FIELD EVALUATION OF MOSQUITO CONTROL AND REPELLENT DEVICES IN SOUTHERN LOUISIANA

A Thesis

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by
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ABSTRACT

The effect of 2 mosquito traps and 2 repellent systems upon the catch of an American Biophysics Corporation (ABC) light trap were evaluated over a 14-month period at 3 locations in Louisiana. Devices evaluated included: 1) ABC Mosquito Magnet® with dry ice and octenol, 2) the BioSensory 500 cc Dragonfly® Biting Insect Trap with CO_2, octenol, and Mosquito Cognito® which uses Conceal™ inhibitor, 3) the SC Johnson OFF!® Mosquito Lantern, and 4) the ThermaCell® cordless mosquito repellent system for residential use. The number of mosquitoes caught in the ABC light traps at the SC Johnson OFF!® Mosquito Lantern and ThermaCell® cordless mosquito repellent treatment sites was significantly less than the number collected at the ABC Mosquito Magnet® or the Dragonfly®/Mosquito Cognito® trap system sites. When the two repellent devices were placed with ABC traps they reduced mosquito numbers in the ABC traps when compared to sites with ABC traps alone. These data indicate that the SC Johnson OFF!® Mosquito Lantern and ThermaCell® cordless mosquito system may reduce attack from biting mosquitoes.

CHAPTER 1

REVIEW OF LITERATURE

Recently, several new commercially developed mosquito control devices have become available to control mosquitoes and other biting arthropods. These products claim that they can significantly reduce or even eliminate the number of mosquitoes and other biting arthropods present by effectively trapping or repelling them from residential properties (American Biophysics Corp. 2004, BioSensory 2004, SC Johnson 2004, Schawbel Corp. 2004). The removal of mosquito breeding areas, chemical treatment for mosquitoes using pesticides and repellents, or avoidance of outside activities when mosquitoes are active are often the only effective options a homeowner has to prevent from being bitten by mosquitoes. Although the use of pesticides works to reduce or eliminate mosquitoes from a treated area, it is often a temporary measure and not always environmentally safe.

In the past, homeowners relied heavily on pesticides as the primary tool for controlling mosquitoes and other biting arthropods from their yards. Winner et al. (1989) demonstrated the effectiveness of using Raid® Yard Guard (SC Johnson Inc., Racine, WI), a readily obtainable consumer product, to control *Wyeomyia* in Bromeliads for up to 35 days. Burning mosquito-coils containing pyrethrin or a synthetic pyrethroid have also been used by consumers as a means to reduce numbers of biting mosquitoes (Chang and Lin 1997). However, health problems resulting from exposure to allethrin-containing mosquito-coil smoke and possible ineffectiveness make this control method unreliable (Chang and Lin 1997). Another control uses outdoor foggers or sprayers with insecticides such as carbaryl, malathion, resmethrin or other pesticide formulations approved for residential use to treat the yard around the home. Outdoor spraying and fogging can be effective, but limiting factors such as inadequate insecticide dose, mosquito resistance, unfavorable weather conditions, inadequate coverage of areas treated or rapid mosquito reinfestation of the treated area can reduce treatment effectiveness (Mount 1998). Insecticides are available for controlling mosquito larvae, but their application in either large bodies of water or small artificial breeding sites can be difficult and expensive, particularly for an individual homeowner (Hopkins et al. 2002). Larviciding is often done by professionals and has been shown to provide various levels of control depending on the chemical formulation. For example, one study conducted by Nasci et al. (1994) indicated that the Abate® pellet (temephos, active ingredient), Altosid® pellet (methoprene, active ingredient) and Altosid® sand formulations were able to provide excellent control of *Aedes albopictus* Skuse for up to 150 days when applied at 2 grams per container to small breeding sites in Lake Charles, Louisiana. In field studies, Bti (*Bacillus thuringiensis* var. *israelensis*) has been shown to be effective against several mosquito species in widely differing water quality conditions, including irrigated pastures, storm drains, ponds, dairy lagoons, and salt marsh potholes (Olkowski 2001). In another study, a lethal ovitrap designed and developed to kill dengue vectors via an impregnated insecticide-treated ovistrip was evaluated in Rio de Janeiro, Brazil, and shown to be effective in reducing *Aedes aegypti* (L.) populations in and around homes (Perich et al. 2003). However, further evaluations are required to determine if the lethal ovitrap is effective in reducing artificial container breeding mosquito species in other regions of the world where they are a problem.

