately monthly). Larval and adult calliphorid flies were collected, as were meteorological data relating to the study site.

Seven species of Calliphoridae were collected from the pig carrion. Relative abundance of each species as a percentage of the total adult Calliphoridae assemblage (% aerially collected/% reared) for the study was *Phaenicia coeruleiviridis*, 68.1 vs. 77.9%; *Cochliomyia macellaria*, 16.0 vs. 8.5%; *Chrysomya rufifaces*, 7.0 vs. 8.0 %; *Phormia regina*, 8.2 vs. 3.9%; *Chrysomya megacephala*, 0.3 vs. 1.6 %; *Calliphora livida*, 0.4 vs. 0.1%; and *Calliphora vicina*, 0.0 vs. 0.02%. There were obvious seasonal and successional variations of the species assemblage. *Phaenicia coeruleiviridis* (Macquart) was the predominant species year-round but was lower in abundance during the summer, mid-June to mid September. Only a few specimens of *C. vicina* Robineau –Desvoidy (= *C. erythrocephala* Meigen) and *C. livida* Hall were found during the coldest months, November to February, while *C. megacephala* (Fabricus) was collected during the hottest months, June to September. *Cochliomyia macellaria* (Fabricus) was found during the warm months, April to June, when the temperature did not rise above 30.0º C. *Chrysomya rufifaces* (Macquart) was found in all but the coldest months of the year, mid December to mid March. *Phormia regina* (Meigen) was not found during the winter.

Different species of calliphorid flies arrived at the pig carrion at different stages during the decomposition process. Within minutes of placing the pig carcass on the ground, *P. coeruleiviridis* usually began to arrive. *Cochliomyia macellaria*, *C. rufifaces*, *P. regina*, *C. vicina* and *C. livida* arrived at the carcass after a delay of about 24 hours.

CHAPTER 1
INTRODUCTION AND LITERATURE REVIEW

Definition of and Scope of Forensic Entomology

Forensic entomology is an extensive discipline where arthropod science and the judicial system interact (Hall 2001). The field of forensic entomology has been divided into three areas: medicocriminal entomology (also referred to as medicolegal entomology), urban entomology and stored product entomology. Information gained from medicolegal entomology typically is used to determine time of death, place of death and other issues of medical or legal importance (Gordh and Headrick 2001). Urban entomology concentrates mainly on controversies involving termites, cockroaches, and other insect problems accruing to the human environment, whereas stored product entomology involves disputes over arthropods and arthropod parts in food and other products (Hall 2001).

When human remains are found, the most important questions usually are how, when, where and why the person died. Historically, determination of the postmortem interval (PMI) has been estimated through observation and measurement of body conditions such as core body temperature (Nelson 1999), muscular flaccidity, rigor mortis, lividity, pallor of the skin and others (Smith 1986, Bass 2001, Byrd and Castner 2001a). Entomological specimens in medicolegal death investigations can be reliable indicators for estimating the PMI in both early and advanced stages of cadaver decomposition (Nuorteva 1977, Smith 1986, Goff et al. 1988, Kashyap and Pillay 1989, Greenberg 1991, Byrd 1998).

Insects and other invertebrates feeding on carrion form a distinct faunal succession associated with the various stages of decay (Smith 1986). Recognition of the different immature stages of each species involved, together with the knowledge of their rates of development, can give an indication of the PMI (Smith 1986). A forensic (= medicolegal) entomologist can also determine the age of immature insects, based upon knowledge of the variables regarding insect invasion of human remains. Evaluation and interpretation of entomological evidence at a crime scene can address other complicated issues including season of death, geographic location of death, movement or storage of the remains following death, location of specific sites of trauma on the body, sexual molestation and use of drugs (Haskell et al. 1997).

In case studies conducted in varying temperate and tropical climates where human remains were exposed to the environment for 2.5 months or less, entomology-based PMI estimates differed by ± 48 hours when compared with the intervals determined by independent corroboration such as confessions and eyewitness testimony (Greenberg 1985, Goff et al. 1988, Lord 1990, Byrd 1998). Entomological evidence is statistically the most reliable scientific means of estimating PMI when compared to other methods such as police reports and autopsy results (Kashyap and Pillay 1989, Catts and Haskell 1990, Anderson 2001).

History of Forensic Entomology

The first documented forensic entomology case is from thirteenth century China in a book entitled “Hsi yüan chi lu” which can be translated as “The Washing Away of Wrongs.” The author, Sung Tz’u, was an educated man. He was a doctor, a sheriff and eventually a Judicial Intendant. The book describes applications of forensic entomology used in criminal cases during that period. A man was murdered by the roadside

apparently by an assailant with a sickle. Sung Tz'u made a proclamation that the nearest neighbors were to bring all their sickles to him for examination (McKnight 1981). At inquest time, the weather was hot and blow flies were attracted to one sickle only, even though it had no discernable traces of blood. The owner of the sickle confessed to the murder.

In addition to medical and legal experts, sculptors, painters and poets have closely observed the decomposition of human bodies, noting, in particular, the effects of feeding maggots. Artwork from the Middle Ages accurately depicts the insect-mediated pattern of body mass reduction, particularly the early skeletonization of the skull and the reduction of internal organs, with large parts of the skin left intact (Benecke 2001). In May 2004, a new painting of Prince Philip entitled "Portrait of a Prince" was released by artist Stuart Pearson Wright. The painting shows Prince Philip with a bluebottle fly sitting on his left shoulder, which represents a memento mori; the prince's mortality (The Associated Press 2004).

In 1855, Dr. Bergeret, a French physician, used insect succession as a tool (incorrectly) to solve a case (Benecke 2001). In the mid-1880s, J.P. Mégnin, also in France, published La Faune des Cadavres: Application de Entomologie à la Medicin Legale. The recognition by Mégnin of a sequence and progression of decomposition of a corpse was recorded in this work and in association with this decomposition progression, he observed changes in the insect assemblages as the corpse aged (Haskell et al. 1997, Benecke 1998).

This early interest in insects and decomposition led to a study on insect succession on human corpses in Quebec, Canada, in 1897 by Wyatt Johnston and Geoffrey

Villeneuve (Anderson 2001, Benecke 2001). At the same time in the United States, Murray Motter systematically tabulated the insect fauna from 150 exhumed corpses from the Washington, D.C. area (Haskell et al. 1997, Benecke 2001).

Species identification of the most important fly groups, Calliphoridae (blow flies) and Sarcophagidae (flesh flies), used in forensic cases could not have been accomplished had it not been for Aldrich's (1916) monograph on the Sarcophagidae which illustrated the distinctive male genitalia of adult flies. Knipling (1936) initiated taxonomic work on the larvae of sarcophagids and calliphorids. Hall's 1948 book, *The Blowflies of North America*, made it possible to identify the mature larvae of most species of calliphorids.

In northern Europe, the blow fly *Phaenicia sericata* (Meigen) is the most economically important ectoparasite of domesticated sheep. Sheep myiasis is a widespread disease and can cause high levels of mortality. The desire to develop control methods against sheep myiasis led to studies of calliphorid attractants (Wardle 1921, Cragg and Thurston 1949, Hammack and Holt 1983, Ashworth and Wall 1994, Wall and Warnes 1994, Morris et al. 1998). The attractant studies prompted additional studies on blow fly distribution and ecology (Parish and Cushing 1938, James 1947, Green 1951, Wolff et al. 2001) and were followed by studies that addressed effects of temperature on developmental time of blow fly life cycles (Davidson 1944, Kamal 1958, Nuorteva 1977, Greenberg 1991, Byrd and Butler 1996, 1997, 1998).

Regional successional studies of Calliphoridae in the United States have been conducted in California (James 1955), Hawaii (Goff et al. 1986, Goff et al. 1988, Goff 1991), Mississippi (Goddard and Lago 1985), Missouri (Hall and Doisy 1993), Virginia (Hall and Townsend 1977), Indiana (Haskell 1989), Illinois (Baumgartner 1988), Arizona

(Deonier 1942, Baumgartner 1986, Galloway et al. 1989), Colorado (Adair 1999), Maryland (Introna et al. 1991), West Virginia (Joy et al. 2002), Louisiana (Tessmer et al. 1995, Watson and Carlton 2003), and South Carolina (Tomberlin and Adler 1998). Four species--two of which are now found in Florida--of Old World blow flies have been confirmed from South or North America (Baumgartner and Greenberg 1984, Baumgartner 1986, Greenberg 1988, Tantawi and Greenberg 1993, Martin et al. 1996): *Chrysomya rufifaces* (Maquart), *C. albiceps* (Wiedemann), *C. megacephala* (F.) and *C. putoria* (Wiedmann). Studies by Byrd (1998) and Peters (2003) were conducted in the Gainesville, FL (= north-central Florida) area. This study will add rural north-central Florida to the list.

The study of insects important to forensic entomology has been conducted mainly through the use of non-human animal models. Decomposition studies worldwide have used a variety of different carcass types and sizes, including dogs (Jiron and Cartin 1981, Early and Goff 1986, Richards and Goff 1997), cats (Early and Goff 1986), alligators (Watson and Carlton 2003), voles (Lane 1975), rats (Greenberg 1990, Tomberlin and Adler 1998, Faucherre et al. 1999, Kocarek 2001), squirrels (Johnson 1975), deer (Watson and Carlton 2003), foxes (Easton and Smith 1970, Smith 1975), harbor seals (Lord and Burger 1984b), herring gulls (Lord and Burger 1984a), guinea pigs (Bornemissza 1957), mice (Putnam 1978, Blackith and Blackith 1989), lizards and toads (Cornaby 1974), raccoons (Joy et al. 2002), turtles (Abell et al. 1982), poultry (Hall and Doisy 1993, Tessmer et al. 1995), sheep (Deonier 1940), rabbits (Denno and Cothran 1975, Tantawi et al. 1996, Bourel et al. 1999), elephants (Coe 1978), opossums (Goddard and Lago 1985), black bears (Anderson 1998, Peters 2003, Watson and Carlton 2003),

impala (Braack 1981), and pigs (Payne 1965, Tullis and Goff 1987, Haskell 1989, Anderson and VanLaerhoven 1996, Tessmer and Meek 1996, Richards and Goff 1997, Byrd 1998, deCarvalho et al. 1999, Shahid et al. 1999, Davis and Goff 2000, deCarvalho and Linhares 2001, Wolff et al. 2001, Tenorio et al. 2003, Watson and Carlton 2003). The only faunal succession research on human remains was conducted in Tennessee (Rodriguez and Bass 1983, Catts and Haskell 1990).

Human cadavers are not easily obtainable for detailed decomposition studies. Pigs, *Sus scrofa*, are omnivorous, have similar gut fauna, are relatively hairless and have skin that is very similar to that of humans (Anderson and VanLaerhoven 1996). The putrefaction of pigs proceeds approximately at the same rate as for human bodies that are of the same weight (Campobasso et al. 2001). Haskell's 1989 study in Tennessee (Schoenly and Haskell 2000) compared the insect community structure and decomposition rates between adult and infant human remains to a pig model and found no significant difference in the composition of the insect communities in human and pig carcasses (Campobasso et al. 2001). Therefore, twenty-two kg pigs have been recommended as suitable human models for adult decomposition (Catts and Goff 1992).

Current Status of Forensic Entomology

The popularity of television shows such as C.S.I. (Crime Scene Investigation), Forensic Files, and Court TV have created a recent surge of interest in the forensic sciences. Several colleges report long waiting lists for forensic science courses, and dozens of others are developing courses or entire programs in the science of crime fighting (Lewerenz 2003). Purdue University instituted its first forensic science course in the fall of 2003, formatted by Neal Haskell and Ralph Williams. Assuming that the course would not generate much enthusiasm, a 25-student capacity room was assigned

for the class. Once fall registration was completed, the room had to be changed to a lecture hall to accommodate the 425 students who registered for the class (Haskell 2003, personal communication).

Lord and Stevenson's 1986 directory (the only one ever published) of forensic entomologists listed only 62 scientists involved in this field of study; of the 62, only about a third were linked solely with the "medicolegal" subdiscipline (Catts and Haskell 1990).

In 1996, the American Board of Forensic Entomologists was created. Currently, there are only 8 members. However, forensic entomologists have no special group within the American Academy of Forensic Science or the Entomological Society of America.

The European Association for Forensic Entomology was created in May, 2002, at the First European Forensic Entomology Seminar, held at the headquarters of the National Gendarmerie in Rosny sous Bois, France. This association was created to promote forensic entomology in Europe (Hall 2003). In August, 2003, the first annual meeting of the American Association of Forensic Entomologists was held in Las Vegas, NV; approximately 45 people attended the meeting. The second annual meeting is scheduled for July 24-27, 2004 and will be conducted at the University of California-Davis.

The highly specialized field of forensic entomology has never had a large following. Several reasons may explain this lack of interest, including:

- It involves having a close relationship with the larval stages of flies, commonly known as maggots. Most people think that these creatures, along with insects in general, are disgusting.
- Only a small number of colleges or universities offer a course in the specific field of forensic entomology, and none offer majors or minors.

- Historically, there has been little opportunity for full-time employment in this field.

Biology of Calliphoridae

Two major groups of insects are predictably attracted to cadavers and provide the majority of information in forensic investigation; the flies and the beetles (Castner 2001). This research focused on the Family Calliphoridae, commonly called the blow flies (blowflies if you live outside the USA), which are the first insects to find and colonize human corpses. Experimental studies indicate that these flies arrive at carcasses within minutes of their exposure (Byrd and Castner 2001b, Watson and Carlton 2003).

There are more than 1000 species of blow flies throughout the world; about 90 species exist in North America (Haskell 2003, personal communication). This family includes the green bottle flies (genus *Phaenicia*), blue bottle flies (genus *Calliphora*), the screwworm flies (genus *Cochliomyia*) and the black blow flies (tribe Phormiini). According to (Hall 1948), “to blow” is an ancient term that refers to depositing of eggs. The family name means ‘beauty bearer’ in Greek (Greenberg and Kunich 2002).

Common blow flies carry at least 2,000,000 bacteria per specimen externally. Internally, each individual fly can carry from eight to ten times as many (Hall 1948). They can carry typhoid, cholera, the plague, anthrax, tuberculosis, tularemia, trypanosomes, leishmanias and can cause primary, secondary and tertiary myiasis (infestations of human skin).

Some species of blow flies, such as *Phaenicia sericata*, are used for cleaning of non-healing wounds. This healing method is called “maggot therapy” and has been in use for hundreds of years (Sherman and Pechter 1988). Sterile maggots debride the wounds by eating necrotic tissue. Urea, ammonium carbonate and allantoin secreted by the larvae disinfect deep tissue wounds and healing is stimulated. Maggot therapy is appropriate for

cases where antibiotics are ineffective and surgery is impracticable (Sherman and Pechter 1988).

Calliphorid flies have highly specialized sense organs on their antennae that are stimulated by putrefaction odors and gases which are released during post-mortem decomposition of organic matter. Some species of *Phaenicia* are attracted to various organic sulphur compounds, either alone or in combination with hydrogen sulphide, and also by ammonia (Cragg 1956, Cragg and Cole 1956, Ashworth and Wall 1994, Wall and Warnes 1994). Flight traps baited with dimethyl trisulphide are strong attractants for some calliphorids (Nilssen et al. 1996). Odors from *Proteus mirabilis* Hauser, a bacterium that causes infections in the fleece of sheep, are attractants to some calliphorid flies (Morris et al. 1998).

Some plants have developed a pollination strategy that targets calliphorid flies. The dead-horse arum (*Helicodiceros muscivorus* L. fil.) floret emits an odor that smells like a dead animal. Blow flies are deceived into pollinating the plant. The volatile compounds of the dead-horse arum and of a carcass were identified by gas chromatography as three structurally similar oligosulphides: dimethyl mono-, di- and trisulphide. When calliphorid flies were exposed to each of the odors, identical antennal response patterns were elicited (Stensmyr et al. 2002).

Landing behavior of calliphorids may be affected by visual cues such as white and yellow colors (Wall et al. 1992, Hall et al. 1995). Oviposition is elicited primarily by the presence of ammonia-rich compounds, moisture, pheromones, and tactile stimuli (Ashworth and Wall 1994) yet is rarely stimulated by chemicals alone (Cragg 1956).

Unfortunately, the complex interaction of semiochemical and visual cues used for resource location remains little studied in calliphorids (Wall and Fisher 2001).

Blow flies are heliotropic and usually rest at night. Eggs are not usually laid at night although clearly there are exceptions. Green (1951, page 484) observed that *Calliphora* deposited eggs at night under artificial light in slaughter houses. He wrote that "under laboratory conditions it has been found that *Calliphora erythrocephala* (now called *C. vicina*), *Lucilia sericata* and *Phormia terrae-novae* will all oviposit in total darkness, although Wardle (1921) asserts that blowflies do not oviposit in the complete absence of light. Greenberg (1990) observed that *Phaenicia sericata*, *Phormia regina* (Meigen) and *Calliphora vicina* (Robineau-Desvoidy) oviposited a very small number of eggs on rat carrion at night. Singh (2001) pointed out that the flies in Greenberg's experiment probably were resting on a nearby bush and literally crawled over to oviposit on the rat carrion, thus indicating that blow flies were not actively searching for an oviposition site. Nocturnal oviposition has not been observed in large-scale studies in other areas (Greenberg 1990, Byrd and Butler 1997, Haskell et al. 1997).

Other factors that affect blow fly activity are temperature, size of the carcass, geographical location, humidity, light and shade, seasonal and daily periodicity, availability of food and competition, maggot mass temperature and manner of death (Rodriguez and Bass 1983).

Insect Succession on Carrion

The first organisms to arrive on a body after death are usually the insects. They arrive at predictable times during the decomposition process. Each decomposition stage is attractive to a different group of sarcosaprophagous arthropods. Smith (1986, page 13), in

A Manual of Forensic Entomology, defines four ecological categories in the carrion community:

1. Necrophagous species:	Feed on the carrion itself and constitute the most important category in establishing time of death, e.g., Diptera: Calliphoridae (blow flies); Coleoptera (beetles): Silphidae (in part), Dermestidae.
2. Predators and parasites:	Second most important forensic category, e.g., Coleoptera: Silphidae (in part), Staphylinidae; Diptera: some carrion feeders become predaceous in later instars, e.g., *Chrysomya* (Calliphoridae), *Ophyra* and *Hydrotaea* (Muscidae) on the necrophagous species.
3. Omnivorous species:	Wasps, ants and some beetles feed both on the corpse and its inhabitants.
4. Adventive species	Use the corpse as an extension of their environment, e.g. Collembola (springtails), spiders (which may become incidental predators).

Blow flies are attracted by the odors and gases which are released during the onset of autolysis and putrefaction, depending on time of year and situation of the corpse (Smith 1986). As decomposition proceeds, the odors emanating from the corpse change, making the cadaver more attractive to some species of blow flies and less attractive to others. Once the dry decay stage has been reached, blow flies are no longer attracted to the corpse (Nuorteva 1977, Anderson 2001). After the invasion of North America by the Chrysomyinae in the 1980's, the blow fly sequence in North America may be *Phaenicia*, *Cynomyopsis*, *Chrysomyinae*, *Calliphora*, and *Cochliomyia* (Campobasso et al. 2001). Obviously, species lists will differ by region.

Beginning with Mégnin's (1894) work, eight waves of arthropod invasion on human bodies have been described. Other forensic entomologists reduced the number of stages in attempts to define biological communities, but ultimately this reduction complicated and lessened the forensic applicability. Payne (1965) defined the associated

insect community and analyzed the percentage abundance of species attracted to the various stages of decay. He condensed eight to six stages of decay: fresh, bloated, active, advanced, dry and remains. Lord and Burger (1984a) and Bornemissza (1957) recognized five stages of carcass decomposition. According to Smith (1986, page 17), there exists a broad general agreement in the observations of Mégnin, Bornemissza (1957), Reed (1958) and the series of publications by Payne (1965) and (Payne 1965, Payne and King 1970) as follows:

1. Initial decay stage (0-2 days). Carcass appears fresh externally but is decomposing internally due to the activities of bacteria, protozoa and nematodes present in the animal before death.
2. Black putrefaction stage (12-20 days). Flesh of creamy consistency with exposed parts black. Body collapses as gases escape. Odor of decay very strong.
3. Butyric fermentation stage (20-40 days). Carcass drying out. Some flesh remains at first and cheesy odor develops. Ventral surface of body moldy from fermentation.
4. Dry decay stage (40-50 days). Carcass almost dry; slow rate of decay.

The aforementioned stages of decay are not easy to delineate and there is controversy regarding these definitions, but they are useful in describing the sequence of decomposition. For example, the number of days varies considerably with temperature.

Factors that Affect Blow Fly Succession on Carrion

Temperature and access to a body are the two most important factors affecting insect succession. Temperature is the most important variable influencing the rate of maggot development. High temperatures generally reduce development time of Diptera. Large aggregations of dipteran larvae (maggot masses) develop heat due to their frenetic activity and fast metabolism, thus raising the microenvironmental temperature (Campobasso et al. 2001). The heat of the maggot mass is related to the density of the mass and the size of the carcass (weight and mass). The size of maggot masses and the

degree to which the corpse is either exposed to, or insulated from, the environment affects the amount of heat absorbed or dissipated, which in turn has a significant effect upon the rate of larval development and the decomposition of a corpse. Goodbrod and Goff (1990) studied the effects of maggot-generated heat during the development cycle in experimental cultures of *C. megacephala* and *C. rufifaces* and found an inverse relationship between density and the duration of larval stage.

The insects that colonize corpses vary in species depending on the biogeoclimatic zone in which the remains are found. Each zone has different habitat types, vegetation, soil pH, soil type, flora and fauna, altitude and climatic conditions that affect the species of insects present. Decomposition also is affected by the time of year, and the location in which remains are found (Anderson 2001).

Many blow fly species vary in abundance depending on season and even time of day. Presence or absence of sunlight or shade can have an effect on which blow fly species will colonize a corpse. Cragg (1956) demonstrated that *P. sericata* prefer heated surfaces and will not oviposit on carcasses that have surface temperatures below 30° C. Results of a sun-exposed versus shaded pig carrion study indicated that more *Lucilia illustris* (Meigen) and *Phormia regina* (Meigen) were observed at the sun-exposed pig whereas *Calliphora vomitoria* (Linnaeus) were observed in greater numbers at the shaded pig (Shean et al. 1993).

Blow flies can be found in both urban and rural areas but some species may be found only in wooded areas. Flies primarily associated with human refuse (synanthropy) are usually found in urban areas. Presence of certain species of blow flies found on a body may indicate that the body was moved from an urban to a rural environment or vice

versa (Erzinclioglu 1985, Catts and Haskell 1990). Blow flies are capable of colonizing corpses inside dwellings and cars, depending upon how well they are sealed.

Competition for the food source is the most important factor affecting size and completion of the life history of carrion. Smith (1986, page 34) listed ways in which this occurs:

1. Intraspecific competition may reduce the size of the larvae and can reduce the number and fecundity of individual adults
2. Interspecific competition has similar results as to intraspecific competition, plus a possibility of total elimination
3. Predators and parasites-selective predation or parasitization of one species can be advantageous to a competing species.

The early arrivers (such as *Calliphora* and *Phaenicia*) at a corpse may have an advantage. Some female blow flies (Tribe Calliphorini) are capable of moving a single egg from one of the ovaries into the vagina (termed "precocious egg development") where it is fertilized before an oviposition site has been found (Wells and King 2001). Delayed arrivers such as *Chrysomya* may compensate for this by being viviparous and deposit larvae on the carcass. Some dipteran larvae begin life as carrion feeders and become predators after the second molt.

Biology of Human Decomposition

Campobasso et al. (2001, page 18) describe the decomposition of corpses as

> a mixed process ranging from autolysis of individual cells by internal chemical breakdown, to tissue autolysis from liberated enzymes and from external processes introduced by bacteria and fungi from both the intestine and outer environment. The bacterial enzymatic structures cause putrid liquefaction of tissues by the breakdown of proteins, carbohydrates and lipids into their basic components (amino acids, water and carbon dioxide, fat acids and volatile substances) with gas formation (nitrogen, methane, hydrogen sulphide, ammonia, etc.). As the tissues are digested to a fluid consistency with the production of large amounts of foul-smelling gas; they become moist and gas-ridden, and eventually liquefy down to the skeleton.

Calliphorid larvae hasten tissue decay by dissemination of bacteria. The larvae also have digestive enzymes in their saliva that liquefy carcass tissues. As the larvae burrow into and consume the carcass, tissues further disintegrate (Easton and Smith 1970).

Usually, tissues that conduct the highest rates of ATP synthesis, biosynthesis, and membrane transport decompose first. The intestines begin to decompose first, followed by the stomach, accessory organs of digestion, heart, blood and circulation, heart muscle, air passages and lungs, kidneys and bladder, brain and nervous tissues, skeletal muscles and finally, connective tissues and integument (Gill-King 1997).

Over a seven-year period, researchers at the Anthropology Research Facility (ARF—also known as The Body Farm) in east Tennessee studied 150 bodies in various stages of decay, including homicide victims, bodies donated to science, and unidentified persons. They found that variables affecting decay rates of human bodies are (in order of importance): temperature, access to the body by insects, burial and depth, carnivore and rodent activity, trauma (penetrating/crushing), humidity, rainfall, size and weight of the body, embalming, clothing, type of surface body was placed on and the soil pH (Mann et al. 1990).

Further Areas for Study

Entomological studies of Calliphoridae associated with carrion should include investigations of seasonal changes in the fauna and successional events which are influenced by weather factors. Data are needed from different geographic regions including species composition of sarcosaprophagous arthropods and the weather parameters associated with those fauna (including their maximum/minimum threshold

temperature data). Reliable taxonomic keys are needed for identification of early larval instars and of puparia.

The assessment of species composition within rural north-central Florida is addressed in the present study by determining the calliphorid species associated with carrion in north-central Florida and the influence of seasons on the calliphorid species assemblage. The objectives of the study were:

1. To identify the species of Calliphoridae associated with pig carrion in rural north-central Florida.
2. To determine how season (spring, summer, fall and winter) affects the assemblage of calliphorid species associated with pig carrion in rural north-central Florida.
3. To determine the daily succession of calliphorid species associated with pig carrion during each collection period in rural north-central Florida.

CHAPTER 2
MATERIALS AND METHODS

The use of human corpses for field studies is illegal in Florida. As determined in other decomposition studies (Haskell 1989, Anderson and VanLaerhoven 1996, Campobasso et al. 2001) the rate of pig decomposition is very similar to that of humans. Dead pigs, *Sus scrofa* L., were used as animal models for this study.

All pigs were purchased from North Florida Livestock Market, Lake City, Florida. Prior to purchase, the pigs were killed by a lateral, transverse shot into the top of the head with a .22 caliber rifle. This method resulted in instant death of the animal. Each dead pig was immediately double-bagged in a heavy-duty plastic trash bag and was transported from Lake City to the Greathouse Butterfly Farm in Earleton, Florida.

Study Site

Greathouse Butterfly Farm is located 19.3 km east of Gainesville, near Earleton, on the southeast corner of N.E. SR 26 and SR1469. The property consists of 48.6 hectares of north Florida flatwoods (Figure 2-1). Pig carcasses were placed in a wooded habitat where sunlight was somewhat restricted. In some cases, the pigs received direct sunlight during certain parts of the day, while at other times they were shaded. The study site mainly consisted of a moderate stand of live oak, *Quercus virginiana* Mill., and slash pine, *Pinus elliottii* Engelman, with an understory of various saw palmettos and grasses (Florida Chapter 1989).

Pigs were placed at least 18.3 meters apart. Wire cages (86.5 cm long x 50.8 cm wide x 61 cm high) were placed over the pigs to protect them from large vertebrate

scavengers. The cages were constructed of wire mesh (5 cm x 5 cm). At least four metal or plastic tent stakes were driven into the ground around the cage, and bungee cords were attached tightly to the cages and then to tent stakes to minimize disturbance (Figure 2-2). The cages were lifted off and set aside during sampling times.

Data Collection

Trials were conducted from October 14, 2001 to March 5, 2004; however, data from October 2001 were incomplete and therefore not included. The raw data, starting with the second collection on November, 2001, are in appendices A and B. Each trial consisted of 3-4 pigs, with trials conducted throughout the year (Table 2-1). Observations and collections were made daily during the afternoon, if possible, when flies were most active. The duration of each trial lasted until the first wave of maggot dispersal occurred (termed “maggot migration” by forensic entomologists). After the third-instar larvae have reached a certain size, they leave the carcass en mass to pupariate in the soil. The pigs were not moved or disturbed in any way during the study. Digital pictures of the pigs and of the expanding maggot masses were taken at each collection time. At the beginning of each collection time, a laminated identification sheet was placed in front of each pig, indicating the date, time and identification number. A meter-stick was placed below the identification sheet to give document size. Sampling usually occurred in the middle of the afternoon when the adult flies were most active.

Protocol for Day 1

On day 1, the pigs were removed from bags and placed in a location on the site, and the GPS (global positioning system) was noted. After all the pigs were in position, data were collected including pig number, time of death (TOD), date, time, sample number (SA#), ambient temperature (AT^{o}), ground/pig interface temperature (GPI), ground

temperature at 5 cm depth about 3 m from the pig, a brief description of the weather (sunny, cloudy, rain, etc.) and wind velocity in meters per second (M/S).

An aerial collection of adult flies was made over each pig with an insect net, with a target of at least 10 adult calliphorid flies (although this was not always possible to achieve). Flies were placed in vials with 70% isopropyl alcohol and later pinned and identified. A data logger (Figure 2-3) was affixed to a nearby tree or bush and the temperature probe was placed on the ground 1-2 m from each pig. Therefore, the ground temperature being recorded was similar to that which the pig was exposed.

Protocol for Day 2 Onward

Adult flies were sampled with a net (if possible) and paired samples of approximately 50-500 larvae (L = live, P = preserved) were collected from the growing maggot mass, usually located on the head. The location where the sample was taken on the body area (or ground area) was noted on the collection sheet. About half of the sample specimens were boiled in water for about 2 minutes using a camp stove, and then placed in vials with 70% isopropyl alcohol for preservation. The remainder of larvae were placed in containers and reared to the adult stage in order to compare the identity and relative abundance of adult and larval flies.

Meteorological Measurements

Temperatures determined with a Taylor 9841 digital thermometer (Forestry Suppliers, Jackson, MS) shielded from direct rays of the sun (when necessary) include ambient air, ground/pig interface, external tissue, oral cavity of the pig, soil at 5 cm depth 3 m from the pig, and soil at 5 cm depth under the maggot mass. Maggot mass temperatures were taken (MM Tº) but will not be addressed in this thesis. Ground temperatures were taken with HOBO® (Onset Computer Corp., Bourne, MA) data

loggers. These units were not 100% waterproof, so a plastic housing was made for each of the loggers (Figure 2-3). Three hangars were cut and cemented with marine glue into one end of each container. A hole was drilled at the bottom of the container (for the temperature probe cable) and foam was packed around each logger. The HOBO® unit was set to record temperature every 30 minutes for 3 weeks. A temperature probe connected to each logger was set on the ground within 1-2 m of each pig (Figure 2-4).