Homeowners may be able to rely on commercially available repellents instead of pesticides to reduce the biting pressure and nuisance of mosquitoes and other biting arthropods when engaging in activities outside the home. Of these, DEET (N,N-diethyl-m-toluamide) is the most widely used with 230 DEET-containing products from nearly 70 companies (Peterson 2003). Repellents also provide an excellent alternative protection to homeowners who are sensitive, allergic or concerned about the use and toxicity of pesticides (Peterson 2003). Other repellents such as KBR (picaridin), citronella (p-methane-3,8-diol), IR3535 (based on the structure of the amino acid alanine, registered February 1999), and oil of lemon eucalyptus are currently available for use as alternatives (Peterson 2003).

Homeowners also have used biological control methods instead of pesticides as an alternate means to treat their properties and keep arthropods away. One such example is the use of mosquito fish (*Gambusia affinis* Baird and Girard) as an environmentally safe alternative in ornamental ponds and ditches to control mosquito larvae. Many professional mosquito agencies already produce this species for use in man-made habitats such as backyard fishponds, sewage treatment ponds, and rice fields (Olkowski 2001). Other fish such as carp or goldfish have also been used to control mosquito larvae with limited success (Olkowski 2001). Although mosquito research and control personnel have been almost unanimous in their approval of the use of *G. affinis* for mosquito control, members of the ichthyological community have viewed introduction of the fish into non-native habitats with alarm because of real and potential damage to this ecosystem (Rupp 1996). In another example of biological control, Marten et al. (2000) utilized the copepod *Macrocyslops albidus* (Jurine) as a means to treat residential ditches to facilitate natural control of *Culex quinquefasciatus* Say populations. However, this treatment strategy had limited success due to the organism's sensitivity to the polluted water of the ditches (Manten et al. 2000). Homeowners have also used bats and birds, such as Purple Martins (*Progne subis* L.), which consume large numbers of mosquitoes as part of their diet (Hopkins et al. 2002). However, the feeding activity of insect-eating bats and birds may not be sufficiently selective to noticeably reduce mosquito populations (Hopkins et al. 2002).

Modern vector management programs rely heavily on environmental manipulation, also referred to as source reduction or physical control (Eldridge and Edman 2000). Emphasis on non-chemical control methods is the preferred procedure for removal of all possible mosquito-breeding habitats from the property (Eldridge and Edman 2000). Schofield and White (1983) illustrated the importance of a good house design, which can eliminate breeding-sites for synanthropic arthropods such as fleas, bed bugs, ticks and container-breeding mosquitoes.

In order to control mosquitoes, and prevent them from biting, effective integrated vector management (IVM) by the homeowner must be properly implemented (Eldridge and Edman 2000). To suppress mosquitoes and thus reduce possible arthropodborne disease transmission, homeowners must know where to search for and eliminate mosquitoes, such as *Aedes aegypti* and *Culex quinquefasciatus*, where they are breeding. Surveying the immediate area in and around the residence for mosquitoes is critical in determining if mosquitoes are breeding. Since some species of mosquitoes are artificial container breeders, destroying the larval habitat by emptying or removing standing water from all containers such as old tires, flower pots and water storage containers in and around the yard is key to the control effort (Eldridge and Edman 2000). Where rainwater is collected in artificial containers, covering the opening of these containers by placing properly fitted screening material will prevent mosquitoes from breeding. In areas where standing water can not be drained or removed, larviciding with an appropriate registered larvicide will help. For homes, screened windows that are well maintained will exclude mosquitoes from entering. A community survey can determine which bodies of standing water have mosquito larvae. This survey includes dipping for "wrigglers" (larvae and pupae) to determine if mosquitoes are developing in the water. Once identified, appropriate pest management practices such as draining, filling standing bodies of water with dirt, and larviciding should follow.