Table 2-4 lists the mean temperatures that were taken during the collection intervals during the months of the project. The mean temperatures were taken with the Taylor thermometer during the collection times. The temperature at 3:56 AM, taken from the data logger's data, was used as the mean low temperature (Figures 3-5 A and B). There was no solar interference at this time. For collections 2 and 3, the data logger was not used and the mean low temperatures were taken from the NOAA (National Oceanic and Atmospheric Administration) daily data available for Gainesville Regional Airport.

Rearing Procedures

Maggots were removed from the carcass with a plastic spoon and placed immediately into rearing pouches constructed from aluminum foil (Catts and Haskell 1990) and placed into Rubbermaid 28 L or plastic Gladware containers half-filled with substrate for pupation. The container lids each had approximately ten 2-mm holes randomly drilled for air circulation. A paper towel was placed under each lid to prevent larvae/adult flies from escaping through lids and also to prevent other flies from getting into the containers.

Each foil pouch was filed with 100-200 g of calves' liver, which served as food. The containers of live maggots were kept outside—except when temperatures were below 4.5ºC—on shelving placed in a screened enclosure. The maggots were checked

daily. Once the maggots migrated off the liver, the pouch was removed from the container. On occasion, the maggots would not move out of the foil pouch. When this occurred, a small amount of fresh liver was placed directly onto the substrate, and the maggots were gently moved from the foil pouch onto the liver. The liver would be removed a day or two later after the maggots migrated into the substrate to pupate.

At adult emergence, the containers were placed into the freezer for 15 minutes to kill the flies. Adults were put in labeled vials of 70% isopropyl alcohol, then later pinned and identified (White et al. 1940, Dodge 1953, Seago 1953, Furman and Catts 1982, Wells et al. 1999). The preserved maggots were separated into first, first-second transitional, second, second-third transitional and third instars. Only third-instar larvae were identified to species because there are no reliable taxonomic keys for first- and second-instar calliphorid larval identification. Gary Steck, dipterist at Florida Division of Plant Industry (DPI, Department of Agriculture and Consumer Services, Gainesville, FL), verified the identifications of representative samples of the flies. All data were entered into a Microsoft Office XP Excel version 2002 spreadsheet (Microsoft Corp.). The percentages of adult and larval specimens were transformed to their square roots to run the Pearson's correlation analysis. The raw data are presented in Appendices 1 and 2. Voucher specimens are being kept in lab 2209 at the University of Florida Department of Entomology and Nematology and will be deposited with the museum at DPI.

Pupation Substrate

Pupation substrate consisted of about 90% dried laurel oak leaves (*Quercus laurifolia* Michx.) and branches, 2 % rye grass (*Lolium perenne* Lam.) cuttings, 8 % magnolia leaves (*Magnolia grandiflora* L.), and a minute amount of sandy soil. The plant mixture was ground up with a Troy-Bilt® Model 4731-10 HP chipper/shredder with a

mulching blade. The substrate was stored in a 200 L (liter) Rubbermaid trash container with a tight fitting top. On most occasions, larvae that migrated into the substrate successfully produced adults in containers half-filled with substrate. On a few occasions (less than 3), no adults were obtained due to mortality from fungi. No information is available; however, on the proportion of pupae that successfully reached adulthood.

Figure 2-1. A caged pig carcass is shown at Greathouse Butterfly Farm property in Earleton, Florida.

Figure 2-2. Wire cage with bungee cords and tent stakes hammered into the ground. The cage protected the carcass from scavengers.

Figure 2-3. A HOBO ® temperature data logger is sealed inside a Gladware container. Data loggers (one for each pig) were used to obtain ground temperatures near pig carcasses at Greathouse Butterfly Farm, Earleton, Florida.

Figure 2-4. The data logger was hung from bush at left and temperature probe was placed on the ground (circled) to record ground temperature near the pig carcass in Earleton, Florida.

Table 2-1. Dates of pig deposition, approximate pig weight, and time each pig was placed on site for sampling dates from November, 2001 to October, 2002.

Date of Pig Deposition	Approx. pig weight (kg)	Number of pigs per date	Approx. deposition time (h)
15-Nov-2001	20	3	1730
23-Dec	20	3	1500
1-Feb-2002	25	4	1530
15-Mar	24	4	1545
29-Apr	30	4	1445
20-May	32	4	1630
22-Jul	20	4	1550
19-Aug	30	4	1445
23-Sep	20	4	1450
24-Oct	20	4	1730
27-Nov	23	4	1500
30-Dec	25	3	1530
28-Feb-2003	21	3	1545
31-Mar	19	4	1445
25-Apr	28	3	1630
12-Jun	22	3	1550
8-Dec	28	3	1440
23-Jan-2004	15	3	1545
5-Mar	28	2	1530

Table 2-2. Mean temperatures (± SD) during the study at the Earleton, Florida site. Mean temperatures were taken during collection times with the Taylor digital thermometer while facing away from sun. Mean low temperatures were taken from the HOBO ® data at the 3:56 AM mark. November 2001 through January 2002 temperature data were obtained from National Oceanic and Atmospheric Administration.

	Mean Temp. ° C	±SD	Mean Low Temp.° C	±SD
Nov. 16-21, 2001	23.6	1.1	5.2	2.8
Dec. 29, 2001-Jan.11, 2002	20.2	3.2	0.9	5.8
February 5-9, 2002	19.9	4.1	8.1	4.5
March 15-19, 2002	30.4	1.2	16.5	3.0
April 29 -May 1, 2002	32.8	1.1	19.4	1.5
May 20-23, 2002	25.9	0.9	17.4	3.2
July 22-25, 2002	33.2	1.3	22.4	0.7
Aug. 19-23, 2002	30.5	2.9	23.9	1.3
September 23-27, 2002	29.3	3.2	23.7	1.7
October 26-28, 2002	28.4	2.2	19.1	0.5
Nov. 30-December 14, 2002	16.8	4.0	9.7	4.3
December 30, 2002-January 11, 2003	17.0	3.3	5.7	5.2
March 2-8, 2003	22.1	6.2	16.9	3.5
April 1-6, 2003	25.0	5.6	10.8	5.9
April 26-May 1, 2003	27.4	3.9	18.4	1.1
June 12-15, 2003	30.3	1.3	23.0	1.1
Dec. 8-20, 2003	17.4	3.4	9.4	4.0
January 23-31, 2004	18.9	4.5	8.9	5.6
March 5-14, 2004	24.5	4.6	13.3	5.4

CHAPTER 3
RESULTS

Species of Calliphoridae Collected on Pig Carrion

The seven species of Calliphoridae collected on pig carrion between November 16, 2001 and March 14, 2004 in rural north-central Florida were *Phaenicia coeruleiviridis* (Macquart), *Cochliomyia macellaria* (Fabricus), *Chrysomya rufifaces* (Macquart), *Phormia regina* (Meigen), *Chrysomya megacephala* (Fabricus), *Calliphora livida* Hall, and *Calliphora vicina* Robineau–Desvoidy (= *C. erythrocephala* Meigen) (Figure 3-1).

Assessment of the fly assemblage by three collection methods (aerial collection of adults, adults reared from larvae, and preserved larvae) produced similar results (Figure 3-1). Pearson's correlation analysis of aerial collections made when adult flies were most active (usually during the early afternoon) indicated a high degree of correlation with maggot abundance for the same time period. The analysis of aerial and reared specimens indicated a high degree of correlation (r = 0.9512, 95% confidence interval = 0.6981 to 0.9930, two-tailed P= 0.0010). The analysis of aerial and preserved specimens (r = 0.9744, 95 % confidence interval 0.8315 to 0.9964, two-tailed P = 0.0002) also indicated a high degree of correlation. Finally, the analysis of reared and preserved specimens (r = 0.9783, 95% confidence interval 0.8557 to 0.9969, two-tailed P = 0.0001) indicated a high degree of correlation. It is much easier to catch adult flies than it is to rear larvae, so an aerial sample taken during the middle of the day represents a good estimation of species present, although, in practice, both adults and larvae should continue to be collected for legal reasons.

Preserved larvae collected during the study were identified and counted by instar. Examined through a microscope, each of the different instars is easily recognizable. First-instar larvae have Y-V shaped spiracular slits (Figures 3-2 A and B). First-second transitional instars have a second set of spiracles behind the Y-V slits (Figure 3-3). The second-instar larvae have two inner spiracular slits (Figure 3-4). The second-third transitional instars have two sets of spiracular slits (Figure 3-5), and the third instars have three inner spiracular slits (Figure 3-6). *Chrysomya rufifaces* larvae are recognizable without the aid of a microscope; they have rows of conspicuous tubercles (Figure 3-7). *Chrysomya megacephala* larvae have a distinguishing accessory oral sclerite, but none were collected in this study. A total of 23,960 larvae were collected. Of these, 8253 were third-instar larvae and their relative abundance was: *P. coeruleiviridis*, 76.5%; *C. macellaria*, 7.3%; *C. rufifaces*, 9.1%; *P. regina*, 6.8%; and 0.3% were unknown (Figures 3-1 and 3-8).

Seasonal Distribution and Succession of Calliphoridae Species

Adult calliphorids collected and reared in year 1 (N=3197) and year 2 (N= 3992) are shown in Figures 3.9 and 3.10, respectively. Differences in seasonal phenology are evident (spring is March 20 to June 20; summer is June 21 to September 21; fall is September 22 to December 20; winter is December 21 to March 19). The mean temperatures taken during afternoon samples and the mean low temperatures for year 1 and year 2 of the study are in Figures 3-11 A and B. Two species, *Calliphora livida* and *Calliphora vicina*, were found only during the winter, from mid-December to mid-March (Figs. 3-9 and 3-10). One species, *Chrysomya megacephala*, was found only in the summer, from mid-June to late-September (Figs. 3-9 and 3-10). *Cochliomyia macellaria*, *C. rufifaces* and *P. regina* and others were not found during the winter (Figs. 3-9 and 3-

10). *Phaenicia coeruleiviridis* generally were found in great abundance year round, but were lower in abundance during the summer (Figures 3-9 and 3-10).

Different species of calliphorid flies arrived at the pig carrion at different stages during the decomposition process. Within minutes of removing the pig from the plastic bag and placing it on the ground *P. coeruleiviridis* usually began to arrive. *Cochliomyia macellaria, C. rufifaces, P. regina, C. livida* and *C. vicina* arrived at the carcass after a delay of about 24 hours.

The data below are discussed in terms of total insects collected, reared, or preserved per collection interval. The figures are shown graphically in an effort to evaluate succession.

Collection 1, November 16-21, 2001

No adult calliphorids were aerially collected. Of the total reared adults (N=232), 94% were *P. coeruleiviridis,* 5.6% *C. rufifaces* and 0.4% were *C. macellaria* (Figure 3-12 A). One hundred percent of the preserved third-instar larvae (N=30) were *P. coeruleiviridis* (Figure 3-12 B).

Collection 2, December 29, 2001-January 11, 2002

No adult calliphorids were aerially collected. Of the total reared adults (N=362), 99.4 % were *P. coeruleiviridis,* while *C. livida* and *C. vicina* each comprised of 0.3% (Figure 3-13 A). Preserved larvae (N=568) consisted of 79.8% *P. coeruleiviridis,* 18.0% *P. regina,* and 2.3% were unknown (Figure 3-13 B).

Collection 3, February 5-9, 2002

One hundred percent of the adults aerially collected (N=39) and adults reared (N=305) were *P. coeruleiviridis* (Figures 3-14 A and B). Preserved larvae (N=151) consisted of 70.9% *P. coeruleiviridis* and 29.1% *P. regina* (Figure 3-14 C).

Collection 4, March 15-19, 2002

Adults aerially collected (N=71) consisted of 97.2% *P. coeruleiviridis* and 2.8% *P. regina* (Figure 3-15 A). Of the reared adults (N=326), 100% were *P. coeruleiviridis* (Figure 3-15 B). Preserved larvae (N=134) consisted of 97.8% *P. coeruleiviridis* and 2.2% were unknown (Figures 3-15 C).

Collection 5, April 29-May 1, 2002

Adults aerially collected (N=107) consisted of 86.0% *P. coeruleiviridis*, 0.9% *C. macellaria* and 13.1% *P. regina* (Figure 3-16 A). Of the reared adults (N=332), 90.1% were *P. coeruleiviridis*, 2.7% were *C. macellaria* and 7.2% were *P. regina* (Figure 3-16 B). Preserved larvae (N=196) consisted of 100% *P. coeruleiviridis* (Figure 3-16 C).

Collection 6, May 20-23, 2002

Figure 3-17 A illustrates successional data. Four species of calliphorids were captured on the first day. *Cochliomyia macellaria* was the most abundant species, but apparently they were not depositing eggs on the first day because the larvae collected on day 3 were 100 % *P. coeruleiviridis*. The abundance of *P. coeruleiviridis* declined (adults and larvae) as decomposition progressed. The abundance of *C. rufifaces* remained about equal, but *P. regina* increased in abundance as decomposition progressed. Aerially collected specimens (N=51) consisted of 17.6% *P. coeruleiviridis*, 39.2% *C. macellaria*, 21.6% *C. rufifaces* and 21.6% *P. regina* (Figure 3-17 A). Of the reared adults (N=67) and preserved larvae (N=175), 100% were *P. coeruleiviridis* (Figures 3-17 B and C).

Collection 7, July 22-25, 2002

Figures 3-18 A-C illustrate successional data. *P. coeruleiviridis* was the most abundant calliphorid present on day 1 and declined in abundance as decomposition progressed while *C. macellaria, C. rufifaces*, and *P. regina* arrived in fewer numbers on

day 1 but increased in abundance as decomposition progressed. *Chrysomya megacephala* arrived when the carcass was in the active decay state on day 3. Adults aerially collected (N=99) consisted of 58.6% *P. coeruleiviridis*, 5.1% *C. macellaria*, 31.3% *C. rufifaces*, 2.0% *P. regina*, and 3.0% *C. megacephala* (Figure 3-18 A). Of the reared adults (N=223), 47.1% were *P. coeruleiviridis* and 52.9% were *C. rufifaces* (Figure 3-18 B). Preserved larvae (N=700) consisted of 31.6% *P. coeruleiviridis* and 68.4% *C. rufifaces* (Figure 3-18 C).

Collection 8, August 19-23, 2002

Figures 3-19 A-C illustrate successional data. *Phaenicia coeruleiviridis* was the most abundant species for the first 2 days but decreased in abundance as decomposition progressed. *Chrysomya rufifaces* and *C. macellaria* did not arrive at the carcass until day 2 (Figure 3-19 A), but increased in abundance as decomposition progressed. *Chrysomya megacephala* arrived when the carcass was in the active decay state, after 3 days. Adults aerially collected (N=118) consisted of 67.8% *P. coeruleiviridis*, 6.8% *C. macellaria*, 23.7% *C. rufifaces*, and 1.7% *C. megacephala* (Figure 3-19 A). Of the reared adults (N=248), 43.1% were *P. coeruleiviridis*, 1.2% *C. macellaria*, 42.3% *C. rufifaces*, and 13.3% *C. megacephala* (Figure 3-19 B). Preserved larvae (N=499) consisted of 83.0% *P. coeruleiviridis*, 0.4% *C. macellaria*, 13.6% *C. rufifaces*, 2.8% *P. regina*, and 0.2% were unknown (Figure 3-19 C).

Collection 9, September 23-27, 2002

Figures 3-20 A-C illustrate the successional data. *Phaenicia coeruleiviridis* was the only calliphorids species collected on day 1 and abundance declined as decomposition progressed. *Cochliomyia macellaria* and *C. rufifaces* arrived at the carcass on day 2, and increased in abundance as decomposition progressed. *Chrysomya megacephala* adults

were reared from the September 26 larval sample, but no adults were aerially collected (Figure 3-20 B). Adults aerially collected (N=76) consisted of 44.7% *P. coeruleiviridis,* 34.2% *C. macellaria,* and 21.1% *C. rufifaces* (Figure 3-20 A). Of the reared adults (N=323), 54.2% were *Phaenicia coeruleiviridis,* 30.7% *C. macellaria,* 1.2% *C. rufifaces,* and 13.0% *C. megacephala* (Figure 3-20 B). Preserved larvae (N=697) consisted of 66.1% *P. coeruleiviridis,* 21.5% *C. macellaria,* 11.3% *C. rufifaces,* and 1.0% *P. regina* (Figure 3-20 C). No P. regina adults were aerially collected or reared (Figure 3-20 B).

Collection 10, October 26-28, 2002

Figures 3-21 A-C illustrate successional data. *Phaenicia coeruleiviridis, C. macellaria,* and *C. rufifaces* were collected on day 1. *Phaenicia coeruleiviridis* was not the most abundant species of adults on day 1, but was the most dominant species of larvae. Their abundance declined as decomposition progressed. Adults aerially collected (N=87) consisted of 12.6% *P. coeruleiviridis,* 35.6% *C. macellaria* and 51.7% *C. rufifaces* (Figure 3-21 A) . Of the reared adults (N=131), 52.7% were *P. coeruleiviridis,* 7.6% *C. macellaria* and 39.7% *C. rufifaces* (Figure 3-15 B). Preserved larvae (N=294) consisted of 59.2% *P. coeruleiviridis,* 8.8% *C. macellaria* and 32.0% *C. rufifaces* (Figure 3-21 C).

Collection 11, November 30-December 14, 2002

Phaenicia coeruleiviridis was the most dominant calliphorid species during this sampling period. Adults aerially collected specimens (N=60) consisted of 91.7% *P. coeruleiviridis,* 1.7% *C. macellaria,* 5.0% *C. rufifaces,* and 1.7% *P. regina* (Figure 3-22 A). Reared adults (N=351) consisted of 88.0% *P. coeruleiviridis* and 12.0% *P. coeruleiviridis,* 19.0% *C. macellaria* (Figure 3-22 B). Preserved specimens (N=1248) consisted of 99.8% *P. coeruleiviridis* and 0.2% *C. macellaria* (Figure 3-22 C).

Collection 12, December 30, 2002-January 11, 2003

Phaenicia coeruleiviridis was the most dominant calliphorid species during this sampling period. Adults aerially collected (N=56) consisted of 98.2% *P. coeruleiviridis* and 1.8 % *C. livida* (Figure 3-23 A). Reared adults (N=371) consisted of 99.2% *P. coeruleiviridis* and 0.8% *C. livida* (Figure 3-23 B). Preserved larvae (N=1248) were comprised of 99.8% *P. coeruleiviridis*, 0.2% *C. macellaria* and 1.0% were unknown (Figure 3-23 C).

Collection 13, March 2-8, 2003

Phaenicia coeruleiviridis was the most dominant calliphorid species during this sampling period. Adults aerially collected (N=66) consisted of 87.9% *P. coeruleiviridis*, 9.1% *P. regina* and 3.0% *C. livida* (Figure 3-24 A). Reared adults (N=166) consisted of 98.2% *P. coeruleiviridis* and 1.8% *P. regina* (Figure 3-24 B). Preserved larvae (N=340) consisted of 71.5% *P. coeruleiviridis*, 28.2% *P. regina* and 0.3% were unknown (Figure 3-24 C).

Collection 14, April 1-6, 2003

Figures 3-25 A-C illustrate successional data. *Phaenicia coeruleiviridis* was the most dominant calliphorid species for the first 4 days of the sample period but decreased in abundance as decomposition progressed. *Cochliomyia macellaria*, *C. rufifaces* and *P. regina* arrived after a delay of about 24 hours and increased in abundance as decomposition progressed. Adults aerially collected (N=247) consisted of 75.3% *P. coeruleiviridis*, 19.0% *C. macellaria* and 5.7% *P. regina* (Figure 3-25 A). Reared adults (N=229) consisted of 69.0% *P. coeruleiviridis*, 12.7% *C. macellaria*, 0.4% *C. rufifaces*, and 17.9% *P. regina* (Figure 3-25 B). Preserved larvae (N=301) consisted of 77.7% *P. coeruleiviridis*, 8.3% *C. macellaria* and 14.0% *P. regina* (Figure 3-25 C).

Collection 15, April 26-May 1, 2003

Figures 3-26 A-C illustrate successional data. *Phaenicia coeruleiviridis* was the most dominant calliphorid species for the first 4 days of the sample period but decreased in abundance as decomposition progressed. *Cochliomyia macellaria*, *C. rufifaces* and *P. regina* arrived after a delay of about 24 hours and increased in abundance as decomposition progressed. Adults aerially collected (N=185) consisted of 68.1% *P. coeruleiviridis*, 29.2% *C. macellaria*, 0.5% *C. rufifaces*, and 2.2% *P. regina* (Figure 3-26 A). Reared adults (N=359) consisted of 50.7% *P. coeruleiviridis*, 46.8% *C. macellaria*, 2.5% *P. regina* (Figure 3-26 B). Preserved larvae (N=651) consisted of 50.5% *P. coeruleiviridis*, 47.9% *C. macellaria*, 1.4% *P. regina* and 0.2% were unknown (Figure 3-26 C).

Collection 16, June 12-15, 2003

Figures 3-27 A-C illustrate successional data. *Phaenicia coeruleiviridis* was the most abundant species of adults aerially collected on the first 2 days of the sampling period, but *C. macellaria* was the most abundant species of calliphorid overall during the sampling period (Figure 3-27 A). Adults aerially collected (N=221) consisted of 37.1% *P. coeruleiviridis*, 56.1% *C. macellaria*, 2.3% *C. rufifaces*, and 4.5% *P. regina* (Figure 3-27 A). Reared adults (N=150) consisted of 6.0% *P. coeruleiviridis*, 64.7% *C. macellaria* and 29.3% *C. rufifaces* (Figure 3-27 B). Preserved larvae (N=388) consisted of 73.7% *P. coeruleiviridis*, 19.3% *C. macellaria*, 5.4% *C. rufifaces*, 1.3% *P. regina* and 0.3% were unknown (Figure 3-27 C).

Collection 17, December 8-20, 2003

Phaenicia coeruleiviridis was the most dominant calliphorid species during the sampling period (Figures 3-28 A-C). Adults aerially collected (N=186) consisted of

89.8% *P. coeruleiviridis*, 0.5% *C. macellaria*, 2.2% *C. rufifaces*, 6.5% *P. regina*, and 1.1% *C. livida* (Figure 3-28 A). Reared adults (N=266) consisted of 95.9% *P. coeruleiviridis*, 3.4% *C. rufifaces* and 0.8% *P. regina* (Figure 3-28 B). Preserved larvae (N=648) consisted of 90.4% *P. coeruleiviridis*, 1.2% *C. rufifaces* and 8.3% *P. regina* (Figure 3-28 C).

Collection 18, January 23-31, 2004

Figures 3-29 A-C illustrate the successional data. *Phaenicia coeruleiviridis* was the most abundant dominant species during the sampling period. *Phormia regina, C. megacephala* and *C. livida* arrived after a delay of about 24 hours. Adults aerially collected (N=220) consisted of 92.3% *P. coeruleiviridis*, 5.9% *P. regina*, 0.5% *C. megacephala*, 1.4% *C. livida* (Figure 3-29 A). Reared adults (N=294) consisted of 94.2% *P. coeruleiviridis* and 5.8% *P. regina* (Figure 3-29 B). Preserved larvae (N=347) consisted of 82.7% *P. coeruleiviridis* and 17.3% *P. regina* (Figure 3-29 C).

Collection 19, March 5-14, 2004

Figures 3-30 A-C illustrate the successional data. *Phaenicia coeruleiviridis* was the most abundant dominant species during the first few days of the sampling period, but decreased in abundance as decomposition progressed. *Cochliomyia macellaria* and *P. regina* arrived after a 24 hour delay and increased in abundance as decomposition progressed. Adults aerially collected (N=165) consisted of 45.5% *P. coeruleiviridis*, 6.7% *C. macellaria*, and 47.9% *P. regina.* (Figure 3-30 A). Reared adults (N=149) consisted of 33.6% *P. coeruleiviridis*, 0.7% *C. macellaria*, 65.8% *P. regina* (Figure 3-30 B). Preserved specimens (N=305) were comprised of 54.8% *P. coeruleiviridis*, 3.0% *C. macellaria* and 42.3% *P. regina* (Figure 3-30 C).

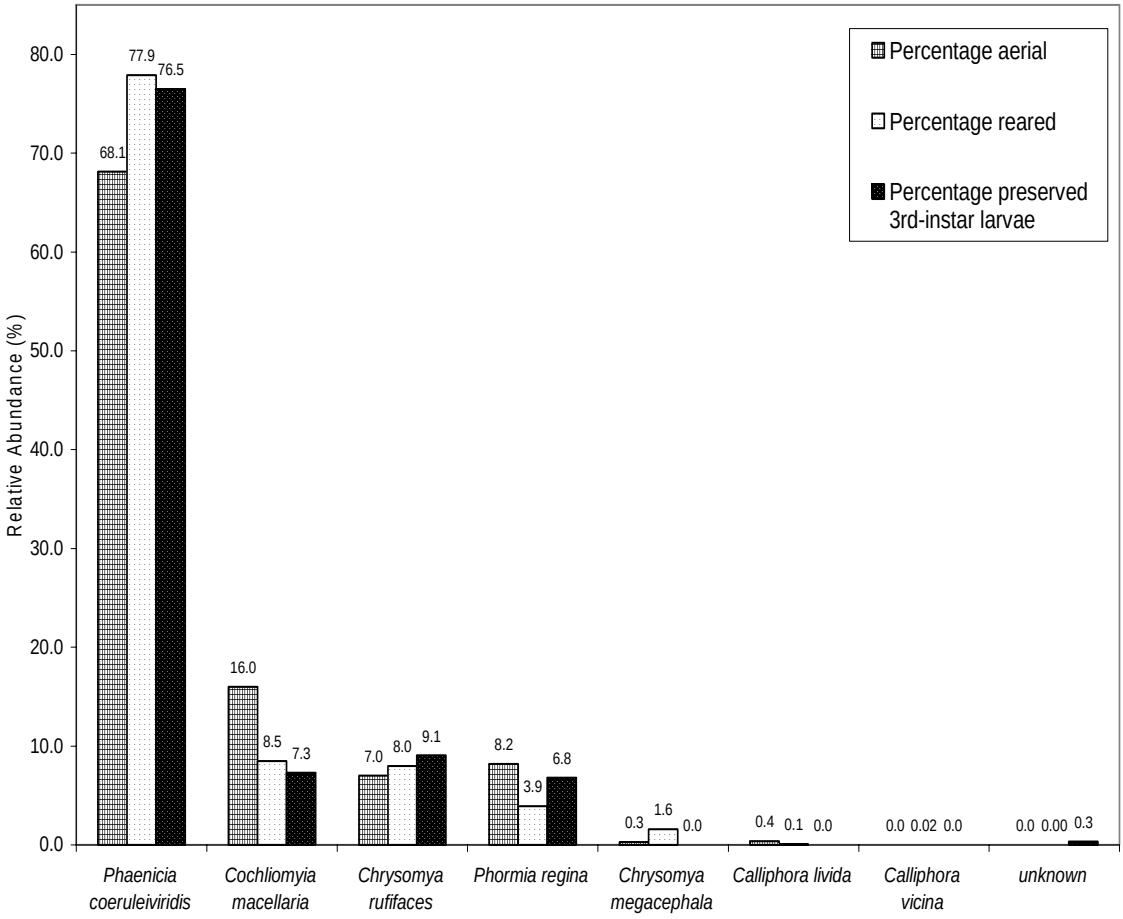


Figure 3-1. Relative abundance of calliphorid adults aerially collected, adults reared from larvae and preserved third-instar larvae collected from pig carrion during the entire study (N=15,396) between November 16, 2001 and March 14, 2004 in Earleton, Florida.

(A)

(B)

Figure 3-2. A calliphorid first-instar larva hatching from its egg, (A), and the tiny Y-V shaped spiracles of a first-instar larva (B).

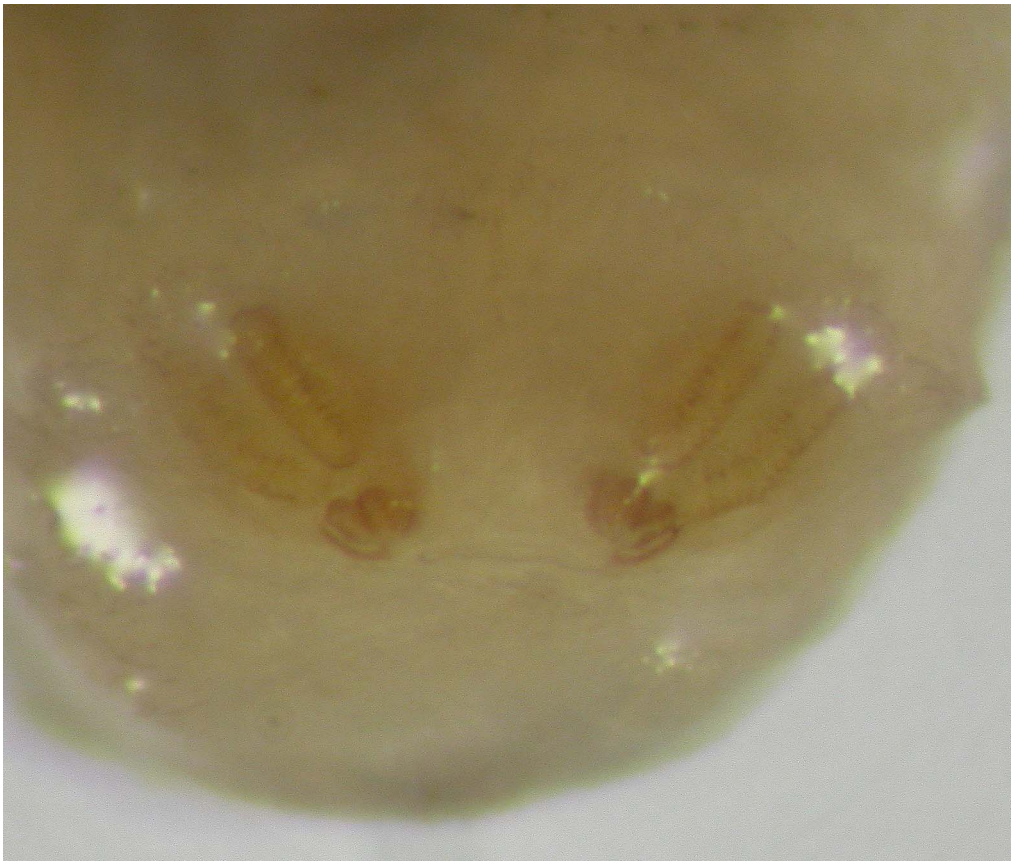


Figure 3-3. The two sets of spiracles of a first-second transitional larva. The first-instar Y-V slits (small, dark) can be seen below the two slit spiracles (larger, light-colored) in this molting larva.