To ensure that future mosquito outbreaks do not reoccur, educating the public on personal protective measures, elimination or destruction of mosquito larval habitats and protecting against day-biting mosquitoes, including the use of screening, protective clothing and repellents is an absolute must (MEDIC 2000). Control of mosquitoes and vectorborne diseases must start at the individual household and continue with neighborhood, local and state/government authorities. Community support and participation in any mosquito eradication program can often determine success or failure in controlling future outbreaks. By supporting area-wide control, homeowners can accomplish much more than individual efforts can alone (USDA 1979). Cleaning up public areas and removing old containers, tires, trash and debris will eliminate harborage that are favorable for mosquito development from the area. This can be accomplished by disseminating educational material to the homeowner and implementing programs that will support the change in public behaviors. Behavior compliance, preparation and distribution of educational material, and utilization of public media must be fully maximized in order to promote and encourage all individuals to participate in the program.

At the local government level, officials must ensure that all waste/trash that can collect water is properly disposed of in a timely manner so as to minimize or eliminate potential breeding habitat for mosquitoes. The removal of abandoned buildings and old construction sites may also reduce potential breeding sites (MEDIC 2000). At the local and state/central government level, polices must continue to be generated, updated, and implemented to insure that surveillance and vector control is done properly.

In a recent study by Hougaard and Dickson (1999) the Mosquito Magnet®(American Biophysics Corp. North Kingstown, RI), a mosquito collection device, reduced *Aedes sierrensis* Ludlow, the western tree hole mosquito, populations when used in close proximity to breeding sources in around residential homes. However, only *Ae. sierrensis* was caught using the Mosquito Magnet® and other species of mosquitoes such as *Culex pipiens* L. were not captured by the trap during the study (Hougaard and Dickson 1999). Also, the study was of limited duration (2 months) and did not determine if the Mosquito Magnet® provided long-term control of *Ae. sierrensis*. The Mosquito Magnet® has been shown to be an effective mosquito-sampling device for *Anopheline* mosquitoes such as *Anopheles sinensis* Weidemann (Burkett et al. 2001). In related work, Burkett et al. (2002) reported that the Mosquito Magnet® could significantly enhance current vector and disease surveillance efforts especially for the primary vector of Japanese encephalitis, *Culex tritaeniorhynchus* Giles. Significantly greater numbers of mosquitoes were captured with mosquito traps using counterflow technology™ (e.g., Mosquito Magnet® and Counterflow Geometry® traps) when compared to standard light and carbon dioxide-baited traps (Burkett et al. 2002). Sithiprasasna et al. (2003) evaluated the Mosquito Magnet® as a sentinel mosquito trap system and determined that a mosquito trap system employing self-powered traps, such as the Mosquito Magnet®, and a real-time PCR system, could be used to monitor for Japanese encephalitis in remote areas. Kline (2002), using large cage and field studies, evaluated the efficacy of various propane-powered mosquito traps and determined that propane traps caught consistently more mosquitoes than the Professional® (PRO) trap and significantly fewer mosquitoes than the Counterflow Geometry® (CFG) traps. Sithiprasasna et al. (2004, in press) evaluated the effectiveness of 5 mosquito traps including the Mosquito Magnet® for *Anopheles* mosquito surveillance in Thailand and determined that none of the traps were as good as human subject landing/biting counts, but were the best alternative to human bait.

In the past, various traps and variations of designs of traps have been used for sampling mosquito populations with varying degrees of effectiveness throughout the world. As early as 1922, Headlee suggested that because human collectors varied in their degree of attractiveness to mosquitoes, and also in their aptitude to catch them, a mechanical device should be developed to sample mosquitoes (Drigger 1993). In response, Mulhern (1934) developed the first working mosquito light trap called the New Jersey light trap. Sudia and Chamberlain (1962) described a battery operated light trap which replaced the 110 volt powered New Jersey light trap as an effective portable means to sample mosquitoes. In another work, Acuff (1976) investigated trap biases influencing mosquito collecting and determined that the New Jersey light trap and the CDC miniature light trap collected the widest spectrum of mosquito species. Odetoyinbo (1969) reported that the CDC trap would catch the maximum numbers of mosquitoes when placed as close as possible to the intended host, and also concluded that numbers of mosquitoes caught would decrease as the trap was moved further away from the host. Driggers et al. (1980) later developed a new portable army miniature solid-state mosquito light trap, which had an improved circuit board allowing the trap to economize power and maintain operation longer in the field. Slaff et al. (1983) determined that the dry ice baited CDC trap closely correlated with landing counts and provided an accurate representation of nuisance mosquitoes in a given area. Collier et al. (1992) later designed a fabric light trap which had the unique features of a cloth body, folding rain shield, and a modified folding net which reduced its size, weight, and storage while retaining the operational characteristics as the Solid State Army Miniature (SSAM) light trap. Service (1993) describes various sampling techniques, traps and procedures, and methods of analyzing results. These mosquito-trapping surveillance devices mentioned here are designed solely to sample mosquito populations in a given survey area and are not specifically designed to provide effective long-term control. They are surveillance tools for pest management professionals to determine if mosquito or arthropodborne disease vector populations require control measures to reduce pest numbers to an acceptable level.

Commercially available mosquito treatment control devices such as the Dragonfly®/Cognito® system (BioSensory, Inc., Willimantic, CT) and the SC Johnson OFF!® Mosquito Lantern (SC Johnson, Racine, WI) have undergone only limited trials by the manufacturers to determine if they can provide long term effective mosquito control. Alten et al. (2003) recently evaluated the ThermaCell® Mosquito Repellent System (Schawbel Corporation, Bedford, MA), which uses cis-trans allethrin against sand flies, and showed significant levels of protection against mosquitoes in the southeastern Anatolia region of Turkey. However, further evaluations are required to determine if this system is an effective alternative for repelling biting mosquitoes in areas. Frequent questions by the general public have been made to pest management professionals concerning the efficacy and reliability of these and other residential treatment control devices available on the market. Since supportive data is limited on these devices, pest management professionals can not validate or recommend to a consumer that they work according to which they are intended. An evaluation of the effectiveness and reliability of mosquito control devices as a means for mosquito control must be conducted before these devices are accepted as working control methods. Further study is also required to determine which species of mosquitoes in Louisiana are attracted or repelled by the treatment control devices.

CHAPTER 2

INTRODUCTION

Mosquitoes and other biting arthropods are pests because of their biting activity and their ability to carry and transmit arthropodborne diseases (Olkowski 2001). Mosquitoes can often interfere with daily outdoor activities, curtailing or strictly limiting activities to indoors. In the past, removal of mosquito breeding areas, chemical treatment using pesticides, repellents, or avoidance when mosquitoes are active were the only options a homeowner relied upon. Although the use of pesticides can eliminate mosquitoes from a treated area, it was often a temporary measure and not always environmentally safe (Peterson 2003).