Figure 3-4. The two inner slits in the spiracles of a second-instar calliphorid larva.

Figure 3-5. The two sets of spiracles of a second-third transitional calliphorid larva. The second-instar spiracles (small, dark) have two slits, while the third-instar spiracles have three (larger, light-colored) in this molting larva.

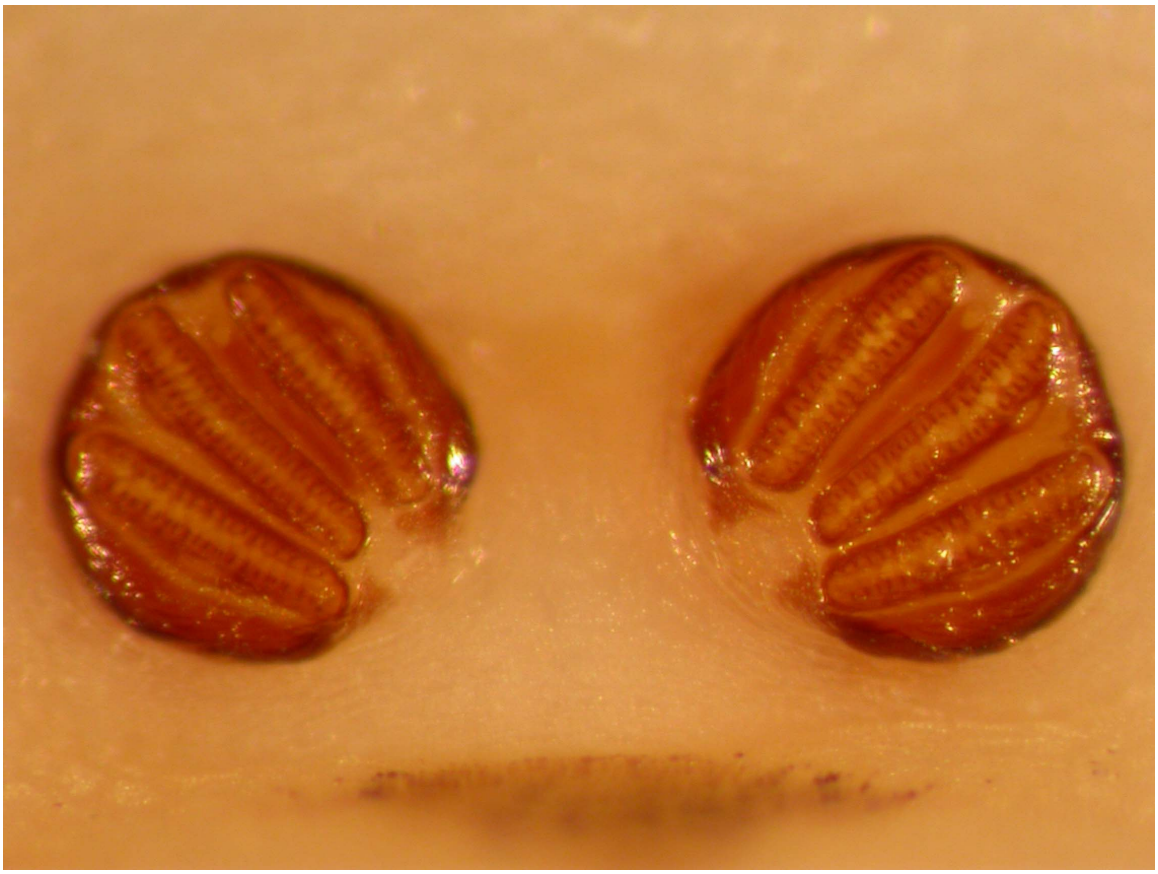


Figure 3-6. The three inner splits in the spiracles of a third-instar calliphorid larva.

Figure 3-7. *Chrysomya rufifaces*, third-instar larvae. The obvious fleshy protuberances found on the second- and third-instar larvae of this species are easy to see without a microscope.

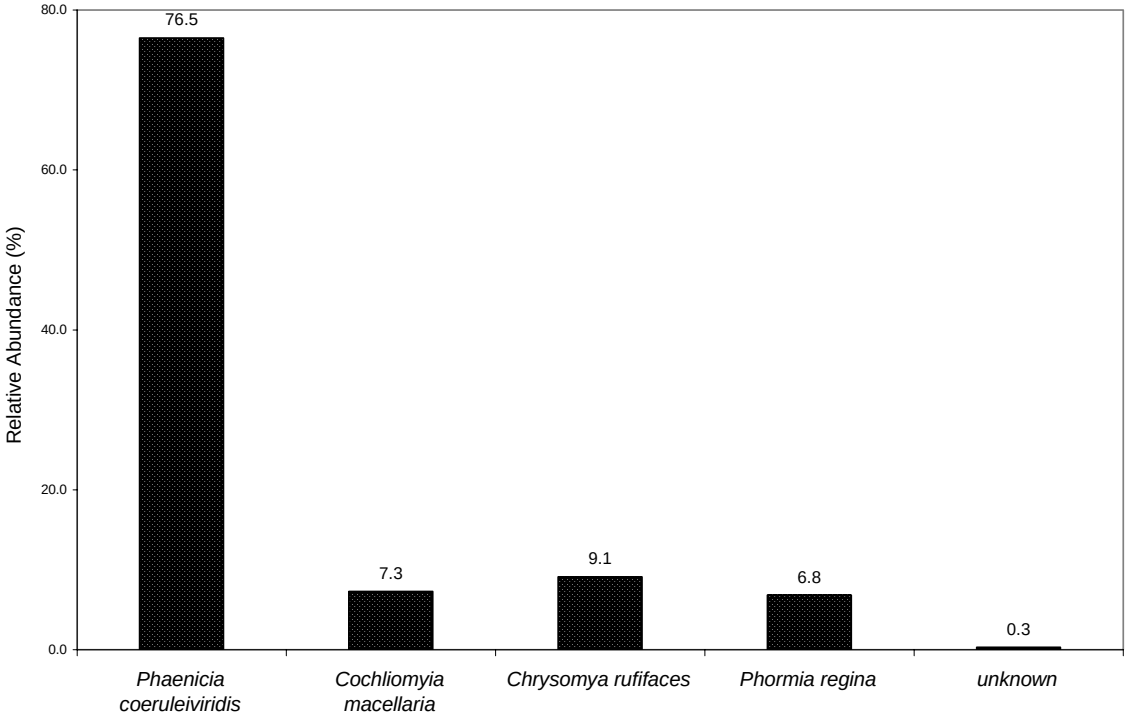


Figure 3-8. Relative abundance of third-instar calliphorid larvae preserved from pig carrion during the study (N=8253) in Earleton, Florida.

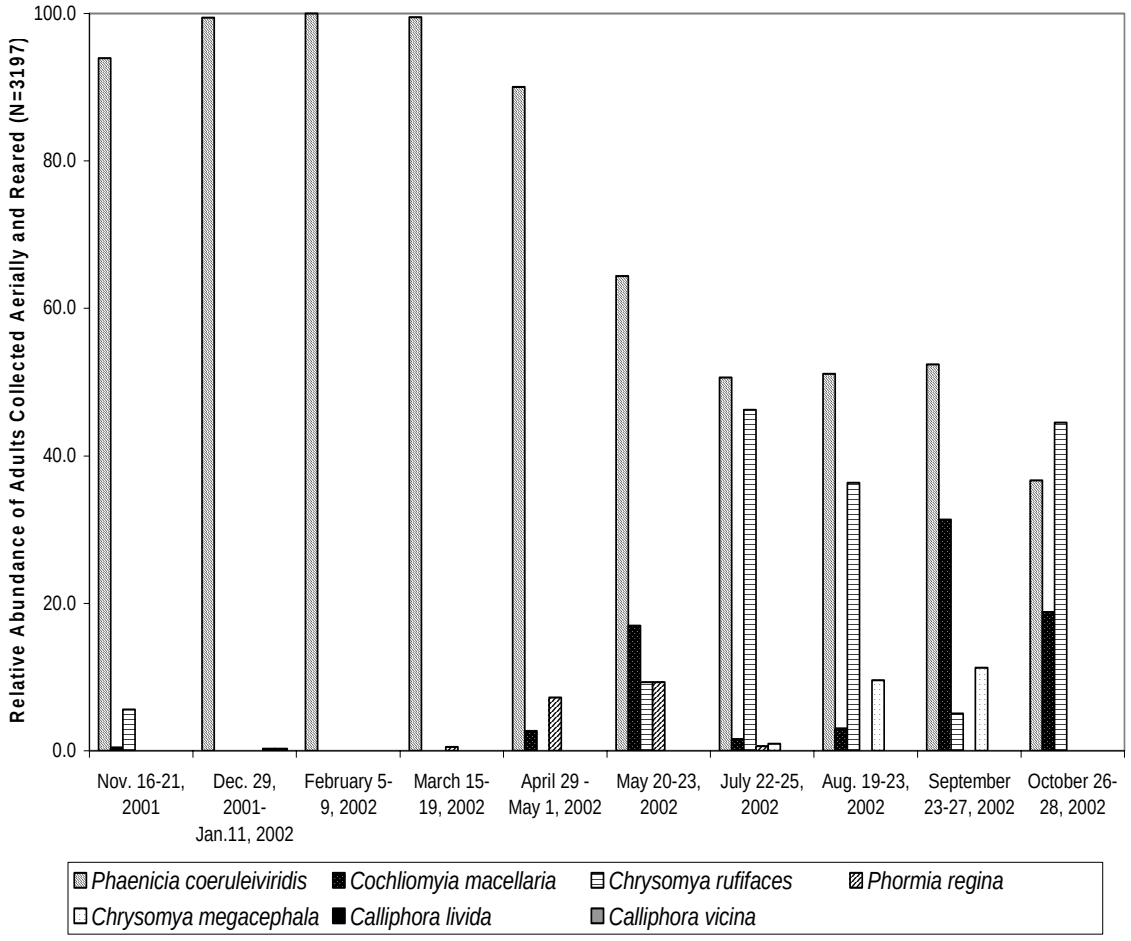


Figure 3-9. Calliphorid activity for year 1 of the study.

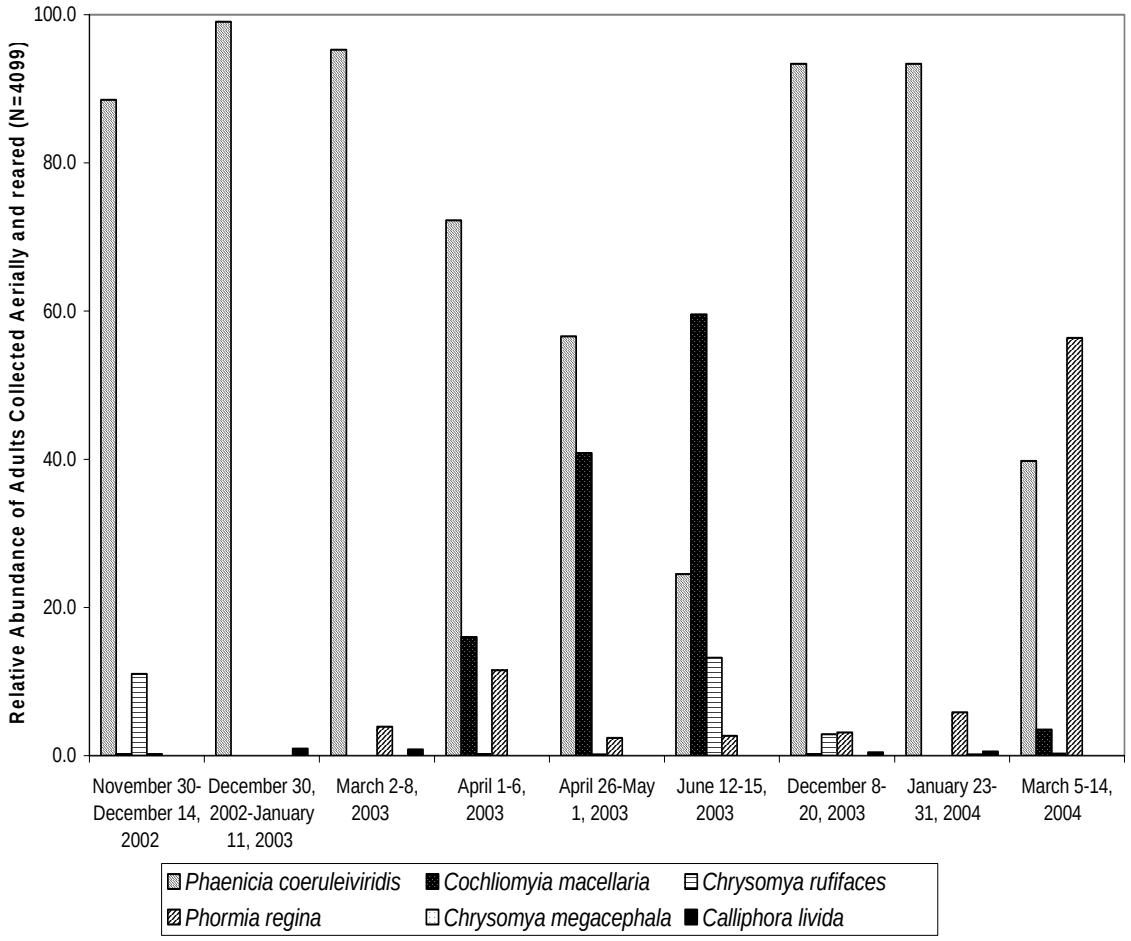
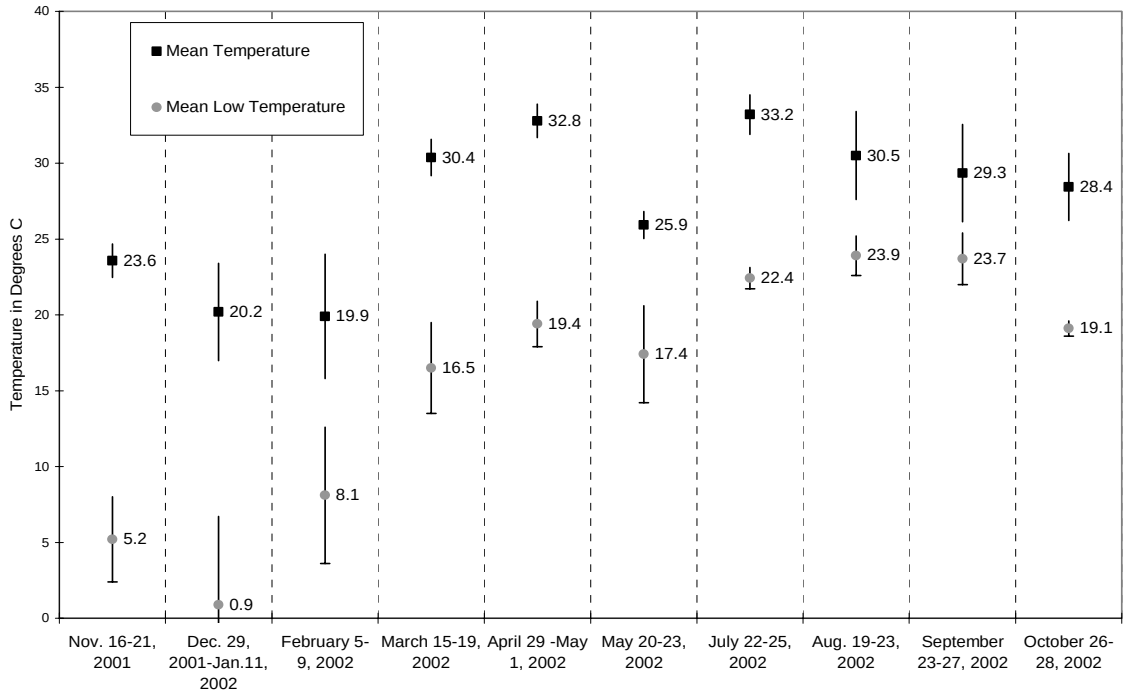


Figure 3-10. Calliphorid activity for year 2 of the study.

(A)



(B)

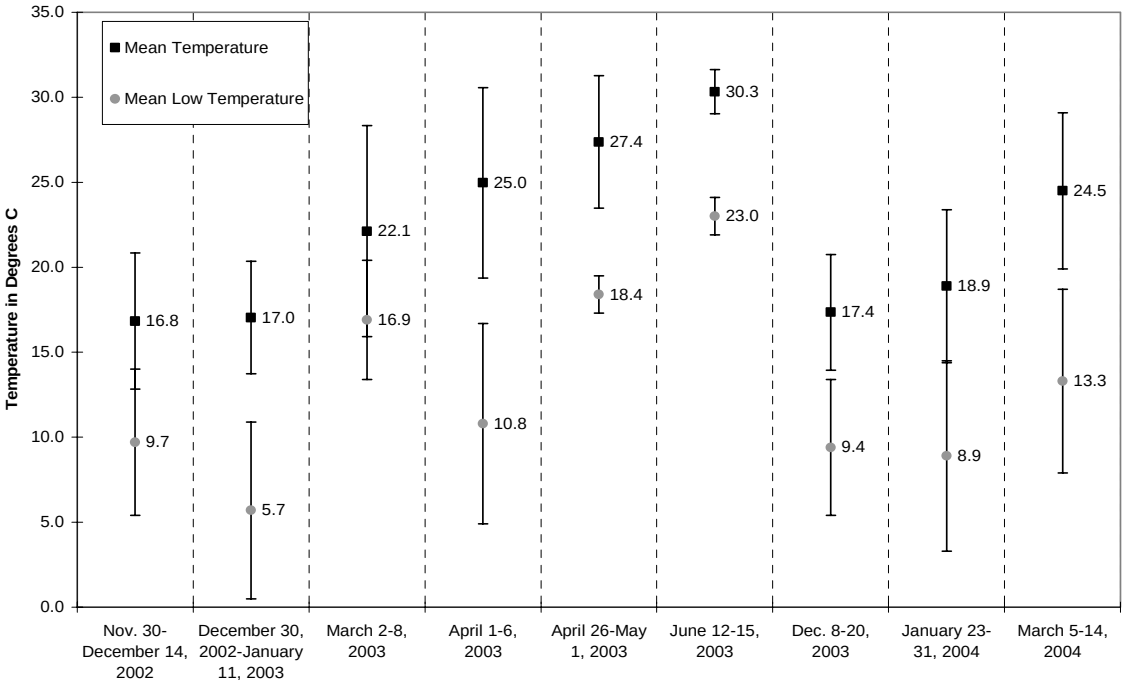
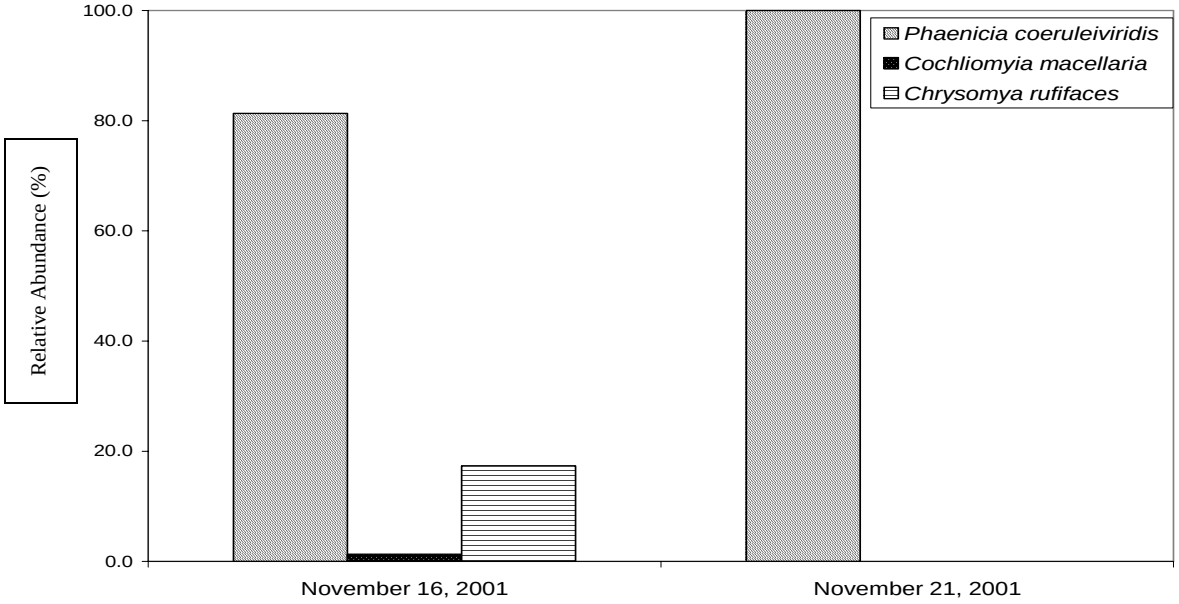


Figure 3-11. Mean daily and mean low temperatures (±SD) for year 1, November 16, 2001 to October 26, 2002 (Part A) and year 2, November 30, 2002 to March 14, 2004 (Part B) of study.

(A) Reared Adults



(B) Preserved Larvae

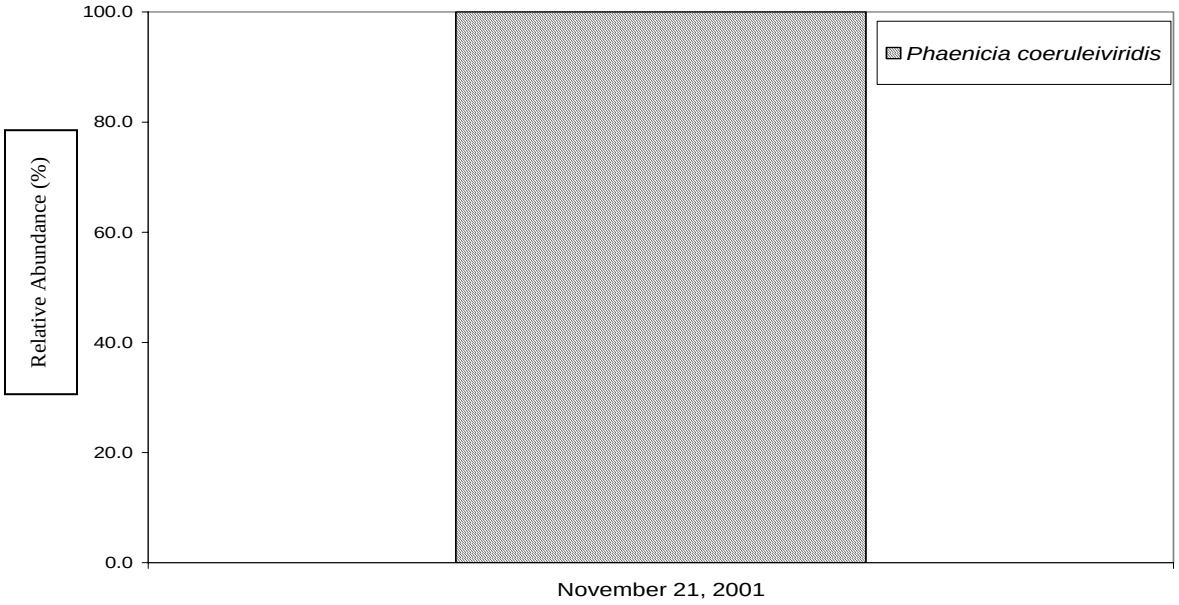
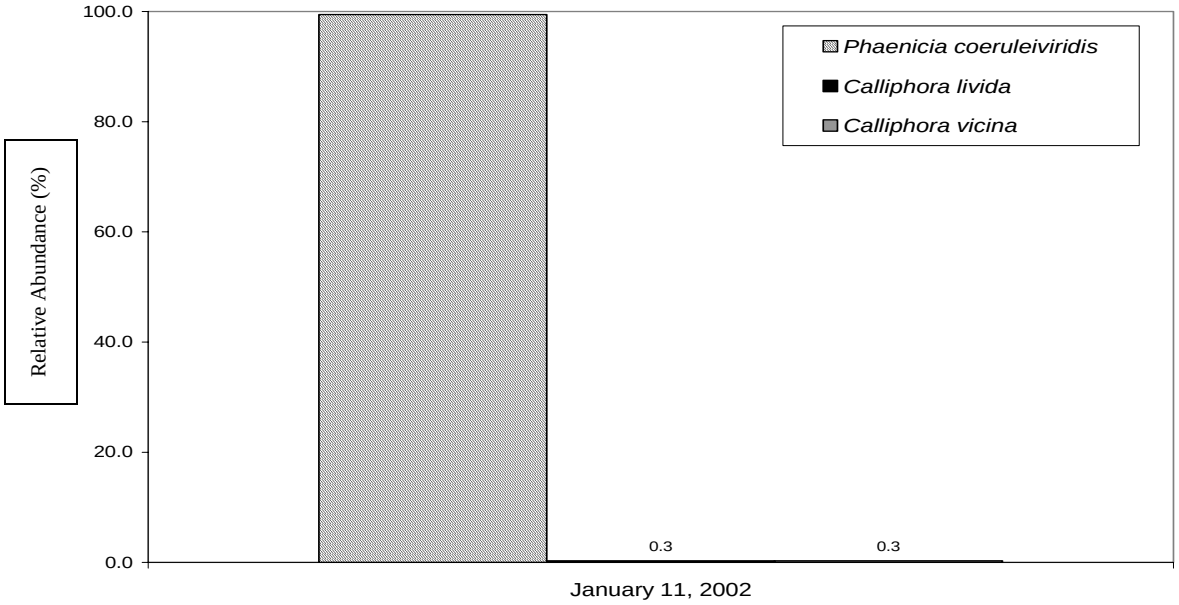


Figure 3-12. Reared adults, N=232, (Part A), and preserved larvae, N=30, (Part B), from collection 1, November 16 to November 21, 2001.

(A) Reared Adults



(B) Preserved Larvae

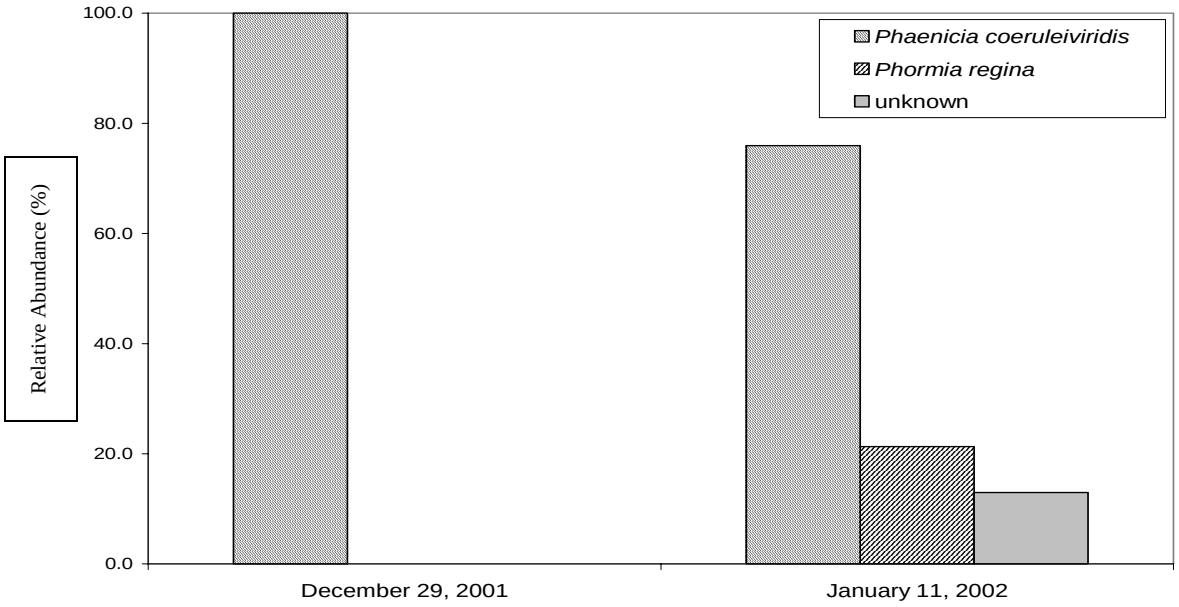


Figure 3-13. Reared adults, N=362, (Part A), and preserved larvae, N=568, (Part B), from collection 2, December 29, 2001 to January 11, 2002.

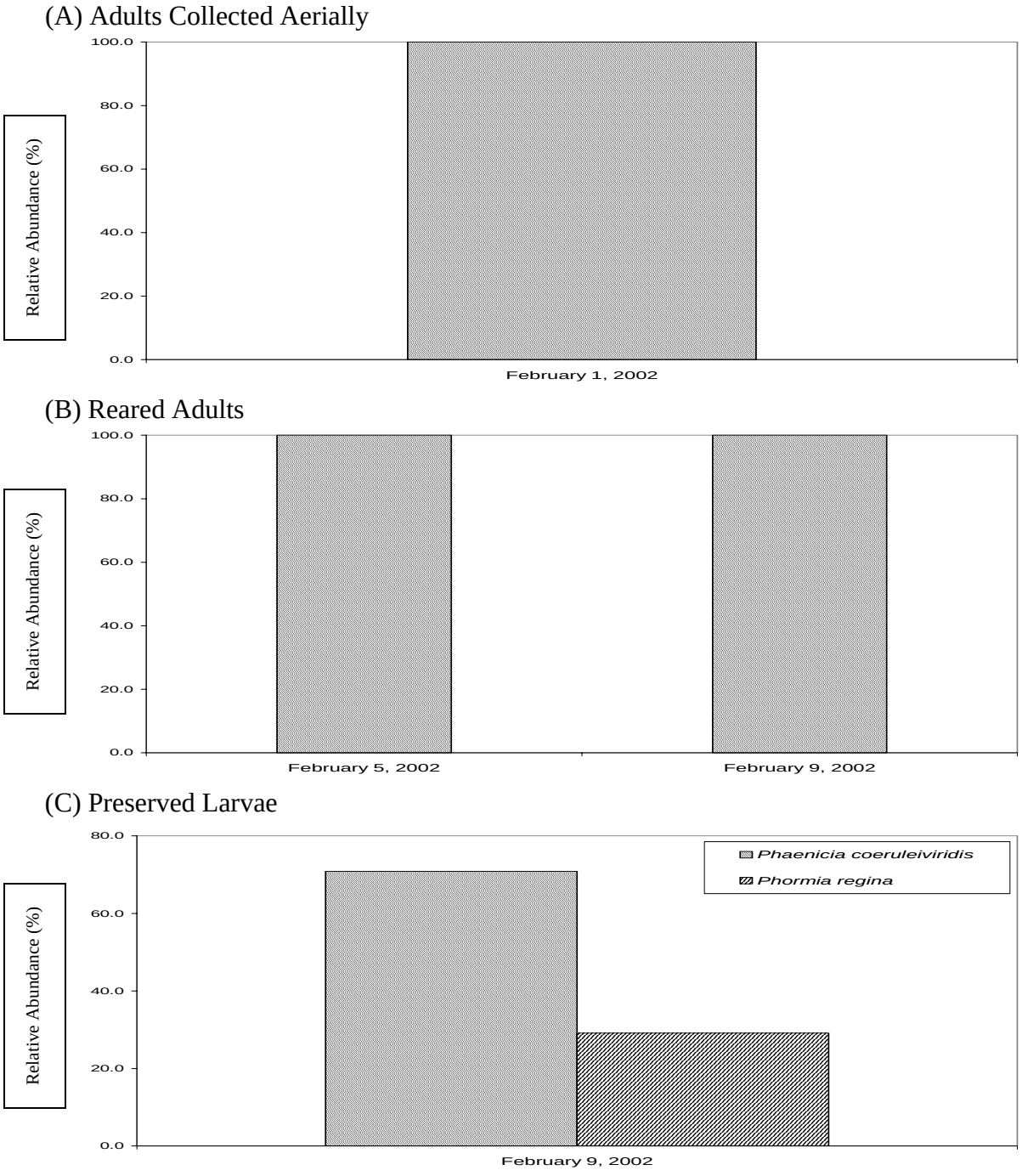


Figure 3-14. Adults aerially collected, N=39, (Part A), reared adults, N=305, (Part B), and preserved larvae, N=151, (Part C), from collection 3, February 1-9, 2002.