Homeowners frequently contact and consult with local pest management professionals seeking guidance on various mosquito control strategies. Often, a pest management professional is asked for a recommendation concerning the effectiveness and reliability of specific mosquito control products currently available on the market. Due to the limited supporting data for some mosquito control devices, pest management professionals can not validate or recommend to a homeowner that they work according to manufacturer claims. In the past, various traps have been used principally for sampling mosquito populations throughout the world (Service 1993, Collier 1992, Driggers 1980, Odetoyinbo 1969, Sudia 1962). With the uses and availability of chemical insecticides likely to become more restricted, and more mosquito species becoming resistant to the available insecticides, alternatives such as attractant-baited traps need to be evaluated for their control potential (Kline 2002). One such device is the Mosquito Magnet®, which uses counterflow technology™, has been shown to be an effective tool in reducing *Aedes sierrensis* (western tree hole mosquito) populations when deployed around residential homes in Salt Lake City, Utah (Hougaard and Dickson 1999). The patented Counterflow Technology™ used exclusively in the Mosquito Magnet® creates a plume of carbon dioxide (CO_2), heat, and moisture that is emitted from the inner attractant tube, while the flared outer tube vacuums along the top of the CO_2 plume without vacuuming up any of the CO_2 (American Biophysics Corporation 2004). This study did not determine if the Mosquito Magnet® provided long-term control or if it was effective at controlling other nuisance species of mosquitoes. Recent studies have shown that the Mosquito Magnet® is an effective mosquito-sampling device for *Anopheline* mosquitoes such as *Anopheles sinensis* and could significantly enhance current vector and disease surveillance efforts especially for the primary vector of Japanese encephalitis, *Culex tritaeniorhynchus* (Burkett et al. 2001, 2002). Significantly greater numbers of mosquitoes were captured with mosquito traps using counterflow technology™ (e.g., Mosquito Magnet® and Counterflow Geometry® traps) when compared to standard light and CO_2 baited traps (Burkett et al. 2002). The Mosquito Magnet® also was evaluated as a self-powered sentinel mosquito trap system and was determined that, when combined with a real-time PCR system, it could be used to monitor Japanese encephalitis in remote areas (Sithiprasasna et al. 2003).

Another attractant-baited trap is the Dragonfly®/Cognito® system, which is a Dragonfly® insect trap and a pair of Mosquito Cognitos®(Biosensory 2004). The Dragonfly® uses CO_2, octenol, and heat to attract mosquitoes. The Mosquito Cognito® is a device that uses Conceal™ inhibitor cartridges (Linalool 95.54%) that reportedly block the insect's sensory receptors from detecting host-odor (BioSensory 2004). When used together, the Dragonfly®/Cognito® is designed to provide an in-depth defense against mosquitoes (See Appendix A, page 61).

Other alternative mosquito control methods available to the homeowner are devices that utilize and incorporate repellents such as cis-trans allethrin to protect a localalized area from mosquitoes. Two such devices that use allethrin to repel mosquitoes are the SC Johnson Off!® Mosquito Lantern and the ThermaCell® Mosquito Repellent System (SC Johnson 2004, Schawbel Corporation 2004). Repellents may provide low-dose, specific and low-toxicity augmentations to conventional pesticides applied around the home and workplace (Peterson 2003). Alten et al. (2003) evaluated the ThermaCell® Mosquito Repellent System which utilizes cis-trans allethrin against phlebotomine sand flies and mosquitoes and found that they provided significant levels of protection from these insects in the southeastern Anatolia region of Turkey. There have been no reports on the efficacy of the Dragonfly®/Cognito® system or the SC Johnson OFF!® Mosquito Lantern to provide humans protection from mosquito attack (Biosensory Inc., 2004, SC Johnson 2004). The purpose of this study was to determine if these devices provide protection from mosquitoes. The species of mosquitoes in Louisiana collected by the different treatment control devices was also determined.