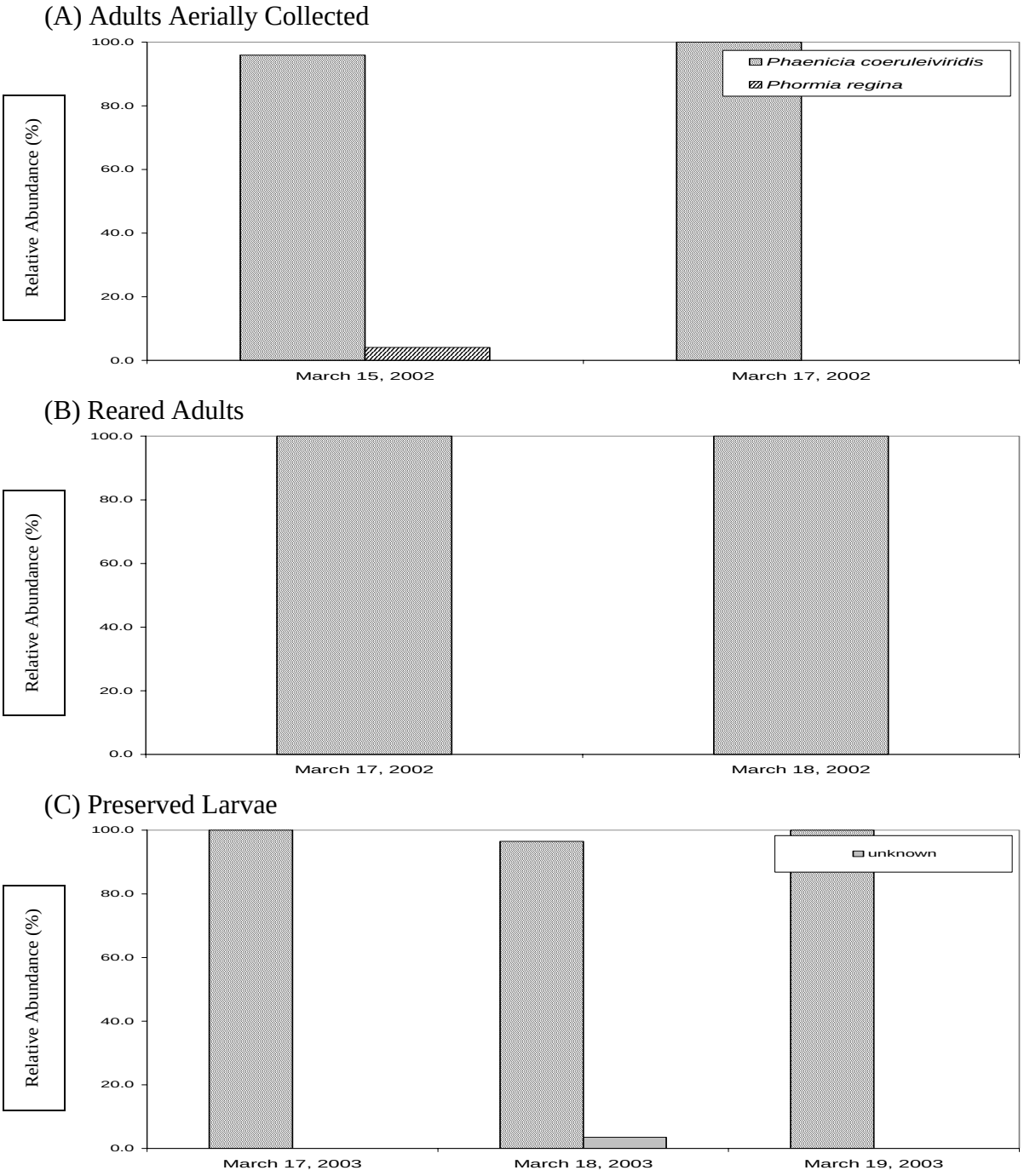
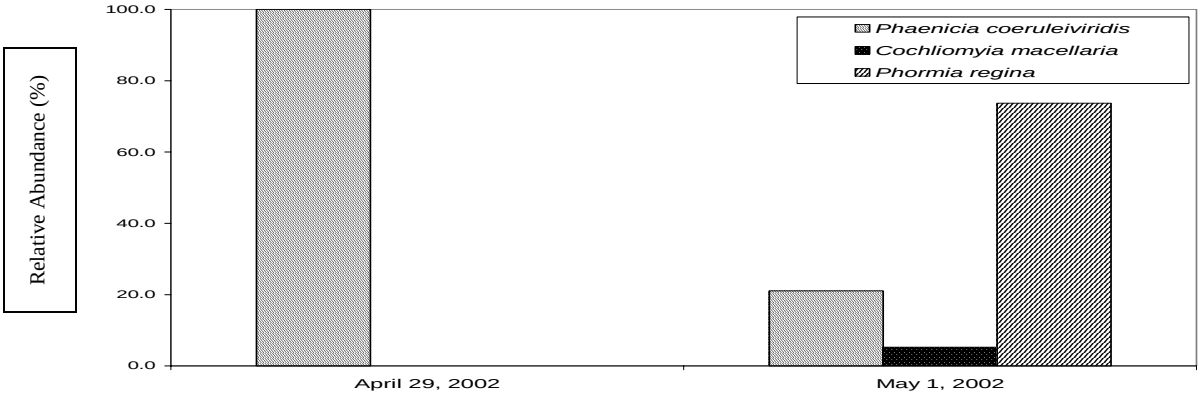
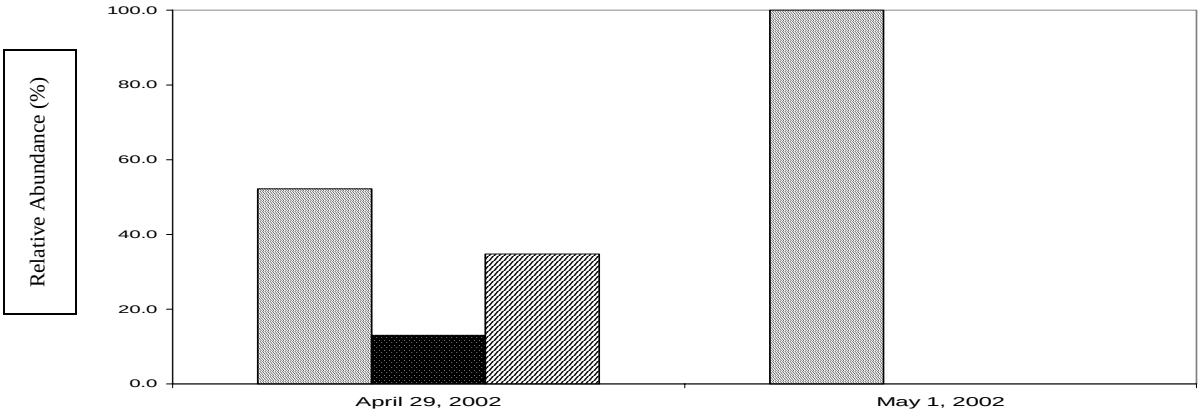


Figure 3-15. Adults collected aerially, N=71, (Part A), reared adults, N=326, (Par B), and preserved larvae, N=134, (Part C), from collection 4, March 15-19, 2002.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

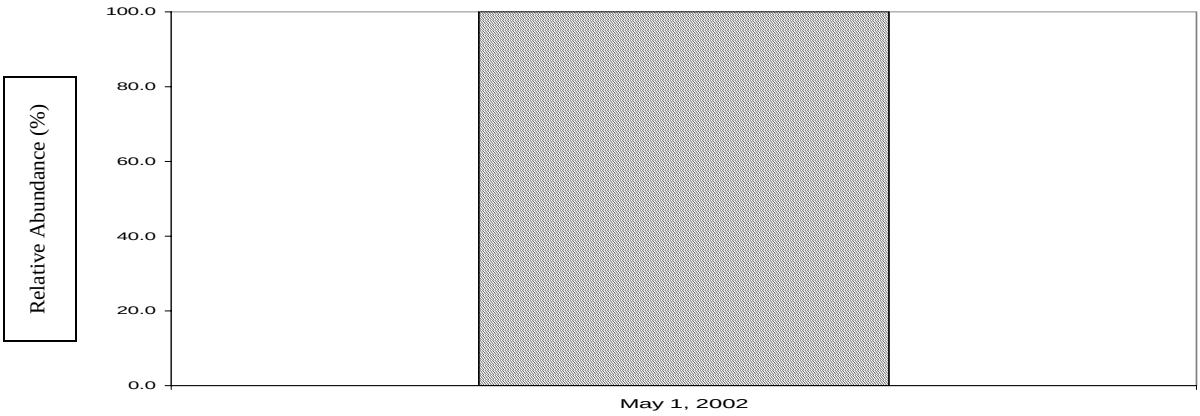


Figure 3-16. Adults aerially collected, N=107, (Part A), reared adults, N=332, (Part B), and preserved larvae, N=196, (Part C), from collection 5, April 29 to May 1, 2002.

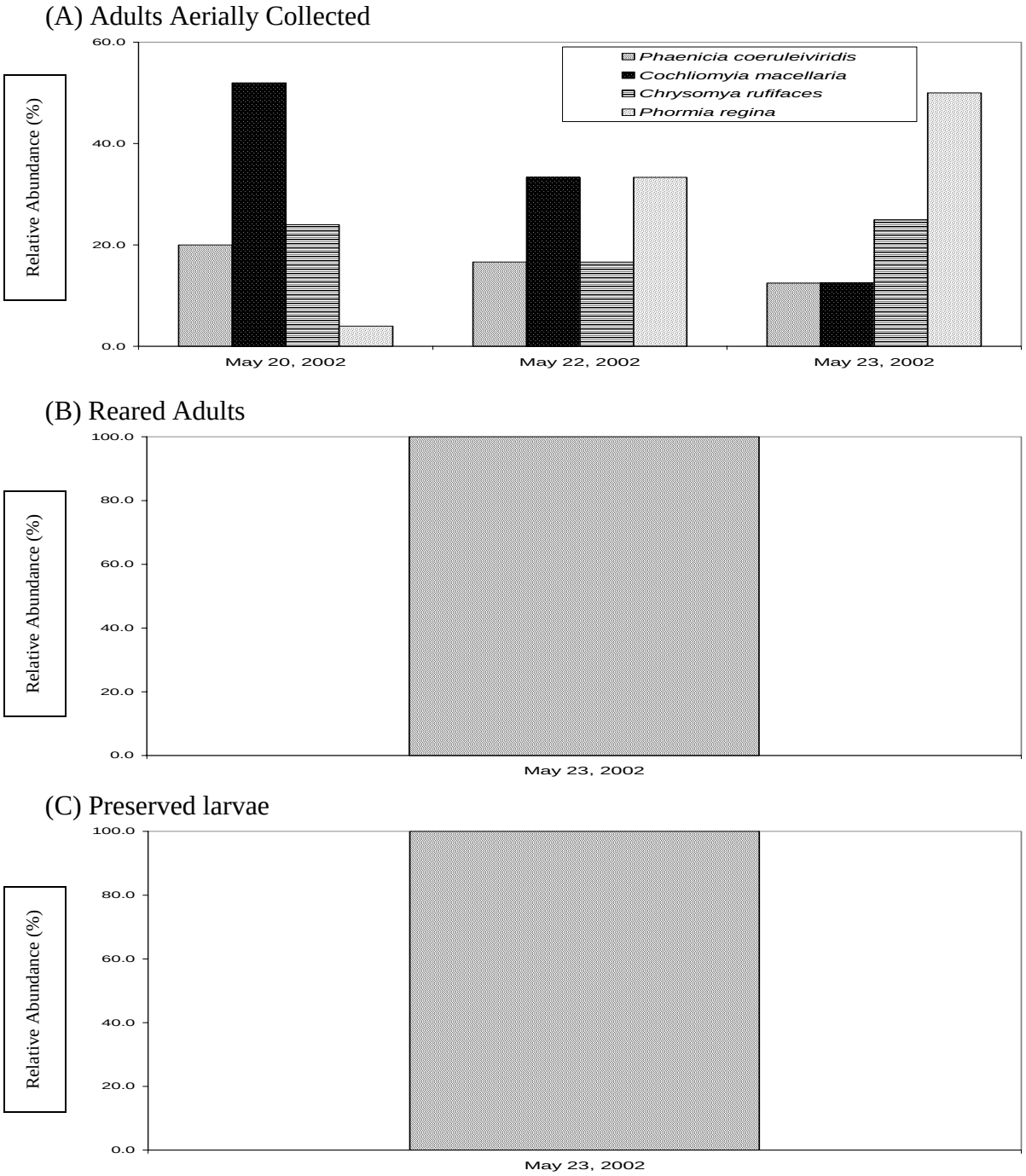
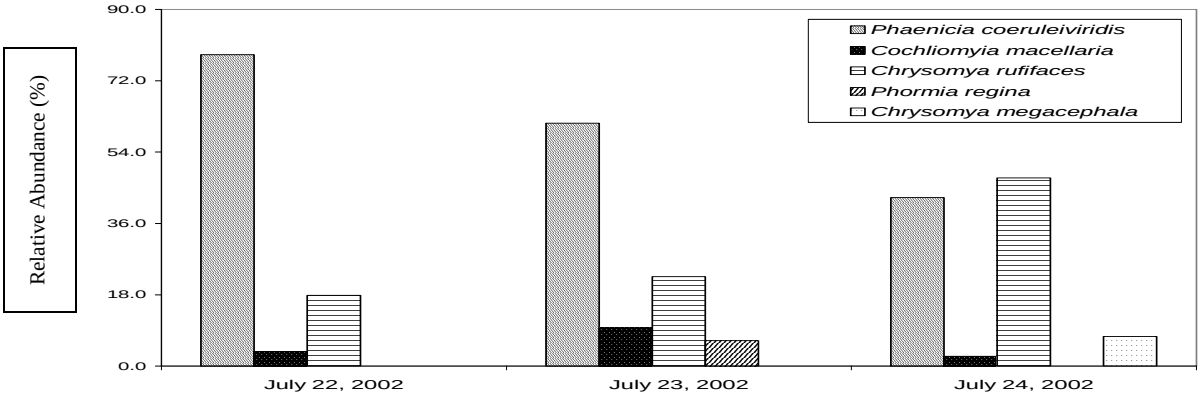
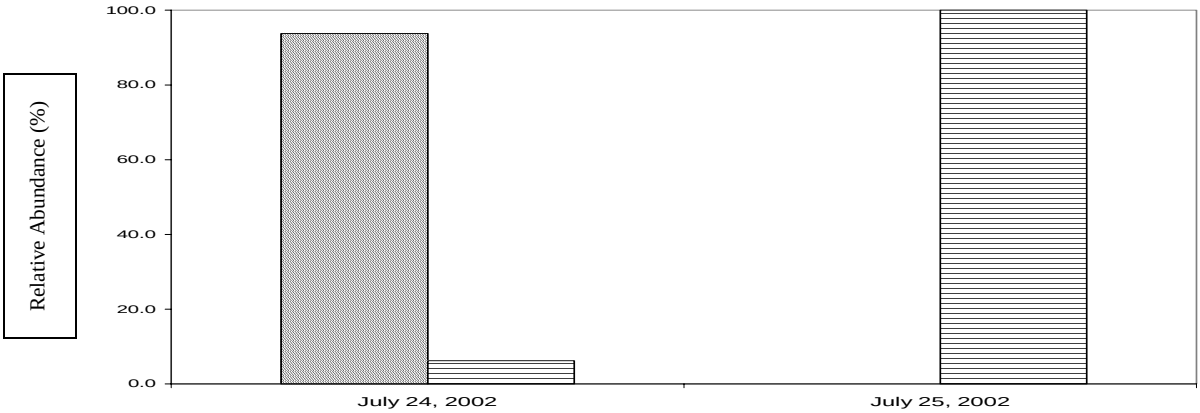


Figure 3-17. Adults aerially collected, N=51, (Part A), reared adults, N=67, (Part B), and preserved larvae, N=175 (Part C), from collection 6, May 20 to May 23, 2002.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

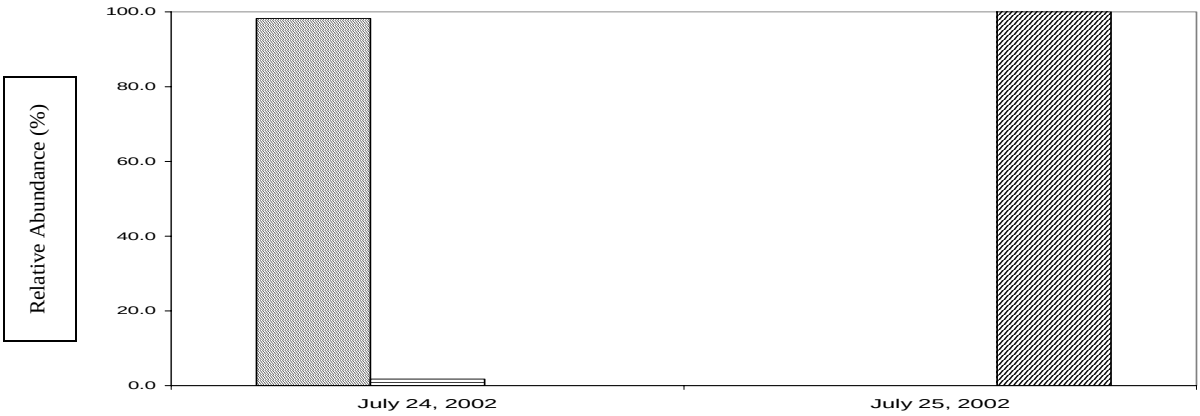


Figure 3-18. Adults aerially collected, N=99, (Part A), reared adults, N=223, (Part B), and preserved larvae, N=700, (Part C), from collection 7, July 22 to July 24, 2002.

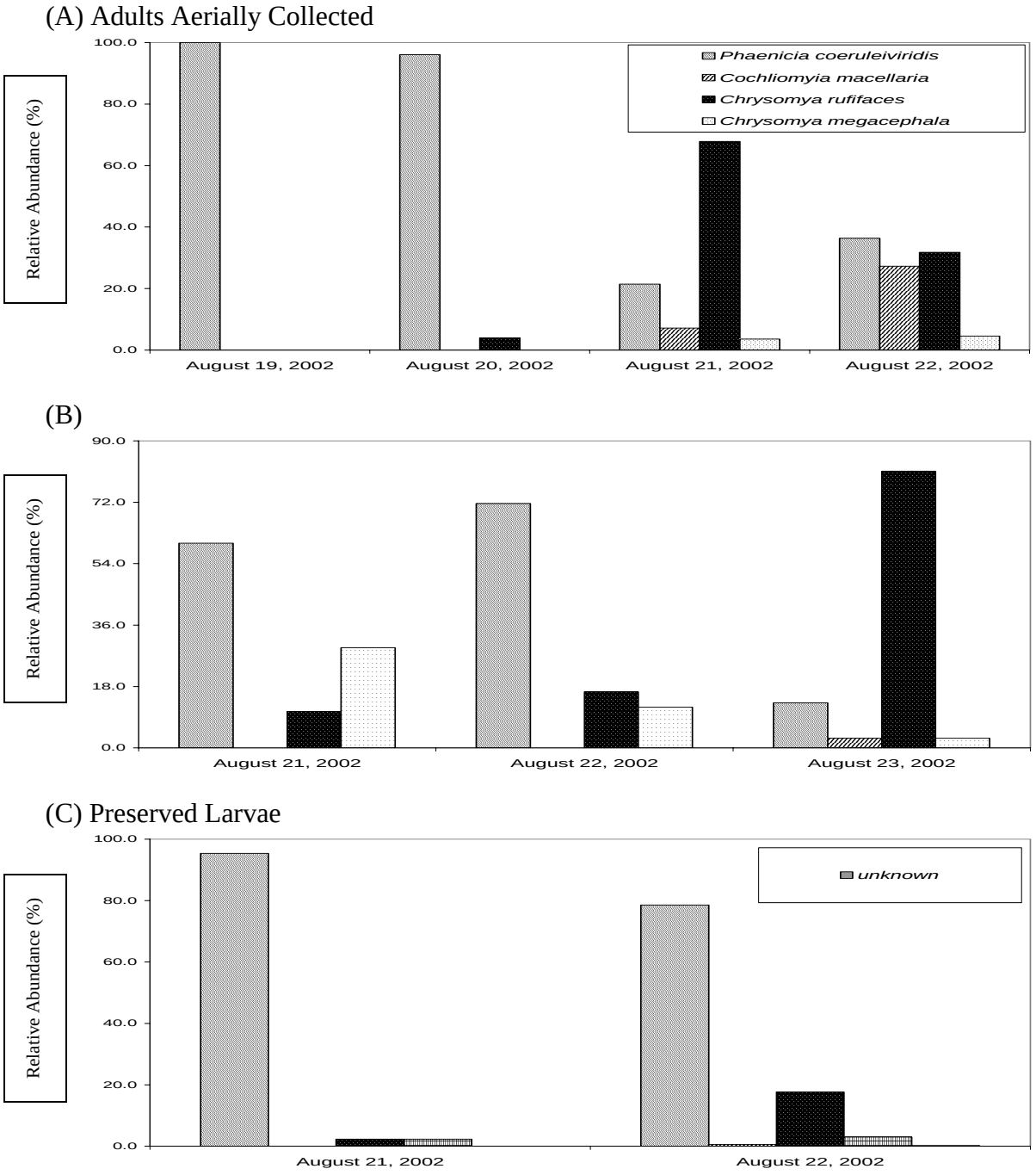
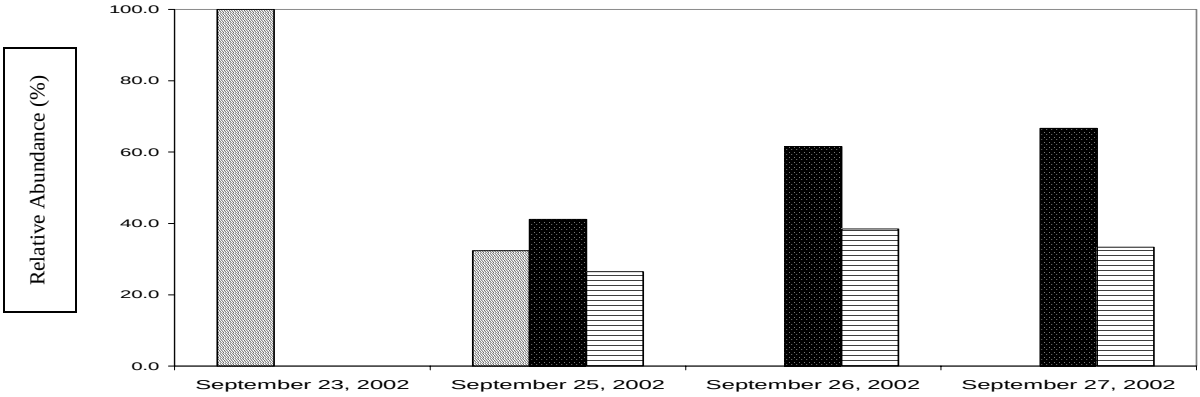
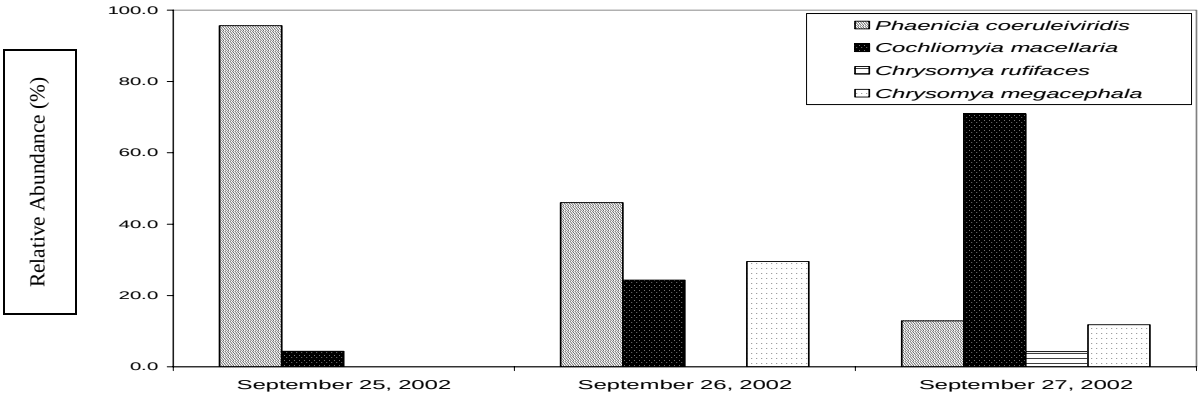


Figure 3-19. Adults aerially collected, N=76, (Part A), reared adults, N=248, (Part B), and preserved larvae, N=499, (Part C), from collection 8, August 19-23, 2002.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

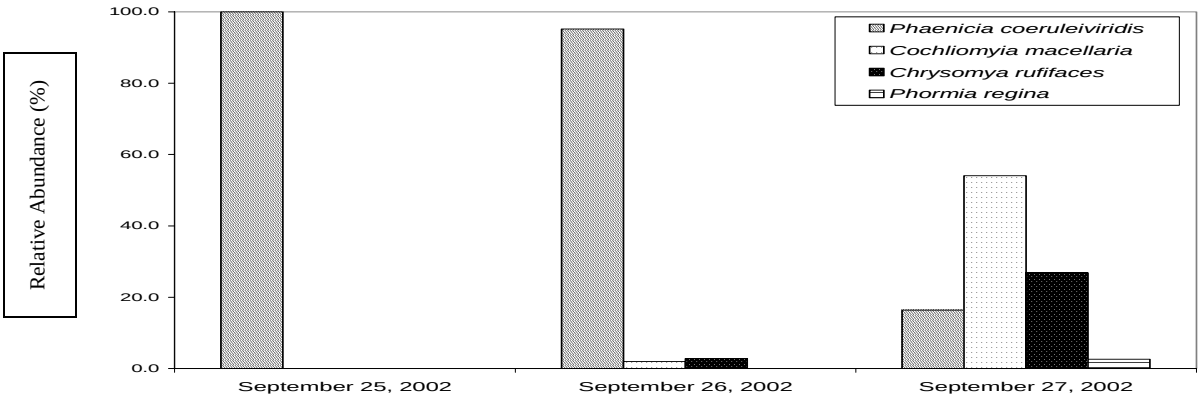
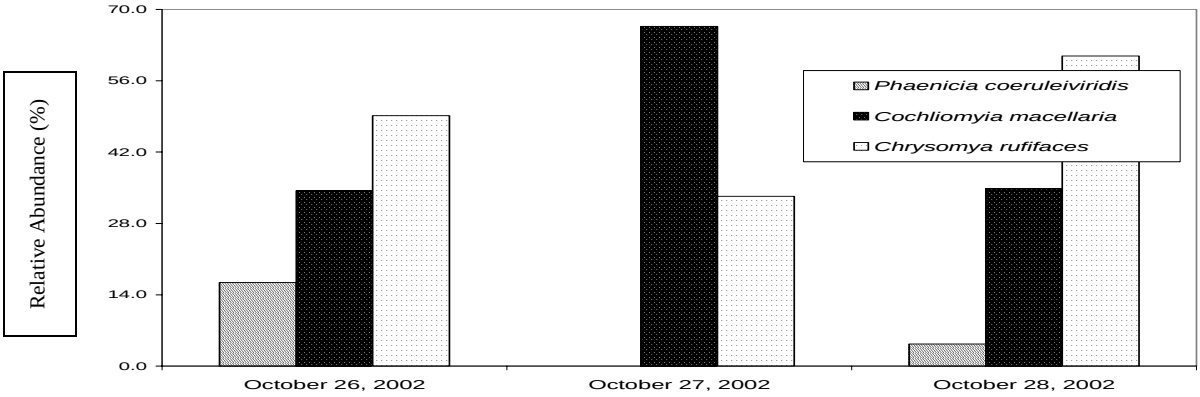
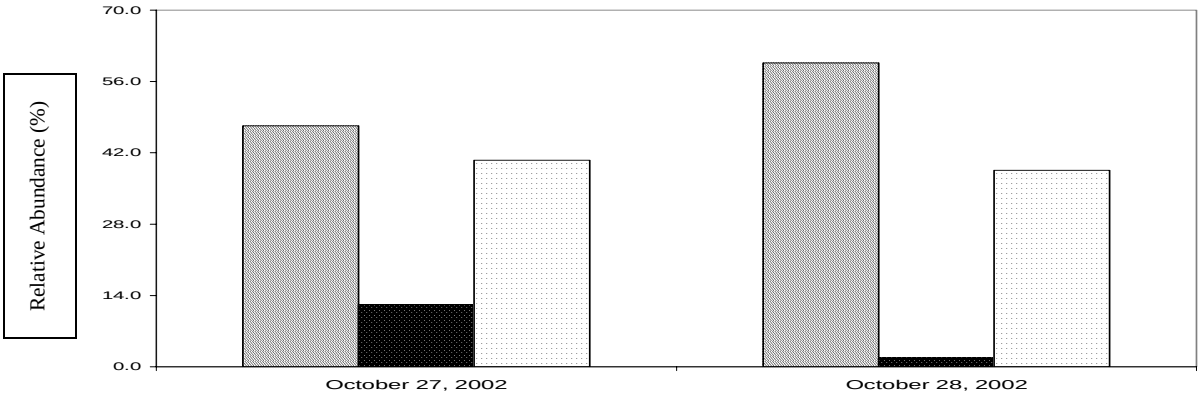