CHAPTER 3

MATERIALS AND METHODS

Two traps (the Mosquito Magnet® and Dragonfly®/Mosquito Cognito® system) were field evaluated along with two repellent systems (the ThermaCell® Mosquito Repellent System and SC Johnson Off!® Mosquito Lantern) to determine if each device effectively reduces and controls mosquito numbers in southern Louisiana. Field tests were conducted at three locations in Louisiana: Baton Rouge (East Baton Rouge Parish), Lake Charles (Calcasieu Parish), and Slidell (St. Tammany Parish). At each location, five residential sites (homes) were selected. The five sites from each location were similar in structural design and had equivalent ecological habitats. Habitats selected were known to harbor mosquito populations based on past mosquito nuisance complaint calls from area residents and by previous pest control operations of the St. Tammany Parish Mosquito Control, Calcasieu Parish Mosquito Control, and East Baton Rouge Mosquito Abatement District. Sites with plenty of mixed vegetation for mosquito resting-places in proximity to potential breeding sources were selected. Sites selected were at least 200 meters apart to avoid treatment interactions. In order to measure the effectiveness of each treatment device and to determine if they reduced mosquito numbers, each treatment site also had an American Biophysics Corporation (ABC) light trap baited with dry ice (CO_2). At each site, a Mosquito Magnet®, Dragonfly®/Mosquito Cognito® system, ThermaCell® Repellent System, or a SC Johnson Off!® Mosquito Lantern was placed in the back yard of each residence where mosquito activity is suspected. An ABC light trap was placed at the fifth site to serve as a control for comparison with ABC traps next to the treatment devices. Each location was visited once a month for 3 consecutive days throughout the 14-month study. The four mosquito treatment devices and control ABC light traps at each site were operated from 18:00 to 22:00 hours for three consecutive days each month. The trap and repellent systems remained in place at each residence and were not rotated. Each mosquito treatment device was set up and operated according to suggested manufacturer recommendations (Appendix A, pages 54-67). The Mosquito Magnet® and Dragonfly®/Cognito® system were set up with 1-octen-3-ol to ensure optimal performance and were operated continuously. The Dragonfly® was operated in the "constant on" mode and at a rate of 125 cc/minute CO_2. The ThermaCell® Repellent System and SC Johnson Off!® Mosquito Lantern were placed so that each repellent system provided coverage according to where residents congregate the most in their back yard according to manufacturers instructions (Appendix A pages 55 and 57). The ABC light traps were baited with approximately 2 kg of dry ice for each trap night and placed within the protected area of each respective treatment device. At the ThermaCell® and SC Johnson OFF!® Lantern sites, the ABC traps were placed approximately 12 feet away from each treatment device. At the Mosquito Magnet® and Dragonfly/Cognito® sites, ABC traps were placed at least 35 feet away from treatment devices. Mosquitoes captured by the ABC traps were collected each trap night from the Mosquito Magnet®, Dragonfly/Cognito® system, ThermaCell® repellent system, SC Johnson Off!® Lantern, and control sites. Mosquitoes collected were brought to Louisiana State University where they were killed by freezing, sorted, counted, and identified to species by the author. The Illustrated Key to Common Mosquitoes of Southeastern United States (Stojanovich, 1960), A Key to the Mosquitoes of North Carolina and the Mid-Atlantic States (Agricultural Extension Service, North Carolina State University, 1989), and Keys to the Adult Females and Fourth-Instar Larvae of the Mosquitoes of Florida (Diptera, Culicidae) (Darsie and Morris, 2000) were used to identify mosquitoes caught in the study. Voucher specimens are stored in the Louisiana State Arthropod Museum (LSAM), Louisiana State University, Baton Rouge, Louisiana.

Temperature, relative humidity, wind speed/direction, and sky condition were recorded each day at the beginning of each 3-day trap trial. A Kestrel® 2000 thermo-anemometer

(Richard Paul Russel Limited, Lymington, UK) was used to record temperature, relative humidity, wind speed and direction.

Comparisons between the trapping/repellent systems and total species collected by the ABC light traps were recorded. A complete randomized block design with a 5 X 14 factorial with repeated measures over time was used to compare the ABC trap catches total at the four treatment sites to the control site at each location. Data collected from the three locations were analyzed with Statistical Analysis System (SAS) and was assessed by a two-way analysis of variance (ANOVA) (SAS Institute 2002). Comparison of treatments to control was made using PROC MIXED and Dunnett's Mean Separation Test with a P value < 0.05 as being significant.