Figure 3-20. Adults aerially collected, N=76, (Part A), reared adults, N=323, (Part B), and preserved larvae, N=499, (Part C), from collection 9, September 23-27, 2002.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

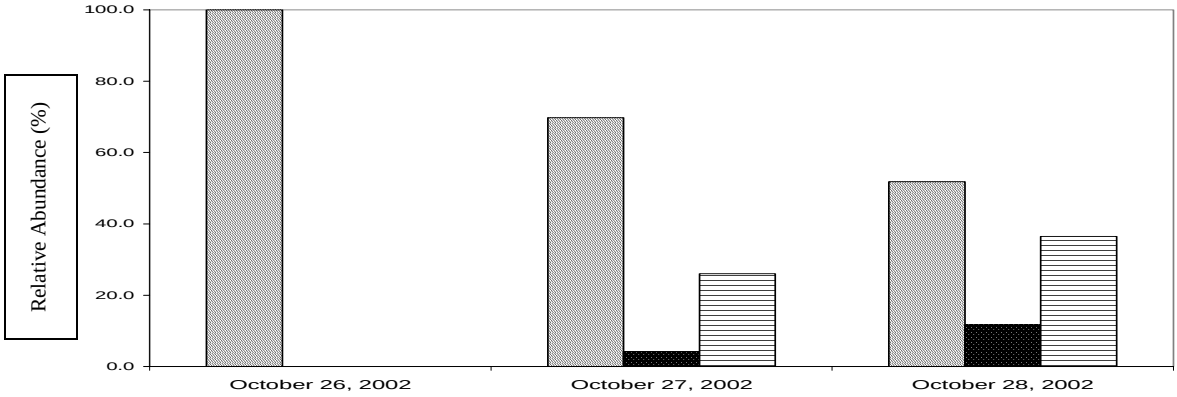
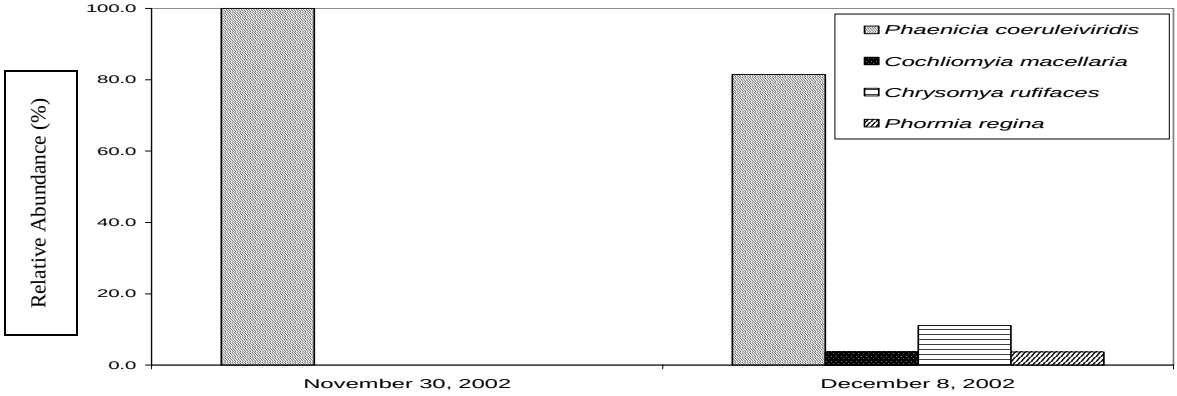
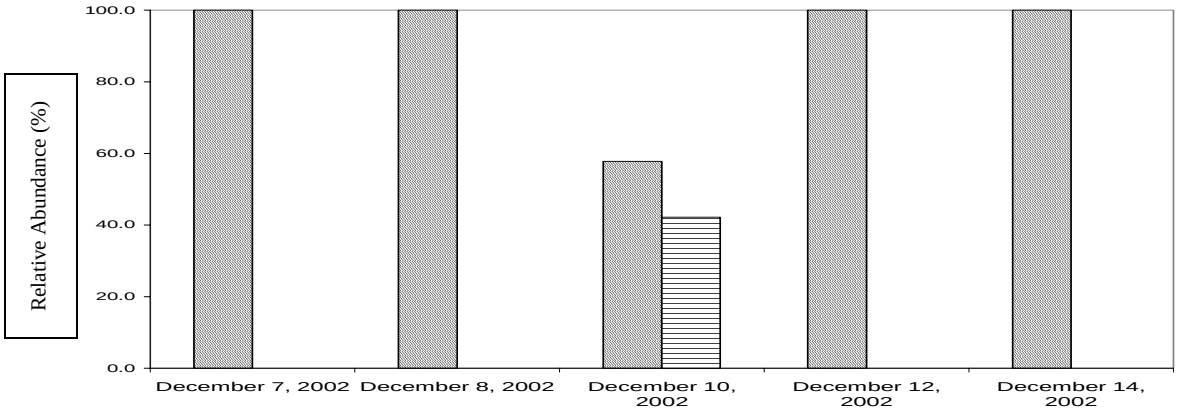


Figure 3-21. Adults aerially collected, N=87, (Part A), reared adults, N=131, (Part B), and preserved larvae, N=294, (Part C), from collection 10, October 26-28. 2002.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

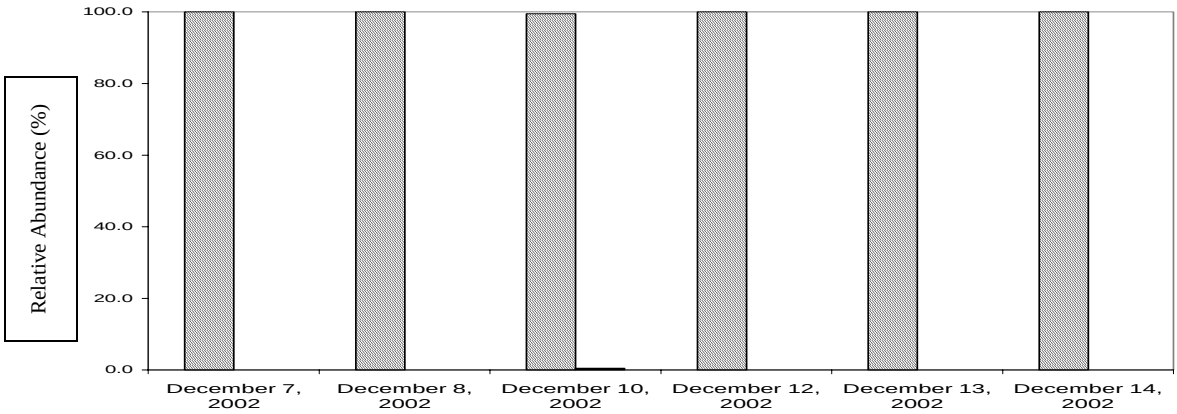


Figure 3-22. Adults aerially collected, N=60, (Part A), reared adults, N= 384, (Part B), and preserved larvae, N=1248, (Part C), from collection 11, November 30-December 8, 2002.

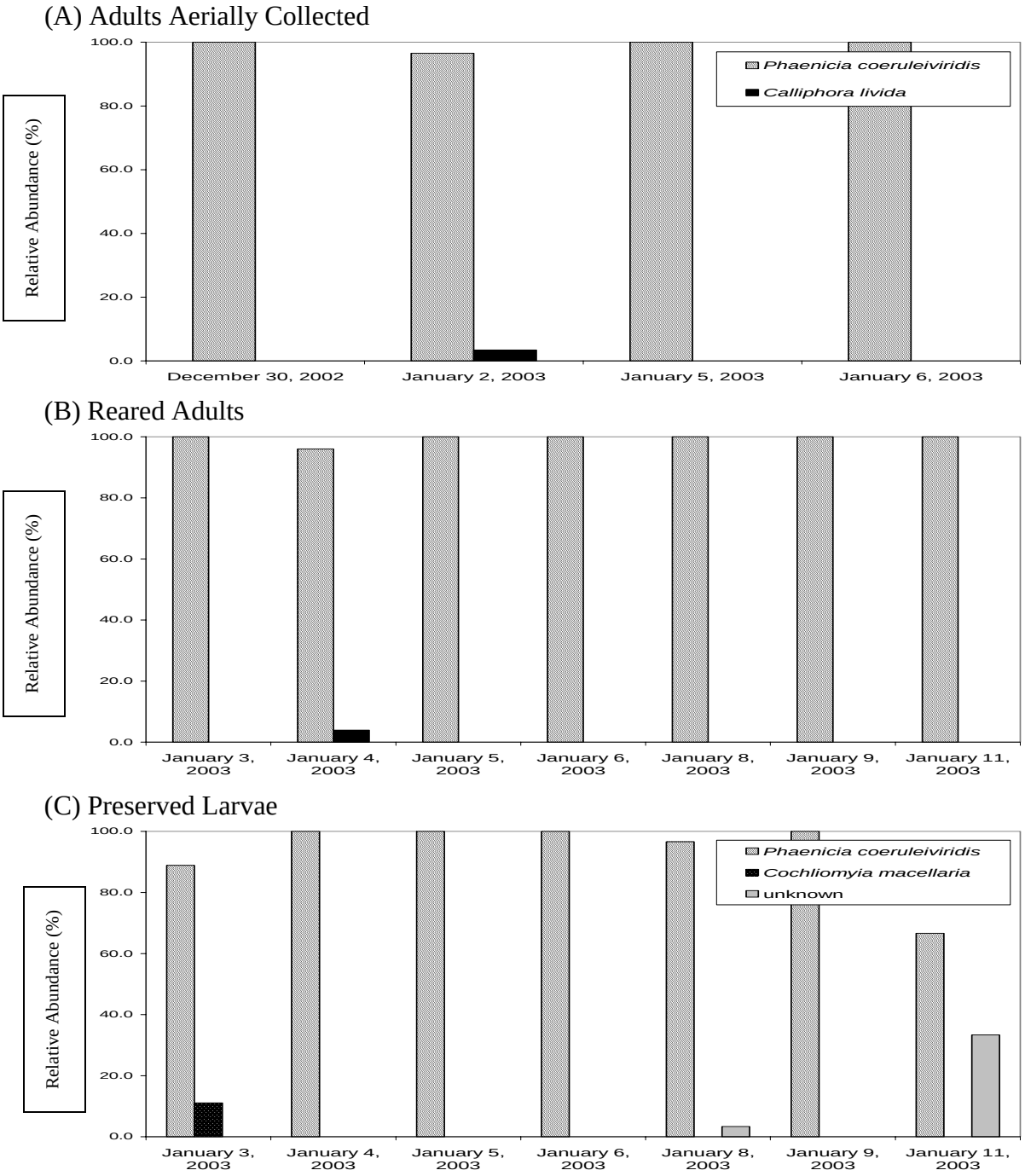


Figure 3-23. Adults aerially collected, N=56, (Part A), reared adults, N= 371, (Part B), and preserved larvae, N=581, (Part C), from collection 12, December 30, 2002 to January 11, 2003.

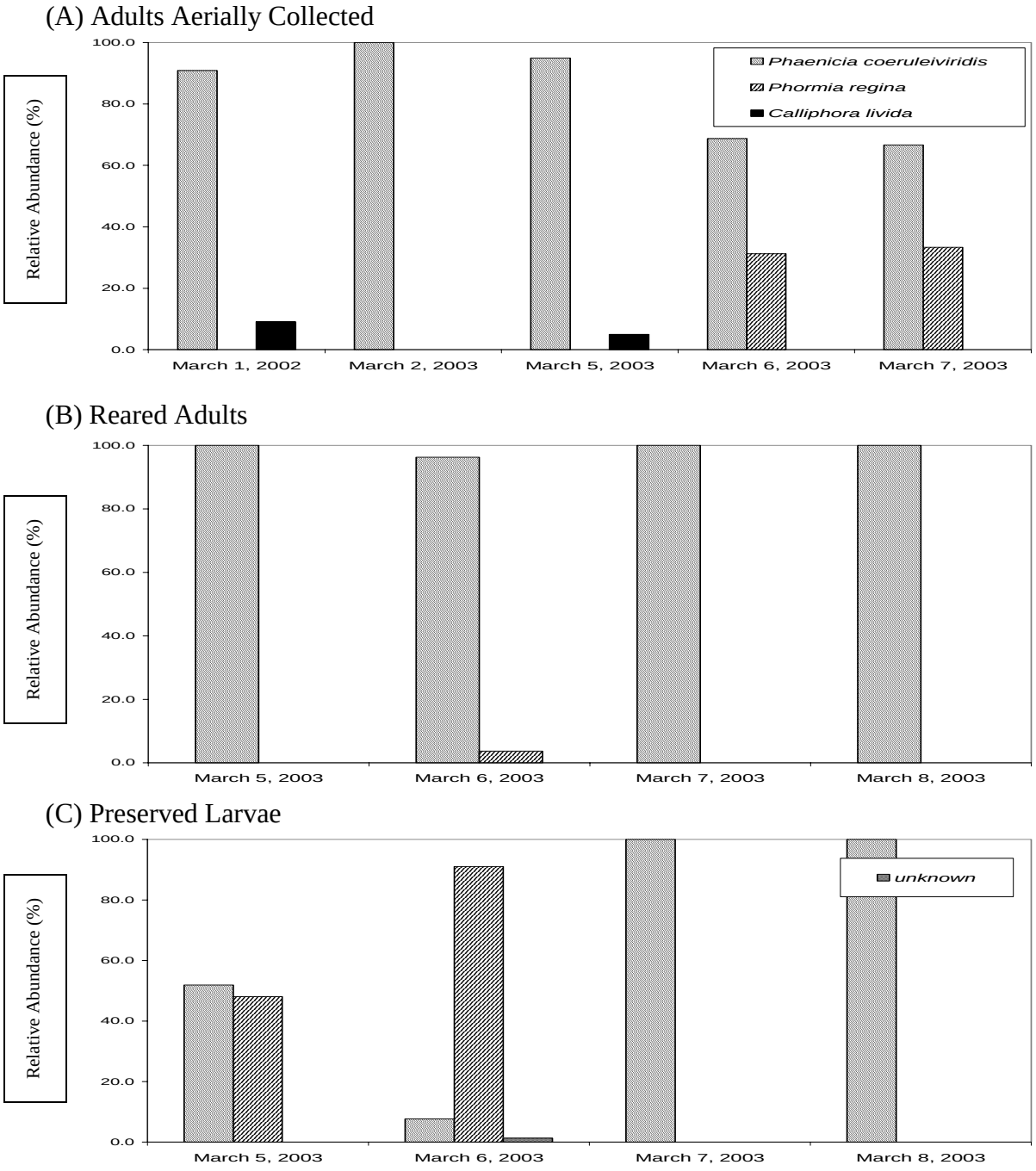
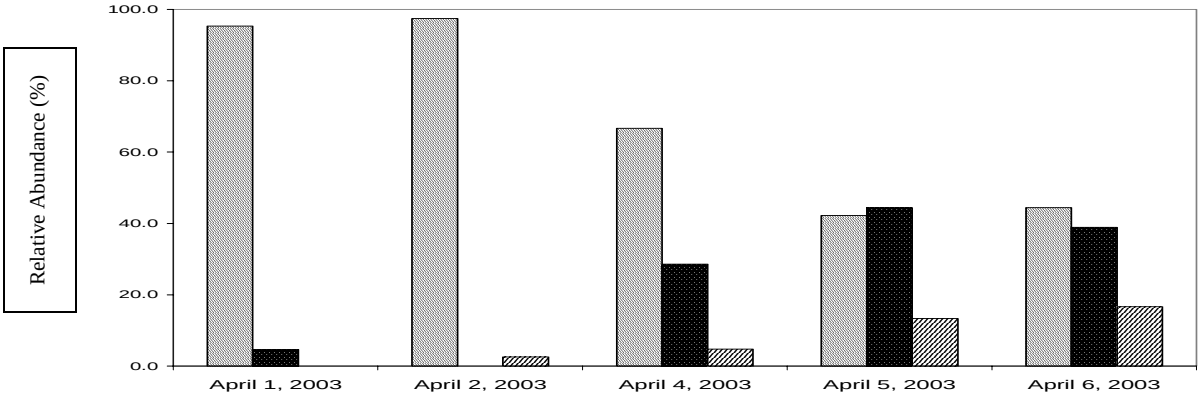
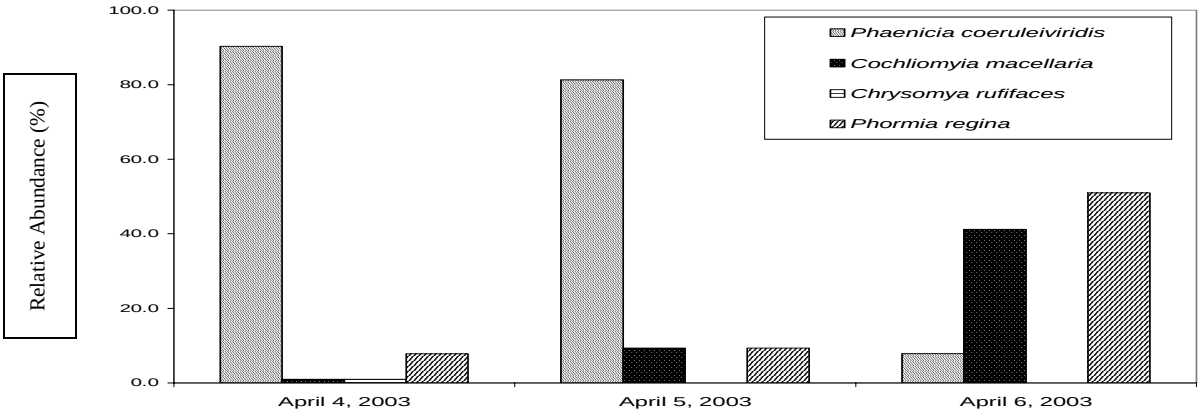


Figure 3-24. Adults aerially collected, N=66, (Part A), reared adults, N=166, (Part B), and preserved larvae, N=340, (Part C), from collection 13, March 1-8, 2003.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

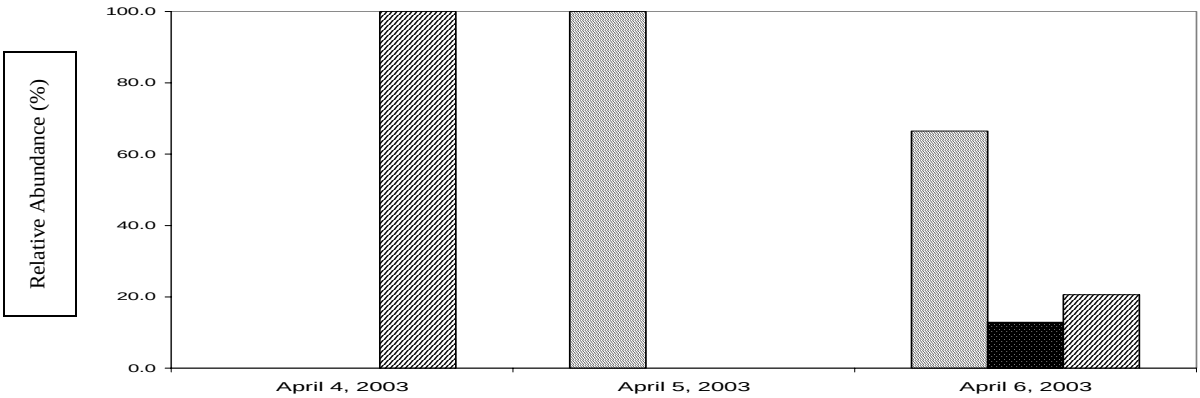
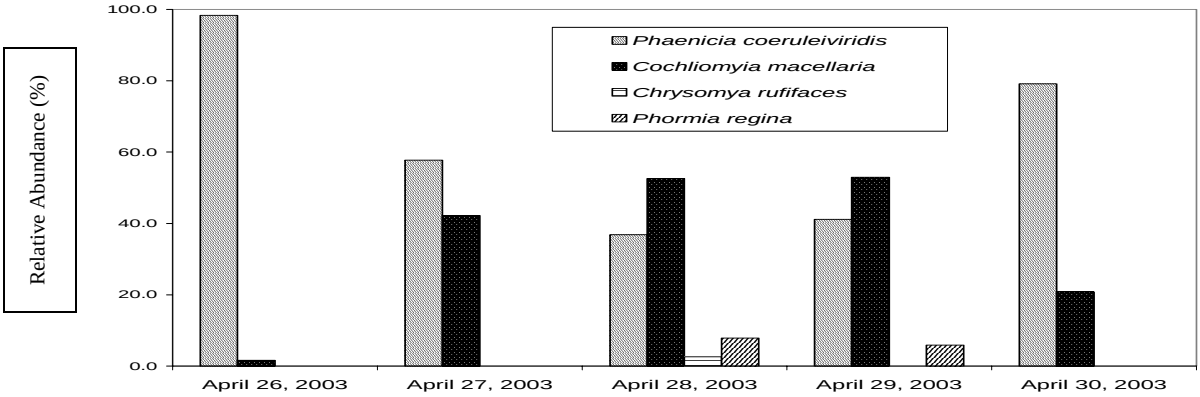
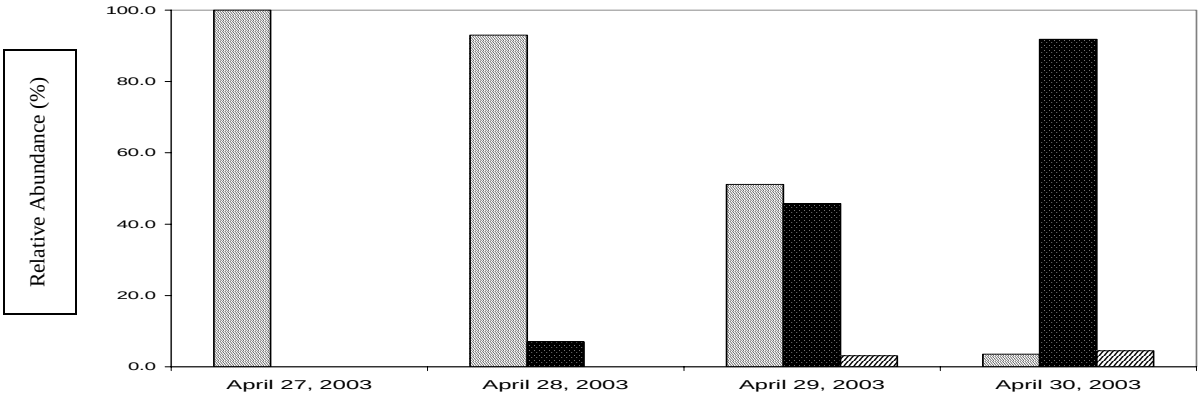


Figure 3-25. Adults aerially collected, N=247, (Part A), reared adults, N=229, (Part B), and preserved larvae, N=301, (Part C), from collection 14, April 1-6, 2003.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

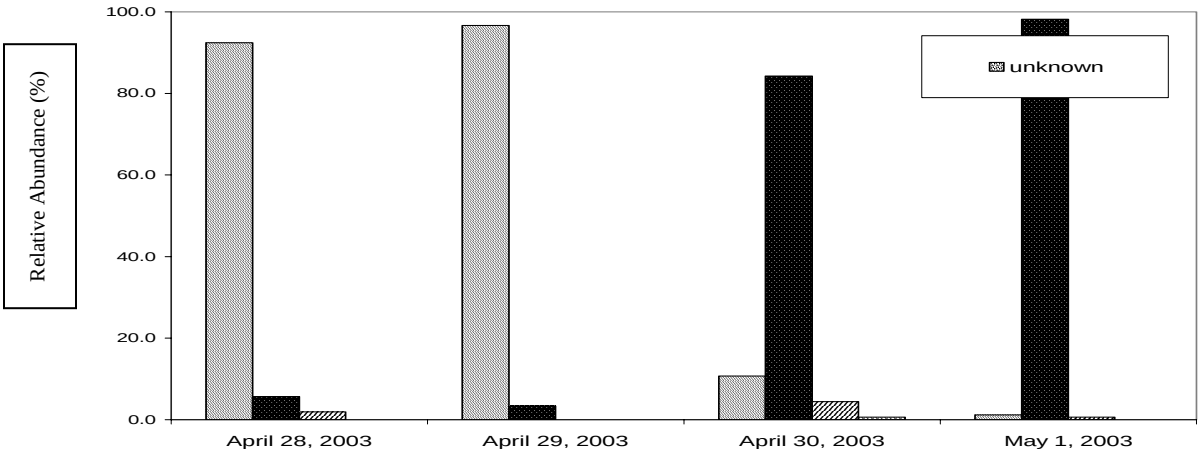
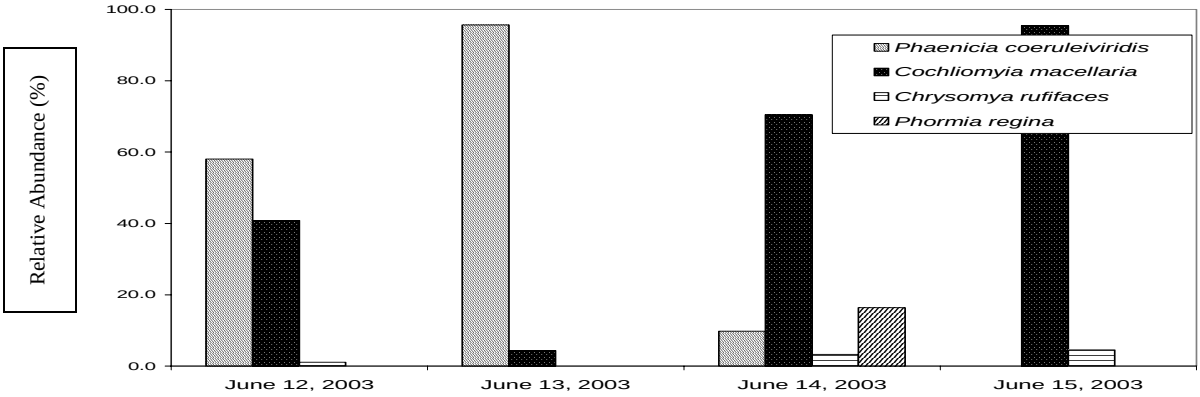
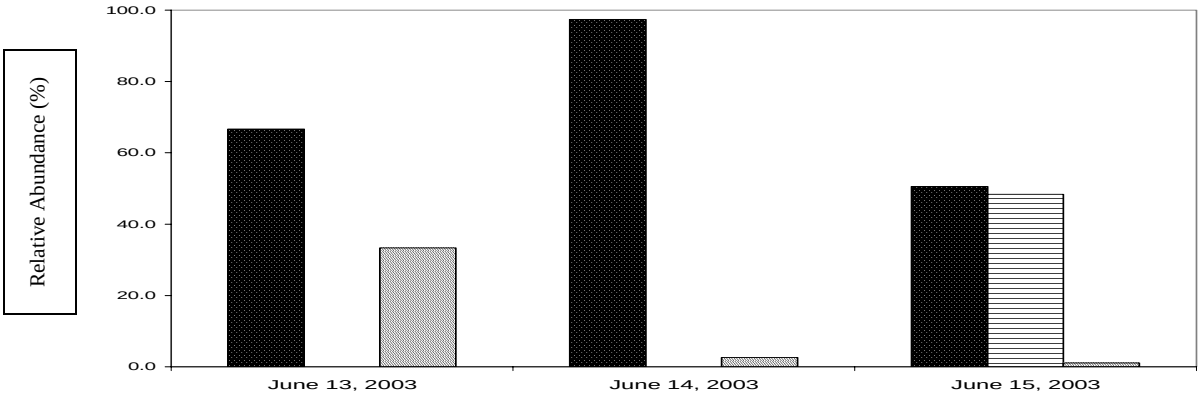


Figure 3-26. Adults aerially collected, N=185, (Part A), reared adults, N=359, (Part B), and preserved larvae, N=651, (Part C), from collection 15, April 26-May 1, 2003.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

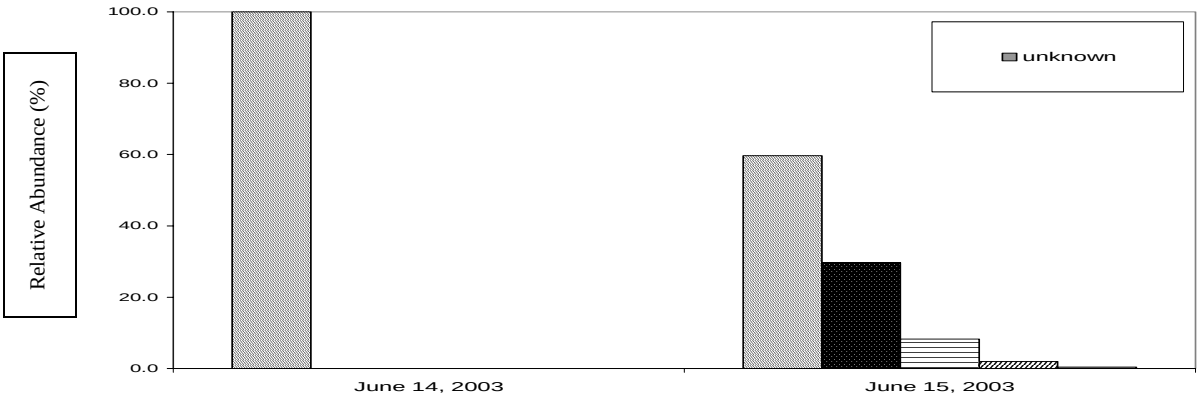
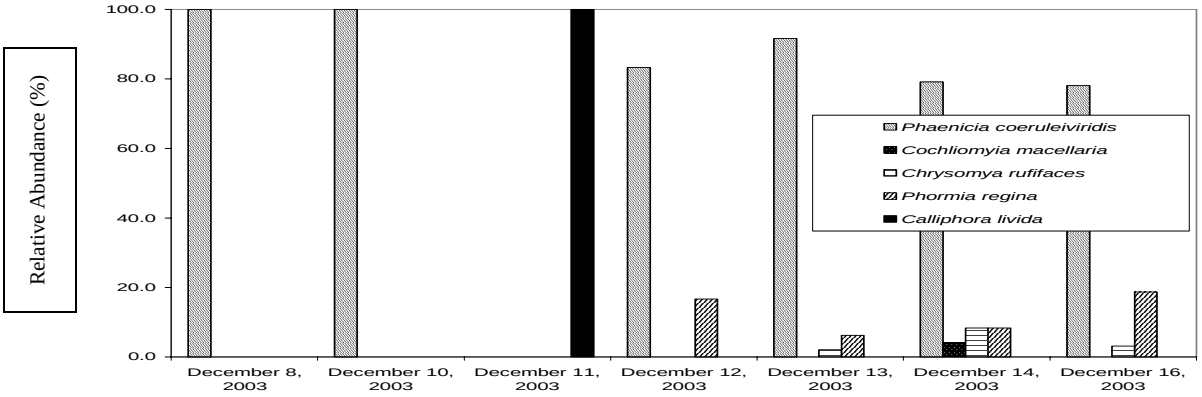
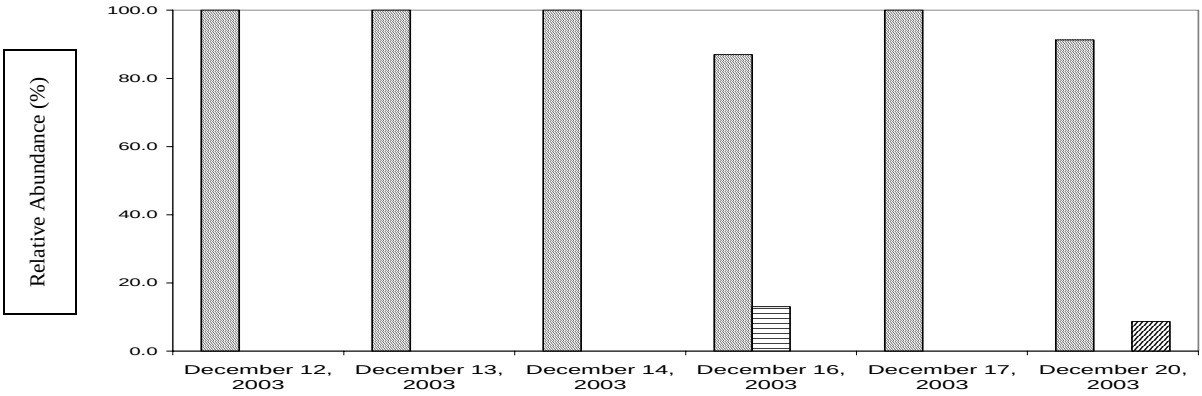


Figure 3-27. Adults aerially collected, N=221, (Part A), reared adults, N=150, (Part B), and preserved larvae, N=388, (Part C), specimens from collection 16, June 12-15, 2003.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

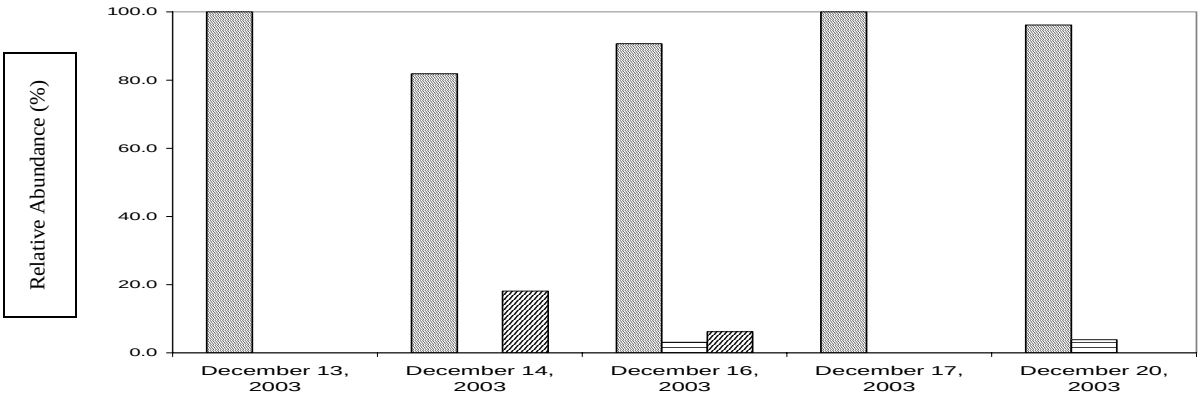


Figure 3-28. Adults aerially collected, N=186, (Part A), reared adults, N=266, (Part B), and preserved larvae, N=648, (Part C), from collection 17, December 8-20, 2003.

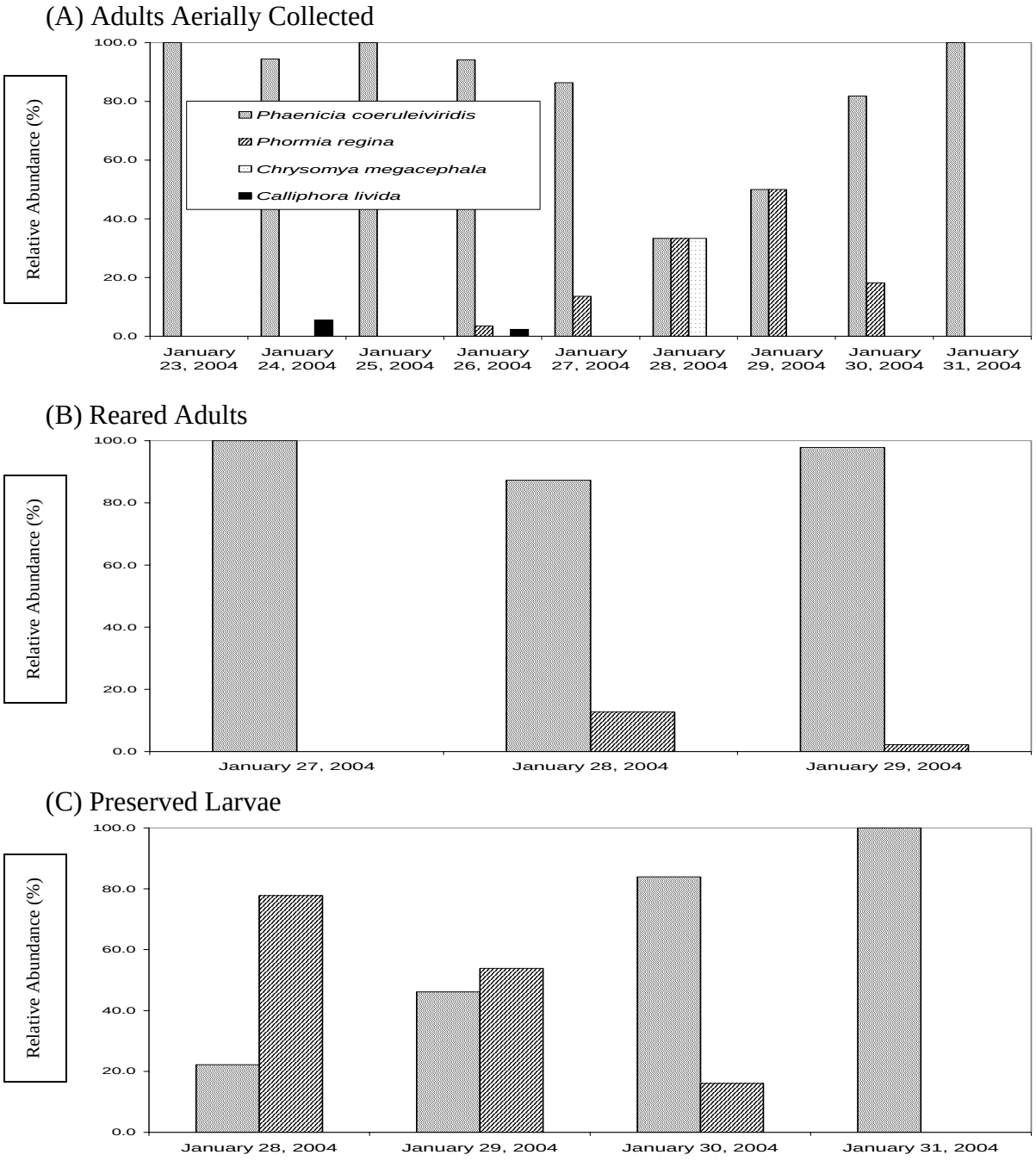
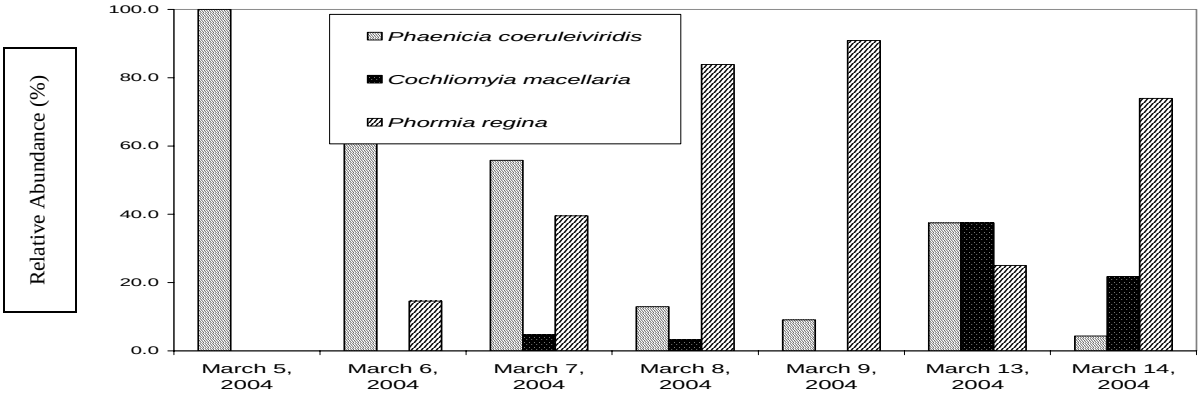
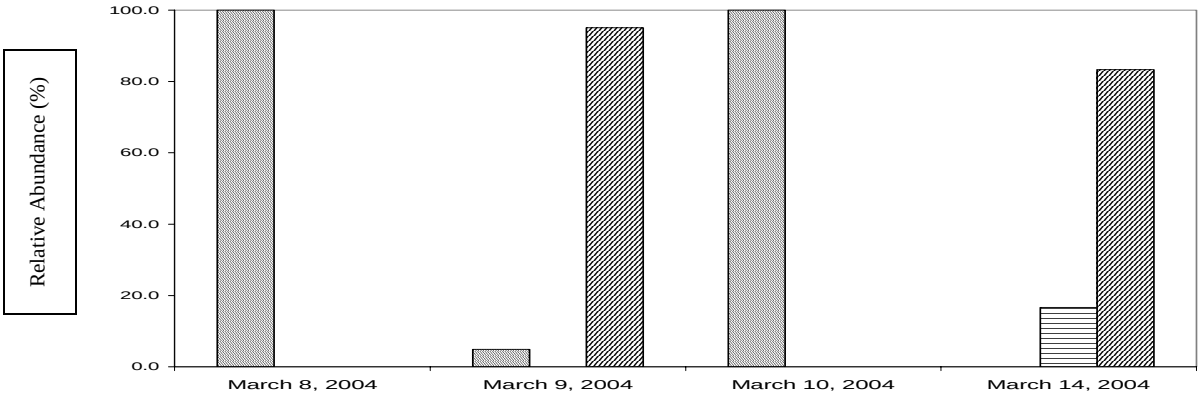


Figure 3-29. Adults aerially collected, N=220, (Part A), reared adults, N=294, (Part B), and preserved larvae, N=347, (Part C), from collection 18, January 23-31, 2004.

(A) Adults Aerially Collected



(B) Reared Adults



(C) Preserved Larvae

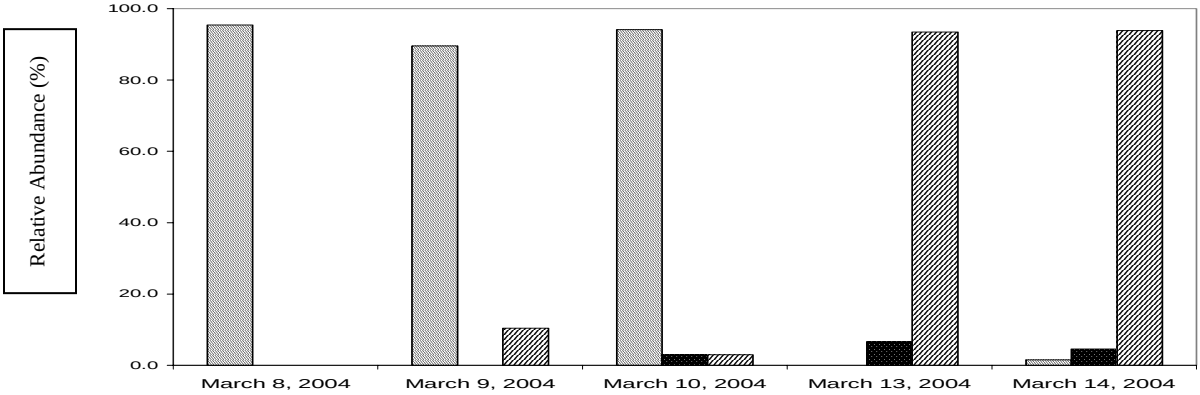


Figure 3-30. Adults aerially collected, N=316, (Part A), reared adults, N=639, (Part B), and preserved larvae, N=675, (Part C), from collection 19, March 5-14, 2004.

CHAPTER 4
DISCUSSION

The most common calliphorid species collected on pig carrion during the study aerially or by rearing was *Phaenicia coeruleiviridis*. Of the total adult specimens (N=6971) identified during the study, 75.0% were *P. coeruleiviridis*. Similarly, of the identifiable third-instar larvae (N=8253), 76.5% were *P. coeruleiviridis*. This species was most abundant from late October to the end of May (Figures 3-9 and 3-10). *Chrysomya rufifaces* and *C. macellaria* were also collected during those months, but in much smaller numbers. *Phaenicia coeruleiviridis* was less abundant during the summer months-when the temperatures were over 25.0º C. *Cochliomyia macellaria* was not present during the winter and was the most abundant species collected in June 2003 (Figures 3-9 and 3-10).

Phormia regina was present from mid-November 2001 until the end of July 2002 (Figures 3-9 and 3-10). No specimens were collected in August or September in 2002. It was the most abundant species collected in March 2004, but that was unusual compared to the rest of the study because *P. regina* was quite low in abundance compared to the other calliphorids. Hall (1948) found that *P. regina* is abundant in the spring months in the southern states (location not defined by Hall) but apparently this was not the case during my study in rural north-central Florida.

Of the seven species of calliphorids collected during the study, all were consistent with published distribution records, seasonality, and successional patterns (Campobasso et al. 2001). However, Byrd (1998) collected *Phaenica cuprina* (Wiedemann) (= *Phaenicia pallescens* Shannon) from pig carcasses in June and September 1996, and also

in September 1997, but this species was not found during this study. Byrd's study was conducted at an undesignated location in the Gainesville area, a "woodland habitat" (page 28 of dissertation), which consisted of a Live Oak hammock with no understory or roosting sites (for female blow flies) within close proximity to the pigs. *Phaenicia cuprina* is an urban fly that prefers excrement to carrion (Byrd 2001), which could explain why it was not found on pig carrion in rural Earleton.

During this study, the species and relative abundances of calliphorids found during adult aerial, reared and larval collections made during December 2002 and 2003 (Figures 3-23 A and B and 3-28 A-C) were similar, as were the collections made during November 2001 and November 2002 (Figures 3-12 A and B, 3-22 A-C). Finally, data obtained for three years (2002, 2003, and 2004) in March (Figures 3-15 A-C, 3-24 A-C, and 3-30 A-C) also yielded similar species and relative abundances of species. The congruence between these samples suggests that there is a consistent pattern in species composition and relative abundance through time in this sample site.

Common calliphorid species such as *Phaenicia sericata* and *Phaenicia eximia* apparently are not normally found in rural north-central Florida, but were found in the urban Gainesville area by Byrd (1998) and Peters (2003). Different calliphorids are associated with different habitats. An urban area, with odors from human refuse, cooking, garbage dumps, and improper sanitation will have different species assemblages than rural, wooded areas or arid regions. Some calliphorid species were not expected to be found because they are not associated with carrion. For example, Hall (1948) stated that the calliphorid *Pollenia rudis* (Fabricus) has been collected in northern Florida, but this species is exclusively a parasite of earthworms.

Calliphorid species (both adults and larvae) found on human remains (in cases from 1991) in Palm Beach and Lake Counties, Florida were identified as *C. rufifaces* and *C. macellaria* (Haskell 2003, personal communication). The evidentiary specimens were identified by Neal Haskell during the court cases. These two species were collected on pig carrion in rural north-central Florida during my study, on pig carrion in Gainesville by Byrd (1998) and on bear carrion in Gainesville by Peters (2003).

In northwest Indiana, Haskell (1989) found *P. regina* to be the most abundant species of Calliphoridae from late spring to early autumn. *Phaenicia coeruleiviridis* was dominant during the spring and autumn. Haskell also found a few *C. vicina* and *C. livida* specimens during the spring and autumn.

In West Virginia, Joy et al. (2002) found *P. regina* to be the dominant calliphorid in May 2002 on raccoon carrion. They found only a few *Phaenicia* species on these raccoons, which were killed by cars so that the time of death was unknown. The dead raccoons were frozen and transported to the site in garbage bags.

In Menard County Texas, Cushing and Parish (1938) captured *Cochliomyia* and *Phaenicia* species from April to November 1933, but *P. regina* was far more abundant. They caught hundreds of thousands of flies with pit-fall traps and traps baited with beef. No *P. coeruleiviridis* were found.

Calliphora vicina, C. livida, P. coeruleiviridis, C. macellaria, C. rufifaces, P. regina and *C. megacephala* were collected at both rural and urban sites during a recent pig carrion study in central Texas (Tenorio et al. 2003). *Phaenicia coeruleiviridis* was found from March until May while *C. livida* and *C. vicina* were found from December to May. *Cochliomyia macellaria* were found all year and *C. rufifaces* was found from

March until November. *Chrysomya megacephala* was found from September to November, and *P. regina* was not found from June through August.

In northern Mississippi, *P. coeruleiviridis, P. regina* and *C. macellaria* were the dominant species from April to September (Goddard and Lago 1985). *Phormia regina* was dominant from October to March on carcasses of rabbits, opossum, and fish carcasses.

Deonier (1937, 1938) collected hundreds of thousands of calliphorids with beef-baited traps in Arizona. *Phormia regina, C. macellaria* and *Phaenicia* species were found. *Cochliomyia macellaria* were captured in enormous numbers all year. A single *P. regina* specimen was collected in August and again in September of 1937, while almost 293,000 *C. macellaria* and 1000 *Phaenicia* species were collected at the same time (Deonier 1942).

Denno and Cothran (1975) found *P. sericata* and *P. regina* to be the dominant calliphorids on rabbit carrion in Davis, CA during June to September. Hall and Doisy (1993) found *C. macellaria, P. regina,* and *P coeruleiviridis* during their field studies in Missouri from mid-June to late August 1992.

Reed (1958) found *C. livida, C. vicina, C. macellaria, P. coeruleiviridis,* and *P. regina* during his dog carcass study in Tennessee. *Phormia regina* was the most abundant calliphorid species on the dog carcasses (Reed 1958).

Watson and Carlton (2003) conducted research in Louisiana from April 1 to July 1999 using bear, deer, alligator, and pig carcasses and found similar species to those of my study. The most common species on all four carcasses (in order of occurrence) were *P. regina, P. coeruleiviridis,* and *P. sericata*. Of note was that *P. coeruleiviridis* landed

on carcasses within minutes of deposition. *Cochliomyia macellaria* and *C. rufifaces* were also found on the pig carcasses, but in smaller numbers.

Peters (2003, page 78) conducted a carrion study using three dead bears (*Ursus americanus floridanus*) in the Gainesville area and concluded that "the most abundant blow fly found in north central Florida is the Hairy Maggot Blow Fly, *Chrysomya rufifaces*". Only 8 *P. coeruleiviridis* adults were among 94 calliphorid specimens collected by Peters (2003). This is contrary to my results, which indicate that *P. coeruleiviridis* is most abundant on pig carrion in this area while *C. rufifaces* consisted of less than 10 % of the total specimens collected during the entire study. The differences in our data are even greater when comparing abundances of *C. megacephala*, which consisted of less than 2.0 % of the total flies during my study while Peters found this species to comprise 44.7 % of adult calliphorids collected in her study.

The differences in our findings may be attributed to the following:

- The actual time of death of the bears was approximated; time "O" was not the actual time of death. Once retrieved by the wildlife officer, the dead bears were not protected in plastic or placed in containers while being transferred to the study site. At least 48 hours passed before any sample collections were taken on Bear 1. Therefore, each bear had a collection delay of **at least** 48 hours. These differences in the method of procuring and placement of carcasses may have resulted in completely missing the first wave of carrion insects attracted to fresh carcasses, specifically *P. coeruleiviridis.* Apparently, *P. coeruleiviridis* larvae were collected on all three bears, which clearly indicate that the adults had been present.

- Bears may decompose differently than do pigs or humans; bears have thick fur, thick skin, and layers of adipose tissue that are unique to bears (Watson and Carlton 2003). These differences may make bear carcasses more attractive to *C. rufifaces* and *C. megacephala* or less attractive to *P. coeruleiviridis*. Watson and Carlton (2003) noticed that *P. coeruleiviridis* arrived earlier on the carcasses of deer, alligator and pigs than on the carcass of the bear.

- The number of larval specimens collected or reared (if any) is not disclosed by Peters (2003). Apparently, only 94 adult calliphorid specimens were aerially collected, of which almost half were *C. megacephala* and 19 were *C. rufifaces*.

Additionally, aerial collections were made late in the day (between 5-6 PM) when some calliphorid flies are less active.

- The three bears were each placed at the site by Peters (2003) during different months of the year. As a result, there could be variability due to a lack of replications or different seasons.

In my study, *P. coeruleiviridis* was the most abundant species of calliphorid found on pig carrion in rural north-central Florida between 2001and 2004 during most of the year. This species was always the first to arrive at fresh pig carrion, the first to deposit eggs, the first to complete development and the first to migrate off the carcass to pupariate in the soil. In the spring and summer, these events took 5 days, or fewer, to complete. Depending on the season, and almost always after an approximate 24-h delay, *C. macellaria*, *C. rufifaces*, *P. regina* and *C. megacephala arrived* at the pig carcasses. *Calliphora livida* and *C. vicina* arrived at the carcasses also after a delay, but only a few specimens of each were collected (Figures 3-3 and 3-4).

Despite the fact that *P. coeruleiviridis* is commonly found in many other states, there are no developmental rate data for this species because, until now, no one has been able to successfully rear the larvae to adulthood (Haskell 1989, Hall and Doisy 1993). During this study, I discovered an organic pupation substrate that results in successful rearing of *P. coeruleiviridis* larvae to adulthood. Now that we can rear *P. coeruleivirdis,* we need detailed developmental rate data for this species so a forensic entomologist can determine accumulated degree hours (ADH) or days (ADD) to determine the postmortem interval.

The fact that we do not have developmental data for *P. coeruleiviridis* is very unfortunate because it is an important indicator species for determining PMI, especially in rural north-central Florida. Standardized rearing data are needed for *P. coeruleiviridis*,

as are rearing data for other calliphorids that are attracted to human remains including *Calliphora vicina, C. vomitoria, Eucalliphora* sp., *Cynomyopsis cadaverina, Phaenicia sericata, Lucilia Illustris, Phormia regina, Cochliomyia macellaria* and *Paralucilia wheeleri.*

APPENDIX A
RAW DATA: FLIES COLLECTED AS ADULTS OR REARED FROM LARVAE

PIG:	DATE:	A, R	sample #	# adults	*P. coerul.*	*C. macellaria*	*C. ruffifaces*	*P. regina*	*C. megaceph.*	*C. livida*	*C. vicina*
2A	11/16/2001	R	7A	21	8	0	13	0	0	0	0
2B	11/16/2001	R	8A	29	28	1	0	0	0	0	0
2B	11/21/2001	R	10A	157	157	0	0	0	0	0	0
2C	11/16/2001	R	9A	25	25	0	0	0	0	0	0
3A	1/11/2002	R	13A	145	145	0	0	0	0	0	0
3B	1/11/2002	R	17A	115	115	0	0	0	0	0	0
3C	1/11/2002	R	15A	102	100	0	0	0	0	1	1
4A	2/1/2002	A	23	4	4	0	0	0	0	0	0
4A	2/5/2002	R	24	54	54	0	0	0	0	0	0
4B	2/1/2002	A	22	12	12	0	0	0	0	0	0
4B	2/5/2002	R	25	71	71	0	0	0	0	0	0
4C	2/1/2002	A	21	12	12	0	0	0	0	0	0
4C	2/5/2002	R	26	38	38	0	0	0	0	0	0
4E	2/1/2002	A	20	11	11	0	0	0	0	0	0
4E	2/5/2002	R	27	55	55	0	0	0	0	0	0
4E	2/9/2002	R	28	87	87	0	0	0	0	0	0
5A	3/15/2002	A	30	17	17	0	0	0	0	0	0
5A	3/17/2002	R	35	59	59	0	0	0	0	0	0
5A	3/17/2002	A	36	22	22	0	0	0	0	0	0
5A	3/18/2002	R	47	65	65	0	0	0	0	0	0
5B	3/15/2002	A	31	15	15	0	0	0	0	0	0
5B	3/17/2002	R	40	56	56	0	0	0	0	0	0
5C	3/15/2002	A	32	7	7	0	0	0	0	0	0
5C	3/17/2002	R	38	42	42	0	0	0	0	0	0
5E	3/15/2002	A	33	10	8	0	0	2	0	0	0
5E	3/17/2002	R	42	47	47	0	0	0	0	0	0
5E	3/18/2002	R	44A	57	57	0	0	0	0	0	0
6A	4/29/2002	A	49	11	11	0	0	0	0	0	0
6A	5/1/2002	R	53	58	58	0	0	0	0	0	0
6A	5/1/2002	A	55	13	0	0	0	13	0	0	0
6B	4/29/2002	A	50	17	17	0	0	0	0	0	0
6B	5/1/2002	R	57	33	33	0	0	0	0	0	0
6B	5/1/2002	R	59	42	42	0	0	0	0	0	0
6B	5/1/2002	A	61	6	4	1	0	1	0	0	0
6C	4/29/2002	A	51	44	44	0	0	0	0	0	0
6C	5/1/2002	R	63	56	56	0	0	0	0	0	0
6C	5/1/2002	R	65	38	38	0	0	0	0	0	0
6C	5/1/2002	A	66	0	0	0	0	0	0	0	0
6E	4/29/2002	A	52	16	16	0	0	0	0	0	0
6E	4/29/2002	R	70	69	36	9	0	24	0	0	0

PIG:	DATE:	A, R	sample #	# adults	*P. coerul.*	*C. macellaria*	*C. ruffifaces*	*P. regina*	*C. megaceph.*	*C. livida*	*C. vicina*
6E	5/1/2002	R	68	36	36	0	0	0	0	0	0
7A	5/20/2002	A	72	11	0	11	0	0	0	0	0
7A	5/22/2002	A	76	18	3	6	3	6	0	0	0
7A	5/23/2002	A	77	8	1	1	2	4	0	0	0
7A	5/23/2002	R	78	67	67	0	0	0	0	0	0
7B	5/20/2002	A	73	12	4	2	6	0	0	0	0
7C	5/20/2002	A	74	2	1	0	0	1	0	0	0
7E	5/20/2002	A	75	0	0	0	0	0	0	0	0
8A	7/22/2002	A	80	0	0	0	0	0	0	0	0
8A	7/23/2002	A	84	11	4	3	3	1	0	0	0
8A	7/24/2002	A	91	11	0	0	9	0	2	0	0
8A	7/24/2002	R	92	21	21	0	0	0	0	0	0
8A	7/24/2002	R	94	25	24	0	1	0	0	0	0
8A	7/25/2002	R	107	57	0	0	57	0	0	0	0
8B	7/22/2002	A	81	9	8	1	0	0	0	0	0
8B	7/23/2002	A	87	13	10	0	2	1	0	0	0
8C	7/22/2002	A	82	11	11	0	0	0	0	0	0
8C	7/23/2002	A	86	7	5	0	2	0	0	0	0
8C	7/24/2002	A	102	5	0	0	5	0	0	0	0
8C	7/24/2002	R	103	42	42	0	0	0	0	0	0
8E	7/22/2002	A	85	8	3	0	5	0	0	0	0
8E	7/24/2002	A	83	17	17	0	0	0	0	0	0
8E	7/24/2002	A	97	7	0	1	5	0	1	0	0
8E	7/24/2002	R	98	24	18	0	6	0	0	0	0
8E	7/25/2002	R	109	54	0	0	54	0	0	0	0
9A	8/19/2002	A	111	14	14	0	0	0	0	0	0
9A	8/20/2002	A	115	18	18	0	0	0	0	0	0
9A	8/21/2002	R	119	5	2	0	1	0	2	0	0
9A	8/21/2002	A	123	10	3	1	6	0	0	0	0
9A	8/22/2002	A	153	2	0	2	0	0	0	0	0
9A	8/22/2002	R	157	11	8	0	1	0	2	0	0
9A	8/23/2002	R	154	27	4	1	20	0	2	0	0
9B	8/19/2002	A	112	2	2	0	0	0	0	0	0
9B	8/20/2002	A	116	10	10	0	0	0	0	0	0
9B	8/21/2002	R	124	43	16	0	7	0	20	0	0
9B	8/21/2002	A	125	10	3	1	6	0	0	0	0
9B	8/22/2002	A	148	4	1	0	2	0	1	0	0
9B	8/22/2002	R	149	14	12	0	1	0	1	0	0
9B	8/23/2002	R	151	38	0	0	38	0	0	0	0
9C	8/19/2002	A	113	1	1	0	0	0	0	0	0
9C	8/20/2002	A	117	12	11	0	1	0	0	0	0
9C	8/20/2002	A	134	0	0	0	0	0	0	0	0
9C	8/22/2002	R	135	13	4	0	7	0	2	0	0
9C	8/22/2002	R	137	16	14	0	0	0	2	0	0
9E	8/20/2002	A	118	11	10	0	1	0	0	0	0
9E	8/21/2002	A	129	8	0	0	7	0	1	0	0
9E	8/21/2002	R	130	27	27	0	0	0	0	0	0
9E	8/22/2002	A	114	11	7	2	2	0	0	0	0
9E	8/22/2002	A	142	5	0	2	3	0	0	0	0