CHAPTER 4

RESULTS

A total of 8060 mosquitoes representing 23 species were collected by the 15 ABC traps during the 14-month field trial (Table 1). The number of mosquitoes collected per month by treatment for all three locations is shown in Tables 1-3 Appendix B. Overall, the greatest number of mosquitoes captured from the ABC traps were those associated with the Dragonfly/Cognito® (2812). The ABC traps near the Mosquito Magnet® captured 2372 while the controls captured 2273. The ABC traps near the repellent systems caught fewer mosquitoes with the SC Johnson OFF!® Lantern capturing 393, and ThermaCell® repellent system 210. ABC traps located in the Dragonfly®/Cognito® and Mosquito Magnet®, treatment sites caught 64.3% of the total mosquitoes while the ABC traps located at the SC Johnson OFF!® Lantern and ThermaCell® treatment sites caught 7.5%. The ABC control traps collected 28.2% of the total. The most common species collected during the study were *Culex salinarius* Coquillett (3851), followed by *Culex quinquefasciatus* Say (3002), *Aedes vexans* (Meigen) (476), *Anopheles crucians* Wiedeman (174), *Coquillettidia perturbans* (Walker) (174), and *Culex erraticus* (Dyar and Knab) (124). In addition, 258 mosquitoes from 17 species including *Aedes albopictus* Skuse, *Anopheles quadrimaculatus* Say, *Culex restuans* Theobald, *Culiseta inornata* Williston, *Psorophora columbiae* Dyar and Knab, *Culex nigripalpus* Theobald, *Culex tarsalis* Coquillett, *Ochlerotatus sollicitans* Walker, *Ochlerotatus taeniorhynchus* Wiedman, *Mansonia titillans* Walker, *Ochlerotatus infirmatus* Dyar and Knab, *Uranotaenia lowii* Theobald, *Ochlerotatus atlanticus/tormentor* Dyar and Knab, *Psorophora ferox* Humbolt, *Uranotaenia sapphirina* Olsten Sacken, *Ochlerotatus triseriatus* (Say), and *Anopheles punctipennis* Say were also collected. For this study, Aedes *atlanticus* and *Aedes tormentor* were cataloged as *Aedes atlanticus/tormentor* because the identification keys used in this study grouped these species together due to

Table 1. Total Number of Female Mosquitoes Collected in ABC Traps From Treatment Sites in Southern Louisiana

	Treatment Sites																	
	Baton Rouge						Lake Charles						Slidell					
Species	MM	DF	SC	TH	Ctrl	Total	MM	DF	SC	TH	Ctrl	Total	MM	DF	SC	TH	Ctrl	Total
Ae. albopictus	7	5	1	1	4	18	0	0	1	0	2	3	23	22	2	1	7	55
Ae. vexans	70	145	24	4	33	276	11	15	11	1	117	155	13	15	2	1	15	46
An. crucians	1	1	0	0	0	2	23	17	0	11	46	97	11	47	5	1	11	75
An. punctipennis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
An. quadrimaculatus	1	0	0	0	1	2	2	2	1	0	1	6	2	0	0	1	2	5
An. spp.	1	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	1
Cq. perturbans	3	29	0	1	2	35	17	36	12	11	49	125	5	5	3	1	0	14
Cs. inornata	1	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	1
Cx. erraticus	11	16	6	1	1	35	1	0	1	0	3	5	31	24	0	7	22	84
Cx. nigripalpus	0	0	0	0	0	0	0	0	0	0	0	0	14	0	1	0	3	18
Cx. quinquefasciatus	676	291	52	14	91	1124	25	30	21	1	176	253	592	745	98	24	166	1625
Cx. restuans	1	4	0	0	5	10	0	0	0	0	0	0	0	0	0	0	0	0
Cx. salinarius	62	79	4	5	22	172	268	394	33	105	1296	2096	477	838	95	14	159	1583
Cx. spp.	0	0	2	0	1	3	0	0	0	0	0	0	1	0	0	0	0	1
Cx. tarsalis	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Ms. titillans	0	0	0	0	0	0	0	5	0	0	2	7	0	0	0	0	0	0
Oc. atlanticus/tormentor	0	0	0	0	0	0	0	0	1	0	0	1	5	6	3	1	8	23
Oc. infirmatus	0	1	0	0	0	1	0	1	0	0	0	1	2	10	1	0	9	22
Oc. sollicitans	0	0	0	0	1	1	3	3	10	2	0	18	0	3	0	0	0	3
Oc. taeniorhynchus	0	0	1	0	0	1	4	2	1	0	11	18	1	10	0	0	1	12
Oc. triseriatus	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3
Ps. columbiae	1	1	0	0	0	2	3	2	0	1	2	8	0	0	0	0	0	0
Ps. ferox	0	0	0	0	0	0	0	0	0	0	1	1	2	1	0	0	0	3
Ur. lowii	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	1
Ur. sapphirina	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1
Total	835	572	90	26	161	1684	358	509	92	133	1707	2799	1179	1731	211	51	405	3577