PIG:	DATE:	A, R	sample #	# adults	*P. coerul.*	*C. macellaria*	*C. ruffifaces*	*P. regina*	*C. megaceph.*	*C. livida*	*C. vicina*
9E	8/22/2002	R	145	13	10	0	2	0	1	0	0
9E	8/23/2002	R	143	41	10	2	28	0	1	0	0
10A	9/23/2002	A	159	0	0	0	0	0	0	0	0
10A	9/25/2002	A	163	10	3	4	3	0	0	0	0
10A	9/25/2002	R	165	32	32	0	0	0	0	0	0
10A	9/26/2002	A	177	13	0	8	5	0	0	0	0
10A	9/26/2002	R	178	22	22	0	0	0	0	0	0
10A	9/26/2002	R	180	22	15	0	0	0	7	0	0
10B	9/23/2002	A	160	6	6	0	0	0	0	0	0
10B	9/25/2002	A	166	10	3	5	2	0	0	0	0
10B	9/25/2002	R	167	32	27	5	0	0	0	0	0
10B	9/26/2002	R	183	16	16	0	0	0	0	0	0
10B	9/26/2002	R	185	55	0	28	0	0	27	0	0
10C	9/23/2002	A	162	10	10	0	0	0	0	0	0
10C	9/25/2002	A	174	9	5	1	3	0	0	0	0
10C	9/25/2002	R	175	26	26	0	0	0	0	0	0
10C	9/27/2002	A	187	6	0	4	2	0	0	0	0
10C	9/27/2002	R	188	42	12	17	4	0	9	0	0
10E	9/23/2002	A	161	7	7	0	0	0	0	0	0
10E	9/25/2002	A	170	5	0	4	1	0	0	0	0
10E	9/25/2002	R	171	25	25	0	0	0	0	0	0
10E	9/27/2002	R	191	51	0	49	0	0	2	0	0
11A	10/26/2002	A	193	8	2	1	5	0	0	0	0
11A	10/27/2002	A	200	3	0	2	1	0	0	0	0
11A	10/27/2002	R	201	43	20	9	14	0	0	0	0
11A	10/27/2002	R	203	31	15	0	16	0	0	0	0
11A	10/28/2002	A	209	8	0	1	7	0	0	0	0
11A	10/28/2002	R	210	14	14	0	0	0	0	0	0
11A	10/28/2002	R	212	28	20	1	7	0	0	0	0
11B	10/26/2002	A	195	17	3	5	9	0	0	0	0
11B	10/26/2002	R	196	0	0	0	0	0	0	0	0
11C	10/26/2002	A	199	19	2	8	9	0	0	0	0
11C	10/28/2002	A	205	6	1	1	4	0	0	0	0
11C	10/28/2002	R	206	15	0	0	15	0	0	0	0
11E	10/26/2002	A	198	17	3	7	7	0	0	0	0
11E	10/28/2002	A	208	9	0	6	3	0	0	0	0
12A	11/30/2002	A	214	10	10	0	0	0	0	0	0
12A	12/7/2002	R	221	33	33	0	0	0	0	0	0
12A	12/8/2002	R	228	34	34	0	0	0	0	0	0
12A	12/8/2002	A	230	19	14	1	3	1	0	0	0
12A	12/12/2002	R	253	29	29	0	0	0	0	0	0
12A	12/13/2002	A	255	0	0	0	0	0	0	0	0
12A	12/14/2002	R	258	21	21	0	0	0	0	0	0
12B	11/30/2002	A	215	6	6	0	0	0	0	0	0
12B	11/30/2002	R	218	0	0	0	0	0	0	0	0
12B	12/7/2002	R	222	33	33	0	0	0	0	0	0
12B	12/8/2002	R	231	25	25	0	0	0	0	0	0
12B	12/8/2002	A	233	0	0	0	0	0	0	0	0
12B	12/12/2002	R	249	9	9	0	0	0	0	0	0

PIG:	DATE:	A, R	sample #	# adults	*P. coerul.*	*C. macellaria*	*C. ruffifaces*	*P. regina*	*C. megaceph.*	*C. livida*	*C. vicina*
12B	12/12/2002	R	251	2	2	0	0	0	0	0	0
12C	11/30/2002	A	216	10	10	0	0	0	0	0	0
12C	12/7/2002	R	226	24	24	0	0	0	0	0	0
12C	12/10/2002	R	235	27	27	0	0	0	0	0	0
12C	12/10/2002	R	239	46	0	0	46	0	0	0	0
12C	12/12/2002	R	245	9	9	0	0	0	0	0	0
12E	11/30/2002	A	217	7	7	0	0	0	0	0	0
12E	12/7/2002	R	224	38	38	0	0	0	0	0	0
12E	12/8/2002	A	234	8	8	0	0	0	0	0	0
12E	12/10/2002	R	240	36	36	0	0	0	0	0	0
12E	12/12/2002	R	247	18	18	0	0	0	0	0	0
13B	12/30/2002	A	262	2	2	0	0	0	0	0	0
13B	1/2/2003	A	263	17	17	0	0	0	0	0	0
13B	1/3/2003	R	266	27	27	0	0	0	0	0	0
13B	1/4/2003	R	276	30	27	0	0	0	0	3	0
13B	1/5/2003	R	283	21	21	0	0	0	0	0	0
13B	1/9/2003	R	292	20	20	0	0	0	0	0	0
13B	1/9/2003	A	294	0	0	0	0	0	0	0	0
13C	12/30/2002	A	261	7	7	0	0	0	0	0	0
13C	1/2/2003	A	264	8	7	0	0	0	0	1	0
13C	1/3/2003	R	270	27	27	0	0	0	0	0	0
13C	1/4/2003	R	274	21	21	0	0	0	0	0	0
13C	1/5/2003	A	281	1	1	0	0	0	0	0	0
13C	1/5/2003	R	282	34	34	0	0	0	0	0	0
13C	1/8/2003	R	290	9	9	0	0	0	0	0	0
13C	1/9/2003	R	298	27	27	0	0	0	0	0	0
13C	1/11/2003	R	300	28	28	0	0	0	0	0	0
13E	12/30/2002	A	260	13	13	0	0	0	0	0	0
13E	1/2/2003	A	265	4	4	0	0	0	0	0	0
13E	1/3/2003	R	268	17	17	0	0	0	0	0	0
13E	1/4/2003	R	272	25	25	0	0	0	0	0	0
13E	1/5/2003	A	278	1	1	0	0	0	0	0	0
13E	1/5/2003	R	279	28	28	0	0	0	0	0	0
13E	1/6/2003	A	285	3	3	0	0	0	0	0	0
13E	1/6/2003	R	286	39	39	0	0	0	0	0	0
13E	1/8/2003	R	288	9	9	0	0	0	0	0	0
13E	1/9/2003	R	295	9	9	0	0	0	0	0	0
13E	1/9/2003	A	297	0	0	0	0	0	0	0	0
14A	3/2/2003	A	318	16	16	0	0	0	0	0	0
14A	3/6/2003	R	304	39	38	0	0	1	0	0	0
14A	3/6/2003	R	306	42	40	0	0	2	0	0	0
14A	3/6/2003	A	308	16	11	0	0	5	0	0	0
14A	3/8/2003	R	314	15	15	0	0	0	0	0	0
14A	3/8/2003	R	316	26	26	0	0	0	0	0	0
14B	3/5/2003	A	301	20	19	0	0	0	0	1	0
14B	3/5/2003	R	302	21	21	0	0	0	0	0	0
14E	3/1/2003	A	300	11	10	0	0	0	0	1	0
14E	3/7/2003	R	309	23	23	0	0	0	0	0	0
14E	3/7/2003	A	311	3	2	0	0	1	0	0	0

PIG:	DATE:	A, R	sample #	# adults	*P. coerul.*	*C. macellaria*	*C. ruffifaces*	*P. regina*	*C. megaceph.*	*C. livida*	*C. vicina*
14E	3/7/2003	R	312	0	0	0	0	0	0	0	0
15A	4/1/2003	A	320	13	13	0	0	0	0	0	0
15A	4/2/2003	A	324	21	20	0	0	1	0	0	0
15A	4/4/2003	A	330	18	6	12	0	0	0	0	0
15A	4/5/2003	R	340	23	21	0	0	2	0	0	0
15A	4/5/2003	A	342	12	4	8	0	0	0	0	0
15A	4/6/2003	A	352	16	7	6	0	3	0	0	0
15A	4/6/2003	R	353	2	0	0	0	2	0	0	0
15B	4/1/2003	A	321	9	9	0	0	0	0	0	0
15B	4/2/2003	A	325	26	25	0	0	1	0	0	0
15B	4/4/2003	R	331	28	20	1	0	7	0	0	0
15B	4/4/2003	A	333	13	11	2	0	0	0	0	0
15B	4/5/2003	R	343	24	19	2	0	3	0	0	0
15B	4/5/2003	A	345	6	3	1	0	2	0	0	0
15C	4/1/2003	A	319	10	10	0	0	0	0	0	0
15C	4/2/2003	A	323	21	21	0	0	0	0	0	0
15C	4/4/2003	A	327	20	15	3	0	2	0	0	0
15C	4/4/2003	R	329	52	50	0	1	1	0	0	0
15C	4/5/2003	R	337	0	0	0	0	0	0	0	0
15C	4/5/2003	A	339	21	7	10	0	4	0	0	0
15C	4/6/2003	A	349	0	0	0	0	0	0	0	0
15C	4/6/2003	R	350	13	3	4	0	6	0	0	0
15E	4/1/2003	A	322	11	9	2	0	0	0	0	0
15E	4/2/2003	A	326	10	10	0	0	0	0	0	0
15E	4/4/2003	R	334	23	23	0	0	0	0	0	0
15E	4/4/2003	A	336	12	10	1	0	1	0	0	0
15E	4/5/2003	R	346	28	21	5	0	2	0	0	0
15E	4/5/2003	A	348	6	5	1	0	0	0	0	0
15E	4/6/2003	R	355	36	1	17	0	18	0	0	0
15E	4/6/2003	A	357	2	1	1	0	0	0	0	0
16B	4/26/2003	A	358	31	31	0	0	0	0	0	0
16B	4/27/2003	A	365	11	11	0	0	0	0	0	0
16B	4/28/2003	A	372	13	9	3	0	1	0	0	0
16B	4/28/2003	R	373	33	28	5	0	0	0	0	0
16B	4/29/2003	R	381	34	34	0	0	0	0	0	0
16B	4/29/2003	A	389	6	5	1	0	0	0	0	0
16B	4/30/2003	A	388	19	19	0	0	0	0	0	0
16C	4/26/2003	A	360	14	13	1	0	0	0	0	0
16C	4/27/2003	A	361	21	9	12	0	0	0	0	0
16C	4/28/2003	A	366	14	1	11	1	1	0	0	0
16C	4/28/2003	R	367	34	32	2	0	0	0	0	0
16C	4/29/2003	A	375	11	2	8	0	1	0	0	0
16C	4/29/2003	R	376	63	0	59	0	4	0	0	0
16C	4/30/2003	A	383	5	0	5	0	0	0	0	0
16C	4/30/2003	R	384	85	0	84	0	1	0	0	0
16C	5/1/2003	A	393	0	0	0	0	0	0	0	0
16E	4/26/2003	A	359	16	16	0	0	0	0	0	0
16E	4/27/2003	A	362	13	6	7	0	0	0	0	0
16E	4/27/2003	R	363	19	19	0	0	0	0	0	0

PIG:	DATE:	A, R	sample #	# adults	*P. coerul.*	*C. macellaria*	*C. ruffifaces*	*P. regina*	*C. megaceph.*	*C. livida*	*C. vicina*
16E	4/28/2003	A	369	11	4	6	0	1	0	0	0
16E	4/28/2003	R	370	33	33	0	0	0	0	0	0
16E	4/29/2003	A	378	0	0	0	0	0	0	0	0
16E	4/29/2003	R	379	32	32	0	0	0	0	0	0
16E	4/30/2003	R	386	26	4	18	0	4	0	0	0
17B	6/12/2003	A	396	16	8	8	0	0	0	0	0
17B	6/13/2003	A	399	23	22	1	0	0	0	0	0
17B	6/14/2003	A	400	30	0	20	0	10	0	0	0
17B	6/14/2003	R	401	10	1	9	0	0	0	0	0
17B	6/15/2003	R	419	20	0	14	6	0	0	0	0
17B	6/15/2003	A	421	13	0	13	0	0	0	0	0
17C	6/12/2003	A	394	46	27	19	0	0	0	0	0
17C	6/13/2003	A	398	0	0	0	0	0	0	0	0
17C	6/14/2003	R	403	0	0	0	0	0	0	0	0
17C	6/14/2003	A	405	18	6	10	2	0	0	0	0
17C	6/15/2003	R	414	5	0	1	4	0	0	0	0
17C	6/15/2003	A	416	12	0	10	2	0	0	0	0
17C	6/15/2003	R	417	32	0	0	32	0	0	0	0
17E	6/12/2003	A	395	31	19	11	1	0	0	0	0
17E	6/13/2003	A	397	0	0	0	0	0	0	0	0
17E	6/13/2003	R	401	21	7	14	0	0	0	0	0
17E	6/14/2003	R	406	28	0	28	0	0	0	0	0
17E	6/14/2003	A	408	13	0	13	0	0	0	0	0
17E	6/15/2003	R	409	24	0	24	0	0	0	0	0
17E	6/15/2003	A	411	19	0	19	0	0	0	0	0
17E	6/15/2003	R	412	10	1	7	2	0	0	0	0
18A	12/8/2003	A	424	23	23	0	0	0	0	0	0
18A	12/10/2003	A	428	10	10	0	0	0	0	0	0
18A	12/13/2003	R	439	9	9	0	0	0	0	0	0
18A	12/13/2003	A	441	14	14	0	0	0	0	0	0
18A	12/14/2003	R	448	22	22	0	0	0	0	0	0
18A	12/14/2003	A	450	4	4	0	0	0	0	0	0
18A	12/16/2003	R	457	24	24	0	0	0	0	0	0
18A	12/16/2003	A	459	9	7	0	0	2	0	0	0
18A	12/20/2003	R	464	23	21	0	0	2	0	0	0
18B	12/8/2003	A	422	10	10	0	0	0	0	0	0
18B	12/10/2003	A	427	13	13	0	0	0	0	0	0
18B	12/11/2003	A	429	2	0	0	0	0	0	2	0
18B	12/12/2003	A	430	6	5	0	0	1	0	0	0
18B	12/12/2003	R	432	23	23	0	0	0	0	0	0
18B	12/13/2003	A	436	20	17	0	0	3	0	0	0
18B	12/13/2003	R	437	16	16	0	0	0	0	0	0
18B	12/14/2003	R	445	25	25	0	0	0	0	0	0
18B	12/14/2003	A	447	4	2	0	1	1	0	0	0
18B	12/16/2003	A	454	8	5	0	1	2	0	0	0
18B	12/16/2003	R	455	25	25	0	0	0	0	0	0
18C	12/8/2003	A	423	9	9	0	0	0	0	0	0
18C	12/10/2003	A	426	9	9	0	0	0	0	0	0
18C	12/12/2003	A	425	0	0	0	0	0	0	0	0

PIG:	DATE:	A, R	sample #	# adults	*P. coerul.*	*C. macellaria*	*C. ruffifaces*	*P. regina*	*C. megaceph.*	*C. livida*	*C. vicina*
18C	12/13/2003	A	433	14	13	0	1	0	0	0	0
18C	12/13/2003	R	434	20	20	0	0	0	0	0	0
18C	12/14/2003	R	442	20	20	0	0	0	0	0	0
18C	12/14/2003	A	444	16	13	1	1	1	0	0	0
18C	12/16/2003	A	451	15	13	0	0	2	0	0	0
18C	12/16/2003	R	452	20	11	0	9	0	0	0	0
18C	12/17/2003	R	460	19	19	0	0	0	0	0	0
18C	12/17/2003	R	462	20	20	0	0	0	0	0	0
19A	1/23/2004	A	468	14	14	0	0	0	0	0	0
19A	1/25/2004	A	469	19	19	0	0	0	0	0	0
19A	1/26/2004	A	474	16	16	0	0	0	0	0	0
19A	1/27/2004	R	476	0	0	0	0	0	0	0	0
19A	1/27/2004	A	477	21	19	0	0	2	0	0	0
19A	1/28/2004	R	490	31	31	0	0	0	0	0	0
19A	1/29/2004	R	492	27	27	0	0	0	0	0	0
19A	1/29/2004	A	494	2	1	0	0	1	0	0	0
19B	1/24/2004	A	467	7	6	0	0	0	0	1	0
19B	1/25/2004	A	470	22	22	0	0	0	0	0	0
19B	1/26/2004	A	473	27	25	0	0	1	0	1	0
19B	1/27/2004	R	478	45	45	0	0	0	0	0	0
19B	1/27/2004	A	480	15	15	0	0	0	0	0	0
19B	1/28/2004	R	487	32	30	0	0	2	0	0	0
19B	1/28/2004	A	489	1	0	0	0	1	0	0	0
19B	1/29/2004	R	495	37	36	0	0	1	0	0	0
19B	1/30/2004	A	502	3	2	0	0	1	0	0	0
19B	1/31/2004	A	507	1	1	0	0	0	0	0	0
19C	1/24/2004	A	466	11	11	0	0	0	0	0	0
19C	1/25/2004	A	471	0	0	0	0	0	0	0	0
19C	1/26/2004	A	472	42	39	0	0	2	0	1	0
19C	1/27/2004	R	482	41	41	0	0	0	0	0	0
19C	1/27/2004	A	483	8	4	0	0	4	0	0	0
19C	1/28/2004	R	484	55	42	0	0	13	0	0	0
19C	1/28/2004	A	486	2	1	0	0	0	1	0	0
19C	1/29/2004	R	497	26	25	0	0	1	0	0	0
19C	1/30/2004	A	500	8	7	0	0	1	0	0	0
19C	1/31/2004	A	505	1	1	0	0	0	0	0	0
20A	3/6/2004	A	512	31	29	0	0	2	0	0	0
20A	3/7/2004	A	516	21	18	0	0	3	0	0	0
20A	3/8/2004	A	518	17	4	0	0	13	0	0	0
20A	3/8/2004	R	519	47	47	0	0	0	0	0	0
20A	3/9/2004	A	530	4	1	0	0	3	0	0	0
20A	3/9/2004	R	531	14	2	0	0	12	0	0	0
20A	3/14/2004	A	548	0	0	0	0	0	0	0	0
20B	3/5/2004	A	536	1	1	0	0	0	0	0	0
20B	3/6/2004	A	511	17	12	0	0	5	0	0	0
20B	3/7/2004	A	515	22	6	2	0	14	0	0	0
20B	3/8/2004	A	521	14	0	1	0	13	0	0	0
20B	3/8/2004	R	523	0	0	0	0	0	0	0	0
20B	3/9/2004	A	527	7	0	0	0	7	0	0	0

PIG:	DATE:	A, R	sample #	# adults	*P. coerul.*	*C. macellaria*	*C. ruffifaces*	*P. regina*	*C. megaceph.*	*C. livida*	*C. vicina*
20B	3/9/2004	R	528	47	1	0	0	46	0	0	0
20B	3/10/2004	R	537	35	0	0	0	35	0	0	0
20B	3/13/2004	A	543	8	3	3	0	2	0	0	0
20B	3/14/2004	A	545	23	1	5	0	17	0	0	0
20B	3/14/2004	R	547	6	0	0	1	5	0	0	0

APPENDIX B
RAW DATA: PRESERVED SPECIMENS

PIG:	DATE:	sample #	1st instar	1-2 trans.	2nd instar	2-3 trans.	3rd instar	total	*P. coerul.*	*C. mac.*	*C. ruf.*	*P. regina*	? 3rd
2B	11/21/2001	10B	0	0	0	0	0	0	0	0	0	0	0
3A	12/29/2001	11A	0	0	0	0	0	0	0	0	0	0	0
3A	1/11/2002	14	0	0	42	11	219	272	108	0	0	98	13
3B	12/29/2001	12A	0	0	0	0	90	90	90	0	0	0	0
3B	1/11/2002	18	0	0	0	1	152	153	148	0	0	4	0
3C	1/11/2002	16	0	0	8	2	107	117	107	0	0	0	0
4E	2/9/2002	29	19	4	64	16	151	254	107	0	0	44	0
5A	3/17/2002	34	66	17	56	14	0	153	0	0	0	0	0
5A	3/18/2002	46	0	0	17	19	79	115	76	0	0	0	3
5B	3/17/2002	39	82	35	80	2	0	199	0	0	0	0	0
5C	3/17/2002	37	34	3	129	5	14	185	14	0	0	0	0
5C	3/18/2002	43	254	52	16	0	0	322	0	0	0	0	0
5E	3/17/2002	41	82	10	24	0	0	116	0	0	0	0	0
5E	3/18/2002	45	0	0	88	6	7	101	7	0	0	0	0
5E	3/19/2002	48	0	2	61	12	34	109	34	0	0	0	0
6A	5/1/2002	54	17	8	73	10	13	121	13	0	0	0	0
6A	5/1/2002	58	1	2	75	8	59	145	59	0	0	0	0
6B	5/1/2002	58	0	0	0	0	0	0	0	0	0	0	0
6B	5/1/2002	60	174	1	0	0	0	175	0	0	0	0	0
6C	5/1/2002	62	5	2	59	48	10	124	10	0	0	0	0
6C	5/1/2002	64	1	0	14	7	63	85	63	0	0	0	0
6E	5/1/2002	67	12	5	73	0	10	100	10	0	0	0	0
6E	5/1/2002	69	78	5	39	10	8	140	8	0	0	0	0
6E	5/1/2002	71	0	0	17	4	33	54	33	0	0	0	0
7A	5/23/2002	79	1	0	19	1	175	196	175	0	0	0	0
8A	7/23/2002	88	138	7	0	0	0	145	0	0	0	0	0
8A	7/24/2002	93	2	0	31	6	65	104	65	0	0	0	0
8A	7/24/2002	95	51	20	50	0	1	122	1	0	0	0	0
8A	7/24/2002	96	8	1	89	8	2	108	1	0	1	0	0
8A	7/25/2002	106	0	0	14	12	164	190	0	0	164	0	0
8A	7/25/2002	108	0	0	47	8	241	296	0	0	241	0	0
8C	7/23/3003	90	0	0	0	0	0	0	0	0	0	0	0
8C	7/24/2002	104	9	1	76	40	77	203	77	0	0	0	0
8C	7/24/2002	105	15	1	41	28	54	139	54	0	0	0	0
8E	7/23/2002	89	10	4	40	0	0	54	0	0	0	0	0
8E	7/24/2002	99	14	1	111	6	16	148	15	0	1	0	0
8E	7/24/2002	100	400	53	49	0	0	502	0	0	0	0	0
8E	7/24/2002	101	43	14	28	1	10	96	8	0	2	0	0
8E	7/25/2002	110	0	0	3	2	70	75	0	0	70	0	0

PIG:	DATE:	sample #	1st instar	1-2 trans.	2nd instar	2-3 trans.	3rd instar	total	*P. coerul.*	*C. mac.*	*C. ruf.*	*P. regina*	? 3rd
9A	8/21/2002	120	2	1	126	7	17	153	17	0	0	0	0
9A	8/21/2002	120B	6	2	115	15	11	149	11	0	0	0	0
9A	8/21/2002	121	102	23	55	0	0	180	0	0	0	0	0
9A	8/21/2002	122	108	3	45	0	2	158	2	0	0	0	0
9A	8/22/2002	155	4	6	52	5	34	101	34	0	0	0	0
9A	8/22/2002	156	8	0	1	3	14	26	1	0	13	0	0
9A	8/22/2002	158	0	0	7	1	49	57	48	0	0	1	0
9B	8/21/2002	126	29	2	39	24	17	111	17	0	0	0	0
9B	8/21/2002	126B	16	2	42	18	10	88	9	0	0	1	0
9B	8/21/2002	127	183	0	0	0	0	183	0	0	0	0	0
9B	8/21/2002	128	12	0	49	12	2	75	2	0	0	0	0
9B	8/22/2002	150	0	0	6	6	54	66	53	0	0	1	0
9B	8/22/2003	152	13	2	36	22	1	74	0	0	1	0	0
9C	8/22/2002	136	3	0	8	10	32	53	5	0	27	0	0
9C	8/22/2002	138	0	0	2	1	40	43	33	0	0	7	0
9C	8/22/2002	139	9	2	3	3	9	26	4	0	5	0	0
9C	8/22/2002	140	116	17	23	9	18	183	18	0	0	0	0
9C	8/22/2002	141	0	0	11	4	40	55	38	0	1	1	0
9E	8/21/2002	131	0	0	8	3	31	42	31	0	0	0	0
9E	8/21/2002	131B	0	0	15	1	29	45	24	0	3	2	0
9E	8/21/2002	132	0	0	0	0	0	0	0	0	0	0	0
9E	8/21/2002	133	34	4	111	21	11	181	11	0	0	0	0
9E	8/22/2002	144	3	3	42	7	17	72	13	2	0	1	1
9E	8/22/2002	146	1	0	61	9	20	91	2	0	18	0	0
9E	8/22/2002	147	0	0	19	8	41	68	41	0	0	0	0
10A	9/25/2002	164	0	0	20	49	23	92	23	0	0	0	0
10A	9/26/2002	179	0	0	0	0	137	137	135	2	0	0	0
10A	9/26/2002	181	33	8	186	30	32	289	32	0	0	0	0
10B	9/25/2002	168	1	3	50	74	25	153	25	0	0	0	0
10B	9/25/2002	169	3	11	189	17	0	220	0	0	0	0	0
10B	9/26/2002	182	15	1	8	0	73	97	71	0	2	0	0
10B	9/26/2002	184	0	0	0	0	8	8	0	3	5	0	0
10B	9/26/2002	186	89	20	87	0	1	197	1	0	0	0	0
10C	9/25/2002	176	0	0	45	20	9	74	9	0	0	0	0
10C	9/27/2002	189	0	0	29	24	88	141	43	43	0	2	0
10E	9/25/2002	172	0	0	35	17	35	87	35	0	0	0	0
10E	9/25/2002	173	3	2	32	7	86	130	86	0	0	0	0
10E	9/27/2002	190	0	0	0	0	72	72	0	0	72	0	0
10E	9/27/2002	192	0	0	30	7	108	145	1	102	0	5	0
11A	10/26/2002	194	0	0	0	0	0	0	0	0	0	0	0
11A	10/27/2002	202	0	1	7	24	82	114	54	4	24	0	0
11A	10/27/2002	204	94	28	31	30	14	197	13	0	1	0	0
11A	10/28/2002	211	0	0	14	14	98	126	98	0	0	0	0
11A	10/28/2002	213	0	0	28	48	22	98	0	22	0	0	0
11B	10/26/2002	197	170	13	56	2	9	250	9	0	0	0	0
11C	10/28/2002	207	0	0	1	0	69	70	0	0	69	0	0
12A	12/7/2002	220	1	3	111	45	62	222	62	0	0	0	0
12A	12/8/2002	229	0	0	86	5	33	124	33	0	0	0	0
12A	12/12/2002	254	0	4	52	48	52	156	52	0	0	0	0

PIG:	DATE:	sample #	1st instar	1-2 trans.	2nd instar	2-3 trans.	3rd instar	total	*P. coerul.*	*C. mac.*	*C. ruf.*	*P. regina*	? 3rd
12A	12/13/2002	256	0	0	4	0	85	89	85	0	0	0	0
12A	12/13/2002	257	0	0	10	6	61	77	61	0	0	0	0
12A	12/14/2002	259	0	0	10	5	99	114	99	0	0	0	0
12B	11/30/2002	219	0	0	0	0	0	0	0	0	0	0	0
12B	12/7/2002	223	3	2	126	23	6	160	6	0	0	0	0
12B	12/8/2002	232	0	0	59	2	25	86	25	0	0	0	0
12B	12/10/2002	242	7	4	46	14	149	220	146	3	0	0	0
12B	12/10/2002	243	0	0	1	1	111	113	111	0	0	0	0
12B	12/10/2002	244	1	0	3	4	135	143	135	0	0	0	0
12B	12/12/2002	250	3	3	47	12	22	87	22	0	0	0	0
12B	12/12/2002	252	0	6	109	50	24	189	24	0	0	0	0
12C	12/7/2002	227	0	0	55	17	33	105	33	0	0	0	0
12C	12/10/2002	236	22	5	53	16	27	123	27	0	0	0	0
12C	12/10/2002	237	0	0	9	1	56	66	56	0	0	0	0
12C	12/10/2002	238	0	0	6	2	103	111	103	0	0	0	0
12C	12/12/2002	246	2	1	10	0	24	37	24	0	0	0	0
12E	12/7/2002	225	5	8	161	11	5	190	5	0	0	0	0
12E	12/10/2002	241	89	5	24	17	34	169	34	0	0	0	0
12E	12/12/2002	248	0	0	13	1	102	116	102	0	0	0	0
13B	1/3/2003	267	0	0	0	0	0	0	0	0	0	0	0
13B	1/4/2003	277	0	0	0	0	0	0	0	0	0	0	0
13B	1/5/2003	284	2	1	109	2	0	114	0	0	0	0	0
13B	1/9/2003	293	2	1	19	6	69	97	69	0	0	0	0
13C	1/3/2003	271	12	5	76	6	1	100	0	1	0	0	0
13C	1/4/2003	275	0	1	29	25	51	106	51	0	0	0	0
13C	1/5/2003	283	0	0	72	16	33	121	33	0	0	0	0
13C	1/8/2003	291	0	0	6	1	101	108	101	0	0	0	0
13C	1/9/2003	299	0	0	38	5	42	85	42	0	0	0	0
13C	1/11/2003	301	3	0	84	7	3	97	2	0	0	0	1
13E	1/3/2003	269	2	0	69	15	8	94	8	0	0	0	0
13E	1/4/2003	273	21	3	75	46	28	173	28	0	0	0	0
13E	1/5/2003	280	0	0	12	3	61	76	61	0	0	0	0
13E	1/6/2003	287	0	0	0	1	83	84	83	0	0	0	0
13E	1/8/2003	289	0	0	23	37	47	107	42	0	0	0	5
13E	1/9/2003	296	0	0	3	0	54	57	54	0	0	0	0
14A	3/6/2003	305	0	0	2	1	71	74	0	0	0	71	0
14A	3/6/2003	307	44	0	263	4	7	318	6	0	0	0	1
14A	3/8/2003	315	0	0	8	0	97	105	97	0	0	0	0
14A	3/8/2003	317	0	0	2	0	47	49	47	0	0	0	0
14B	3/5/2003	303	0	0	10	2	52	64	27	0	0	25	0
14E	3/7/2003	310	2	0	73	4	37	116	37	0	0	0	0
14E	3/7/2003	313	5	0	60	6	29	100	29	0	0	0	0
15A	4/5/2003	341	1	0	0	11	27	39	27	0	0	0	0
15A	4/6/2003	354	0	0	1	1	66	68	49	0	0	17	0
15B	4/4/2003	332	32	6	130	13	0	181	0	0	0	0	0
15B	4/5/2003	344	105	0	89	8	4	206	4	0	0	0	0
15C	4/4/2003	328	60	5	92	0	0	157	0	0	0	0	0
15C	4/4/2003	329	0	0	0	0	0	0	0	0	0	0	0
15C	4/5/2003	338	15	1	102	1	7	126	7	0	0	0	0

PIG:	DATE:	sample #	1st instar	1-2 trans.	2nd instar	2-3 trans.	3rd instar	total	P. coerul.	C. mac.	C. ruf.	P. regina	? 3rd
15C	4/6/2003	351	1	0	20	2	70	93	70	0	0	0	0
15E	4/4/2003	335	44	10	122	8	2	186	0	0	0	2	0
15E	4/5/2003	347	5	0	30	4	67	106	67	0	0	0	0
15E	4/6/2003	356	0	0	0	0	58	58	10	25	0	23	0
16B	4/28/2003	374	54	10	15	0	0	79	0	0	0	0	0
16B	4/29/2003	382	0	0	106	0	104	210	104	0	0	0	0
16C	4/28/2003	368	1	0	59	6	10	76	6	3	0	1	0
16C	4/29/2003	377	0	0	63	0	32	95	23	9	0	0	0
16C	4/30/2003	385	0	0	4	0	105	109	0	105	0	0	0
16C	5/1/2003	390	0	0	0	0	67	67	0	67	0	0	0
16C	5/1/2003	391	0	0	0	1	61	62	2	58	0	1	0
16C	5/1/2003	392	0	0	0	0	41	41	0	41	0	0	0
16E	4/27/2003	364	28	9	13	0	0	50	0	0	0	0	0
16E	4/28/2003	371	0	0	34	0	43	77	43	0	0	0	0
16E	4/29/2003	380	0	2	2	1	134	139	134	0	0	0	0
16E	4/30/2003	387	0	0	1	0	54	55	17	29	0	7	1
17B	6/14/2003	402	99	17	113	13	22	264	22	0	0	0	0
17B	6/15/2003	420	0	1	12	3	44	60	44	0	0	0	0
17C	6/14/2003	404	192	0	9	0	40	241	40	0	0	0	0
17C	6/15/2003	415	0	0	1	1	29	31	7	4	18	0	0
17C	6/15/2003	418	0	0	6	0	75	81	11	64	0	0	0
17E	6/13/2003	400A	153	6	3	0	0	162	0	0	0	0	0
17E	6/14/2003	407	8	3	73	3	73	160	73	0	0	0	0
17E	6/15/2003	410	0	0	77	1	45	123	35	2	3	5	0
17E	6/15/2003	413	0	0	14	4	60	78	54	5	0	0	1
18A	12/13/2003	440	50	10	88	2	0	150	0	0	0	0	0
18A	12/14/2003	449	28	0	270	2	4	304	2	0	0	2	0
18A	12/16/2003	458	4	0	121	6	14	145	10	0	0	4	0
18A	12/20/2003	465	1	8	31	0	52	92	50	0	2	0	0
18B	12/12/2003	431	129	21	9	3	0	162	0	0	0	0	0
18B	12/13/2003	438	0	0	68	0	2	70	2	0	0	0	0
18B	12/14/2003	446	4	0	84	20	36	144	12	0	0	24	0
18B	12/16/2003	456	0	0	92	8	85	185	77	0	0	8	0
18C	12/13/2003	435	10	2	178	4	0	194	0	0	0	0	0
18C	12/14/2003	443	2	0	0	8	192	202	176	0	0	16	0
18C	12/16/2003	453	0	0	19	2	94	115	88	0	6	0	0
18C	12/17/2003	461	0	0	0	0	70	70	70	0	0	0	0
18C	12/17/2004	463	0	0	15	2	99	116	99	0	0	0	0
19A	1/27/2004	475	122	12	110	0	0	244	0	0	0	0	0
19A	1/28/2004	491	12	0	138	6	18	174	4	0	0	14	0
19A	1/29/2004	493	4	0	68	0	38	110	24	0	0	14	0
19A	1/30/2004	503	0	0	11	0	57	68	57	0	0	0	0
19A	1/31/2004	508	0	0	2	1	58	61	58	0	0	0	0
19B	1/27/2004	479	224	26	44	0	0	294	0	0	0	0	0
19B	1/28/2004	488	107	0	3	0	0	110	0	0	0	0	0
19B	1/29/2004	496	46	2	128	6	12	194	0	0	0	12	0
19B	1/30/2004	501	10	0	70	12	38	130	20	0	0	18	0
19B	1/31/2004	506	0	0	23	1	61	85	61	0	0	0	0
19C	1/27/2004	481	88	0	0	0	0	88	0	0	0	0	0

PIG:	DATE:	sample #	1st instar	1-2 trans.	2nd instar	2-3 trans.	3rd instar	total	P. coerul.	C. mac.	C. ruf.	P. regina	? 3rd
19C	1/28/2004	485	76	0	74	0	0	150	0	0	0	0	0
19C	1/29/2004	498	48	0	150	10	2	210	0	0	0	2	0
19C	1/30/2004	499	0	0	56	1	17	74	17	0	0	0	0
19C	1/31/2004	504	0	0	70	4	46	120	46	0	0	0	0
20A	3/8/2004	520	0	0	138	4	16	158	14	0	0	2	0
20A	3/9/2004	532	13	0	67	2	45	127	38	0	0	7	0
20B	3/8/2004	522	0	0	280	20	28	328	28	0	0	0	0
20B	3/9/2004	529	24	0	70	8	22	124	22	0	0	0	0
20B	3/10/2004	538	0	0	20	0	68	90	64	2	0	2	0
20B	3/13/2004	544	0	0	10	0	61	71	0	4	0	57	0
20B	3/14/2004	546	0	0	0	1	65	66	1	3	0	61	0

LIST OF REFERENCES

Abell, D. H., S. S. Wasti, and G. C. Hartmann. 1982. Saprophagous arthropod fauna associated with turtle carrion. Appl. Entomol. Zool. 17: 301-307.

Adair, T. W. 1999. Three species of blowfly (Diptera: Calliphoridae) collected from a human stillborn infant in the Rocky Mountains of Colorado. J. Med. Entomol. 36: 236-237.

Aldrich, J. M. 1916. Sarcophaga and Allies. Thomas Say Foundation, Lafayette, IN. 301 pp.

Anderson, G. S. 1998. Wildlife forensic entomology: determining time of death in two illegally killed black bear cubs. J. Forensic Sci. 44: 856-859.

Anderson, G. S. 2001. Insect succession on carrion and its relationship to determining time of death. *In* J. H. Byrd and J. L. Castner [eds.], Forensic Entomology: The Utility of Arthropods in Legal Investigations. CRC Press, Boca Raton. pp. 143-175.

Anderson, G. S., and S. L. VanLaerhoven. 1996. Initial studies on insect succession on carrion in southwestern British Columbia. J. Forensic Sci. 41: 617-625.

Ashworth, J. R., and R. Wall. 1994. Responses of the sheep blowflies *Lucilia sericata* and *L. cuprina* to odour and the development of semiochemical baits. Med. Vet. Entomol. 8: 303-309.

Bass, W. M. 2001. Preface. *In* J. H. Byrd and J. L. Castner [eds.], Forensic Entomology: The Utility of Arthropods in Legal Investigations. CRC Press, Boca Raton. pp. ix-x.

Baumgartner, D. L. 1986. The hairy maggot blow fly *Chrysomya Rufifaces* (Maquart) confirmed in Arizona. J. Entomol. Sci. 21: 130-132.

Baumgartner, D. L. 1988. Spring season survey of the urban blowflies (Diptera: Calliphoridae) of Chicago, Illinois. Great Lakes Entomol. 21: 119-121.

Baumgartner, D. L., and B. Greenberg. 1984. The Genus *Chrysomya* (Diptera: Calliphoridae) in the new world. J. Med. Entomol. 21: 105-113.

Benecke, M. 1998. Six forensic entomology cases: description and commentary. J. Forensic Sci. 43: 797-805.

Benecke, M. 2001. A brief history of forensic entomology. Forensic Sci. Int. 120: 2-14.

Blackith, R. E., and R. M. Blackith. 1989. Insect infestations of small corpses. J. Nat. Hist. 24: 699-709.

Bornemissza, G. F. 1957. An analysis of arthropod succession in carrion and the effect of its decomposition on the soil fauna. Aust. J. Zool. 5: 1-12.

Bourel, B., L. Martin-Bouyer, V. Hedouin, J.-C. Cailliez, D. Derout, and D. Gosset. 1999. Necrophilous insect succession on rabbit carrion in sand dune habitats in northern France. J. Med. Entomol. 36: 420-425.

Braack, L. E. O. 1981. Visitation patterns of principal species of the insect-complex at carcasses in the Kruger National Park. Koedoe 24: 33-49.

Byrd, J. H. 1998. Temperature dependent development and computer modeling of insect growth: its application to forensic entomology. Unpublished Dissertation, Department of Entomology and Nematology, University of Florida, Gainesville, FL. 196 pp.

Byrd, J. H., and J. F. Butler. 1996. Effects of temperature on *Cochliomyia macellaria* (Diptera: Calliphoridae) development. J. Med. Entomol. 33: 901-905.

Byrd, J. H., and J. F. Butler. 1997. Effects of temperature on *Chrysomya rufifacies* (Diptera: Calliphoridae) development. J. Med. Entomol. 34: 353-357.

Byrd, J. H., and J. F. Butler. 1998. Effects of temperature on *Sarcophaga haemorrhoidalis* (Diptera: Sarcophagidae) development. J. Med. Entomol. 35: 694-698.

Byrd, J. H., and J. C. Allen. 2001. The development of the black blow fly, Phormia regina. Forensic Sci. Int. 120: 79-88.

Byrd, J. H., and J. L. Castner [eds.]. 2001a. Forensic Entomology: The Utility of Arthropods in Legal Investigations. CRC Press, Boca Raton. 418 pp.

Byrd, J. H., and J. L. Castner. 2001b. Insects of forensic importance. *In* J. H. Byrd and J. L. Castner [eds.], Forensic Entomology: The Utility of Arthropods in Legal Investigations. CRC Press, Boca Raton. pp. 43-79.

Campobasso, C. P., and F. Introna. 2001. The forensic entomologist in the context of the forensic pathologist's role. Forensic Sci. Int. 120: 132-139.

Campobasso, C. P., G. Di Vella, and F. Introna. 2001. Factors affecting decomposition and Diptera colonization. Forensic Sci. Int. 120: 18-27.

Castner, J. L. 2001. General Entomology and Arthropod Biology. *In* J. H. Byrd and J. L. Castner [eds.], Forensic Entomology: The Utility of Arthropods in Legal Investigations. CRC Press, Boca Raton. pp. 17-41.

Catts, E. P., and N. H. Haskell. 1990. Entomology & Death-A Procedural Guide. Joyce's Print Shop, Inc., Clemson, SC. 182 pp.

Catts, E. P., and M. L. Goff. 1992. Forensic entomology in criminal investigations. Annu. Rev. Entomol. 37: 253-272.

Coe, M. 1978. The decomposition of elephant carcases in the Tsavo (East) National Park, Kenya. J. Arid. Environ. 1: 71-86.

Cornaby, B. W. 1974. Carrion reduction by animals in contrasting tropical habitats. Biotropica 6: 51-63.

Cragg, J. B. 1956. The olfactory behavior of *Lucilia* species (Diptera) under natural conditions. Ann. Appl. Biol. 44: 467-477.

Cragg, J. B., and B. A. Thurston. 1949. The reactions of blowflies to organic sulphur compounds and other materials used in traps. Parasitology 40: 187-194.

Cragg, J. B., and P. Cole. 1956. Laboratory studies on the chemosensory reactions of blowflies. Ann. Appl. Biol. 44: 478-491.

Cushing, E. C., and H. E. Parish. 1938. Seasonal variations in the abundance of *Cochliomyia* spp., *Phormia* spp., and other flies in Menard County, Tex. J. Med. Entomol. 31: 764-769.

Davidson, J. 1944. On the relationship between temperature and rate of development of insects at constant temperatures. J. Anim. Ecol. 13: 26-38.

Davis, J. B., and M. L. Goff. 2000. Decomposition patterns in terrestrial and intertidal habitats on Oahu Island and Coconut Island, Hawaii. J. Forensic Sci. 45: 836-842.

deCarvalho, L. M. L., and A. X. Linhares. 2001. Seasonality of insect succession and pig carcass decomposition in a natural forest area in southeastern Brazil. J. Forensic Sci. 46: 604-608.

deCarvalho, L. M. L., P. J. Thyssen, A. X. Linhares, and F. A. B. Palhares. 1999. A checklist of arthropods associated with pig carrion and human corpses in southeastern Brazil. Mem. Inst. Oswaldo Cruz. 95: 135-138.

Denno, R. F., and W. R. Cothran. 1975. Competitive interactions and ecological strategies of sarcophagid and calliphorid flies inhabiting rabbit carrion. Ann. Entomol. Soc. Amer. 69: 109-113.

Deonier, C. C. 1940. Carcass temperatures and their relation to winter blowfly populations and activity in the southwest. J. Econ. Entomol. 33: 166-170.

Deonier, C. C. 1942. Seasonal abundance and distribution of certain blowflies in southern Arizona and their economic importance. J. Econ. Entomol. 35: 65-71.

Dodge, H. R. 1953. Domestic flies: pictorial key to common species in southern U.S. *In*. U.S. Department of Health, Education, and Welfare.

Early, M., and M. L. Goff. 1986. Arthropod succession patterns in exposed carrion on the island of O'ahu, Hawaiian Islands, USA. J. Med. Entomol. 23: 520-531.

Easton, A. M., and K. G. V. Smith. 1970. The entomology of the cadaver. Med. Sci. Law. 10: 208-219.

Erzinclioglu, Y. Z. 1985. The entomological investigation of a concealed corpse. Med. Sci. Law. 25: 228-230.

Faucherre, J., D. Cherix, and C. Wyss. 1999. Behavior of *Calliphora vicina* (Diptera, Calliphoridae) under extreme conditions. J. Insect Behav 12: 687-690.

Florida Chapter, Soil and Water Conservation Society. July 1989. 26 Ecological Communities of Florida. Gainesville, Florida. 66 pp.

Furman, D. P., and E. P. Catts. 1982. Manual of Medical Entomology. Cambridge University Press, Cambridge, London, New York. 207 pp.

Galloway, A., W. Birkby, A. M. Jones, T. E. Henry, and B. O. Parks. 1989. Decay rates of human remains in an arid environment. J. Forensic Sci. 34: 607-616.

Gill-King, H. 1997. Chemical and ultrastructural aspects of decomposition. *In* W. D. Haglund and M. H. Sorg [eds.], Forensic Taphonomy. CRC Press, Boca Raton. pp. 93-108.

Goddard, J., and P. K. Lago. 1985. Notes on blow fly (Diptera: Calliphoridae) succession on carrion in northern Mississippi. J. Entomol. Sci. 20: 312-317.

Goff, M. L., M. Early, C. B. Odom, and K. Tulis. 1986. A preliminary checklist of arthropods associated with exposed carrion in the Hawaiian Islands. Proceed. Hawaiian Entomol. Soc. 26: 53-57.

Goff, M. L., A. I. Omori, and K. Gunatilake. 1988. Estimation of postmortem interval by arthropod succession. Am. J. Foren. Med. Pathol. 9: 220-225.

Goff, M. L. 1991. Comparison of insect species associated with decomposing remains recovered inside dwellings and outdoors on the island of Oahu, Hawaii. J. Forensic Sci. 36: 748-753.

Goodbrod, J. R., and M. L. Goff. 1990. Effects of larval population density on rates of development and interactions between two species of *Chrysomya* (Diptera: Calliphoridae) in laboratory culture. J. Med. Entomol. 27: 338-343.

Gordh, G., and D. Headrick. 2001. A Dictionary of Entomology. CABI Publishing, New York.

Green, A. A. 1951. The control of blowflies infesting slaughter-houses. Ann. Appl. Biol. 38:

Greenberg, B. 1985. Forensic entomology: case studies. Bull. Entomol. Soc. Amer. 25-28.

Greenberg, B. 1988. *Chrysomya megacephala* (F.) (Diptera:Calliphoridae) collected in North America and notes on *Chrysomya* species present in the New World. J. Med. Entomol. 25: 199-200.

Greenberg, B. 1990. Nocturnal oviposition behavior of blow flies (Diptera: Calliphoridae). J. Med. Entomol. 27: 807-810.

Greenberg, B. 1991. Flies as forensic indicators. J. Med. Entomol. 28: 565-577.

Greenberg, B., and J. C. Kunich. 2002. Entomology and the Law: Flies as Forensic Indicators. Cambridge University Press, Cambridge. 306 pp.

Hall, D. G. 1948. The Blowflies of North America. Thomas Say Foundation, Lafayette, IN. 477 pp.

Hall, M. 2003. President's letter, European Association of Forensic Entomology. www.eafe.org/index.php?section=main&page=Letter. September 17, 2003.

Hall, M. J., R. Farkas, F. Kelemen, M. Hosier, and J. M. El-Khoga. 1995. Orientation of agents of wound myiasis to hosts and artificial stimuli in Hungary. Med. Vet. Entomol. 9: 77-84.

Hall, R. D. 2001. Introduction: perceptions and status of forensic entomology. *In* J. H. Byrd and J. L. Castner [eds.], Forensic Entomology: The Utility of Arthropods in Legal Investigations. CRC Press, Boca Raton. pp. 1-15.

Hall, R. D., and L. H. Townsend. 1977. The Insects of Virginia: No. 11. *In*, The Blow Flies of Virginia (Diptera: Calliphoridae). Virginia Polytechnic Institute and State University, Blacksburg, VA. pp. 48

Hall, R. D., and K. E. Doisy. 1993. Length of time after death: effect on attraction and oviposition or larviposition of midsummer blow flies (Diptera: Calliphoridae) and flesh flies (Diptera: Sarcophagidae) of medicolegal importance in Missouri. Ann. Entomol. Soc. Amer. 86: 589-593.

Hammack, L., and G. G. Holt. 1983. Responses of gravid screwworm flies, *Cochliomyia hominivorax,* to whole wounds, wound fluid, and a standard blood attractant in olfactometer tests. J. Chem. Ecol. 9: 913-922.

Haskell, N. H. 1989. Calliphoridae of pig carrion in northwest Indiana: a seasonal comparative study. Unpublished Thesis, College of Agriculture, Purdue University, Lafayette. 57 pp.

Haskell, N. H., R. D. Hall, V. J. Cervenka, and M. A. Clark. 1997. On the body: insect's life stage presence and their postmortem artifacts. *In* W. D. Haglund and M. H. Sorg [eds.], Forensic Taphonomy. CRC Press, Boca Raton. pp. 415-448.

Introna, F., Jr., T. W. Suman, and J. E. Smialek. 1991. Sarcosaprophagous fly activity in Maryland. J. Forensic Sci. 36: 238-243.

James, M. T. 1947. The Flies That Cause Myiasis in Man. United States Department of Agriculture, Washington, D.C. 175 pp.

James, M. T. 1955. The blowflies of California (Diptera: Calliphoridae). Bull. Calif. Ins. Surv. 4: 1-34.

Jiron, L., and V. Cartin. 1981. Insect succession in the decomposition of a mammal in Costa Rica. N. Y. Entomol. Soc. 89: 158-165.

Johnson, M. D. 1975. Seasonal and microseral variations in the insect populations on carrion. Am. Midl. Nat. 93: 79-90.

Joy, J. E., M. L. Herrell, and P. C. Rogers. 2002. Larval fly activity on sunlit versus shaded raccoon carrion in southwestern West Virginia with special reference to the black blowfly (Diptera: Calliphoridae). J. Med. Entomol. 39: 392-397.

Kamal, A. S. 1958. Comparative study of thirteen species of sarcosaphrophagous Calliphoridae and Sarcophagidae (Diptera) I. Bionomics. Ann. Entomol. Soc. Am. 51:

Kashyap, V. K., and V. V. Pillay. 1989. Efficacy of entomological method in estimation of postmortem interval: A comparative analysis. Forensic Sci. Int. 40: 245-250.

Kocarek, P. 2001. Diurnal patterns of postfeeding larval dispersal in carrion blowflies (Diptera: Calliphoridae). Eur. J. Entomol. 98: 117-119.

Knipling, E. F. 1936. Some specific taxonomic characters of common *Lucilia* larvae--Calliphorniae--Diptera. Iowa State Coll. J. Sci. 10: 275-293.

Lane, R. P. 1975. An investigation into blowfly (Diptera: Calliphoridae) succession on corpses. J. Nat. Hist. 9: 581-598.

Lewerenz, D. 2003. 'CSI' boosts interest in forensic science, Associated Press. http://www.sacticket.com/24hour/entertainment/tv/news/story/972073p. September 16, 2003. 2003.

Lord, W. D. 1990. Case histories of the use of insects in investigations. *In* N. H. Haskell and E. P. Catts [eds.], In Entomology and Death: A procedural guide. Forensic entomology specialties, Clemson, SC. pp. 9-37.

Lord, W. D., and J. F. Burger. 1984a. Arthropods asscoiated with herring gull (*Larus argentatus*) and great black-backed gull (*Larus marinus*) carrion on islands in the gulf of Maine. Environ. Entomol. 13: 1261-1268.

Lord, W. D., and J. F. Burger. 1984b. Arthropods associated with harbor seal (*Phoca vitulina*) carcasses stranded on islands along the New England coast. Int. J. Entomol. 26: 282-285.

Mann, R. W., W. M. Bass, and L. Meadows. 1990. Time since death and decomposition of the human body: variables and observations in case and experimental field studies. J. Forensic Sci. 35: 103-111.

Martin, C. S., C. E. Carlton, and C. L. Meek. 1996. New distribution record for the hairy maggot blow fly *Chrysomya rufifacies*. Southw. Entomol. 21: 4.

McKnight, B. E. 1981. The Washing Away of Wrongs: Forensic Medicine in Thirteenth-Century China. The University of Michigan Center for Chinese Studies, Ann Arbor. 181 pp.

Mégnin, P. 1894. La faune de cadavres. Application de l'entomologie à la médicine légale, Encyclopedie scientifique des Aides-Mémoire, Masson, Paris.

Morris, M. C., L. Morrison, M. A. Joyce, and B. Rabel. 1998. Trapping sheep blowflies with lures based on bacterial cultures. Aust. J. Exp. Agri. 38: 125-130.

Nelson, E. L. 1999. Estimation of short-term postmortem interval utilizing core body temperature: a new algorithm. Forensic Sci. Int. 109: 31-38.

Nilssen, A. C., B. Å. Tømmerås, R. Schmid, and S. B. Evensen. 1996. Dimethyl trisulphide is a strong attractant for some calliphorids and a muscid but not for the reindeer oestrids *Hypoderma tarandi* and *Cephenemyia trompe*. Entomol. Exp. Appl. 79: 211-218.

Nuorteva, P. 1977. Sarcosaphrophagous insects as forensic indicators. *In* C. G. Tedeschi, W. G. Eckert and L.G. Tedeshi [eds.], Forensic Medicine: A Study in Trauma and Environmental Hazards. W. B. Saunders and Company, Toronto. pp. 1072-1095.

Parish, H. E., and E. C. Cushing. 1938. Locations for blowfly traps: abundance and activity of blowflies and other flies in Menard County, Tex. J. Econ. Entomol. 31: 750-763.

Payne, J. A. 1965. A summer carrion study of the baby pig *Sus scrofa* Linnaeus. Ecology 46: 592-602.

Payne, J. A., and E. W. King. 1970. Coleoptera associated with pig carrion. Entomol. Monthly Mag. 105: 224-232.

Peters, S. L. 2003. Temperature variations of dipteran larval masses analyzed on Florida black bear carcasses. Unpublished Thesis, Department of Entomology and Nematology, University of Florida, Gainesville. 93 pp.

Portrait of a Prince. 2004. Associated Press. Gainesville Sun. Gainesville, Florida. April 29, 2004. Page 2.

Putnam, R. J. 1978. The role of carrion-frequenting arthropods in the decay process. Ecol. Entomol. 3: 133-139.

Reed, J., H. B. 1958. A study of dog carcass communities in Tennessee, with special reference to the insects. Am. Midl. Nat. 59: 213-245.

Richards, E. N., and M. L. Goff. 1997. Arthropod succession on exposed carrion in three contrasting tropical habitats on Hawaii Island, Hawaii. J. Med. Entomol. 34: 328-338.

Rodriguez, W. C., and W. M. Bass. 1983. Insect activity and its relationship to decay rates of human cadavers in east Tennessee. J. Forensic Sci. 28: 423-432.

Seago, J. M. 1953. Fly larvae: pictorial key to some common species. *In*. U.S. Department of Health, Education, and Welfare.

Shahid, S. A., R. D. Hall, N. H. Haskell, and R. W. Merritt. 1999. *Chrysomya rufifacies* (Macquart)(Diptera: Calliphoridae) established in the vicinity of Knoxville, Tennessee, USA. J. Forensic Sci. 45: 896-897.

Shean, B. S., L. Messinger, and M. Papworth. 1993. Observations of differential decomposition on sun exposed v. shaded pig carrion in coastal Washington state. J. Forensic Sci. 38: 938-949.

Sherman, R.A., and Edward A. Pechter. 1988. Maggot therapy: A review of the therapeutic applications of fly larvae in human medicine, especially for treating osteomyelitis. Med. Vet. Entom. 2: 225-230.

Singh, D. 2001. Further observations on the nocturnal oviposition behavior of blow flies (Diptera: Calliphoridae). Forensic Sci. Int. 120: 124-126.

Smith, K. G. V. 1975. The faunal succession of insects and other invertebrates on a dead fox. Entomol. Gaz. 26: 277-287.

Smith, K. G. V. 1986. A Manual of Forensic Entomology. British Museum of Natural History, London. 207 pp.

Stensmyr, M., I. Urru, I. Collu, M. Celander, B. S. Hansson, and A.-M. Angioy. 2002. Rotting smell of dead-horse arum florets. Nature 420: 625.

Tantawi, T. I., and B. Greenberg. 1993. *Chrysomya albiceps* and *C. rufifacies* (Diptera: Calliphoridae): contribution to an ongoing taxonomic problem. J. Med. Entomol. 30: 646-648.

Tantawi, T. I., E. M. El-Kady, B. Greenberg, and H. A. El-Ghaffar. 1996. Arthropod succession on exposed rabbit carrion in Alexandria, Egypt. J. Med. Entomol. 33: 566-580.

Tenorio, F. M., J. K. Olson, and C. J. Coates. 2003. Decomposition studies, with a catalog and description of forensically important blow flies (Diptera: Calliphoridae) in central Texas. Southw. Entomol. 28: 37-45.

Tessmer, J. W., and C. L. Meek. 1996. Dispersal and distribution of Calliphoridae (Diptera) immatures from animal carcasses in southern Louisiana. J. Med. Entomol. 33: 665-669.

Tessmer, J. W., C. L. Meek, and V. L. Wright. 1995. Circadian patterns of oviposition by necrophilous flies (Diptera: Calliphoridae) in southern Louisiana. Southw. Entomol. 20: 439-445.

Tomberlin, J. K., and P. H. Adler. 1998. Seasonal colonization and decomposition of rat carrion in water and on land in an open field in South Carolina. J. Med. Entomol. 35: 704-709.

Tullis, K., and M. L. Goff. 1987. Arthropod succession in exposed carrion in a tropical rainforest on O'ahu Island, Hawai'i. J. Med. Entomol. 24: 332-339.

Wall, R., and M. L. Warnes. 1994. Responses of the sheep blowfly *Lucilia sericata* to carrion odour and carbon dioxide. Entomol. Exp. Appl. 73: 239-246.

Wall, R., and P. Fisher. 2001. Visual and olfactory cue interaction in resource-location by the blowfly, *Lucilia sericata*. Physiol. Entomol. 26: 212-218.

Wall, R., C. H. Green, N. French, and K. L. Morgan. 1992. Development of an attractive target for the sheep blowfly *Lucilia sericata*. Med. Vet. Entomol. 6: 67-74.

Wardle, R. A. 1921. The protection of meat commodities against blowflies. Ann. Appl. Biol. 9: 1-9.

Watson, E. J., and C. E. Carlton. 2003. Spring succession of necrophilous insects on wildlife carcasses in Louisiana. J. Med. Entomol. 4: 338-347.

Wells, J. D., and J. King. 2001. Incidence of precocious egg development in flies of forensic importance (Calliphoridae). Pan Pac. Entomol. 77: 235-239.

Wells, J. D., J. H. Byrd, and T. I. Tantawi. 1999. Key to third-instar Chrysomyinae (Diptera: Calliphoridae) from carrion in the continental United States. J. Med. Entomol. 36: 638-641.

White, S. R., D. Aubertin, and J. Smart. 1940. The Fauna of British India including the remainder of the Oriental region. Taylor and Francis, Ltd., London. 288 pp.

Wolff, M., A. Uribe, A. Ortiz, and P. Duque. 2001. A preliminary of study forensic entomology in Medellin, Columbia. Forensic Sci. Int. 120: 53-59.

BIOGRAPHICAL SKETCH

Susan V. Gruner was born July 5, 1956, in Wiesbaden, Germany. After her father--an O.S.I. agent--retired from the Air Force, her family moved to the small town of Mattapoisett, MA, a small coastal town not far from Cape Cod. Sue graduated from Old Rochester Regional High School in 1974. Her first attempt at a college career was a brief but unsuccessful stint at Embry-Riddle Aeronautical University, Daytona Beach, Florida.

After the academic attempt in Daytona Beach crashed and burned, Susan got a job in the audio industry in which she worked until 1993. In 1994, she decided to go back to college and enrolled at Santa Fe Community College in Gainesville, FL. Before classes began, Susan received an official letter indicating that she was on academic probation due to the unfortunate academic history that came back to haunt her after 20+ years when she flunked out of Embry-Riddle. Determined to succeed in the face of adversity, Sue forged ahead. She hit the books hard, managed to learn the metric system, successfully plodded through 3 semesters of chemistry involving hair loss and sleepless nights, and was eventually inducted into the Phi Theta Kappa Honor Society in 1995. Both the academic probation letter and Phi Theta Kappa certificate have been saved for posterity.

Sue graduated from S.F.C.C. in 1996 and was accepted at UF immediately, where she began working on her B.S. in the College of Agriculture with a major in entomology. During one of her first entomology classes with Dr. John Strayer, she received a hand-out about human decomposition studies at the Body Farm in TN. At that point, Susan knew what she wanted to do: forensic entomology. But, how?

Sue graduated with her B.S. in the College of Agricultural and Life Sciences in the last semester of the millennium, December, 1999. Dr. Jon Allen signed off on her graduate school entrance form, Dan Slone gave her part of a National Institute of Justice grant and introduced her to Neal Haskell in February of 2001, and the rest has yet to be written.