MM = Mosquito Magnet®, DF = Dragonfly®/Cognito®, SC = SC Johnson OFF!® Mosquito Lantern, TH = ThermaCell®, Ctrl = Control

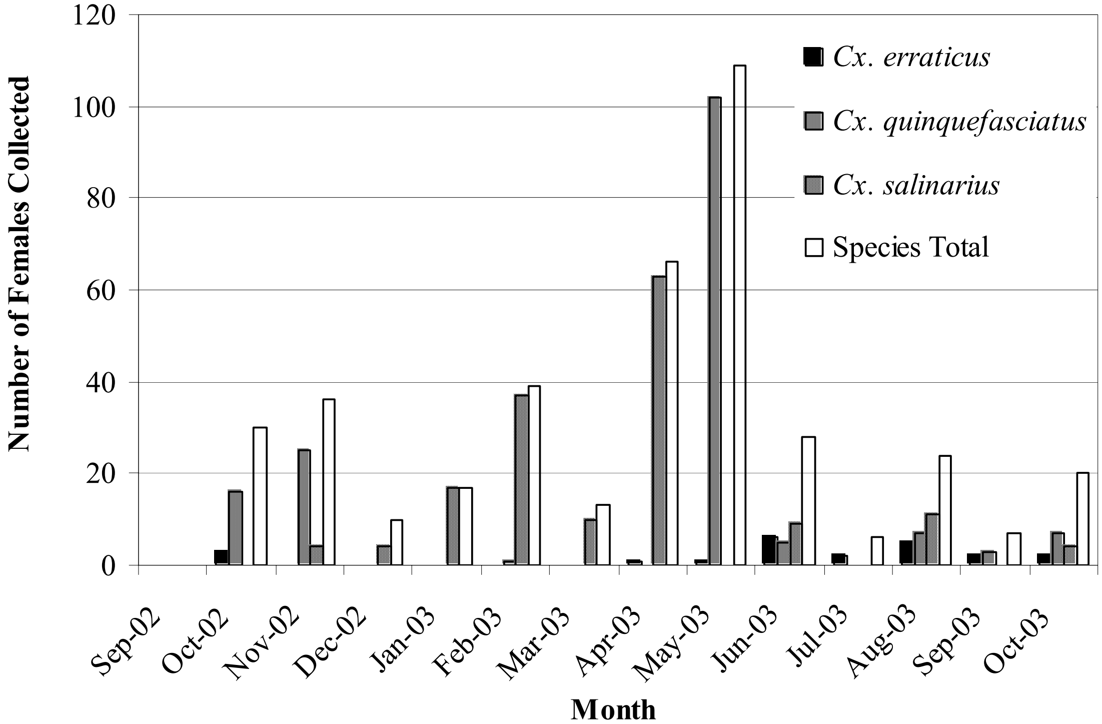

Figure 1. Three Most Abundant Mosquito Species Caught at Control Site in Slidell, LA

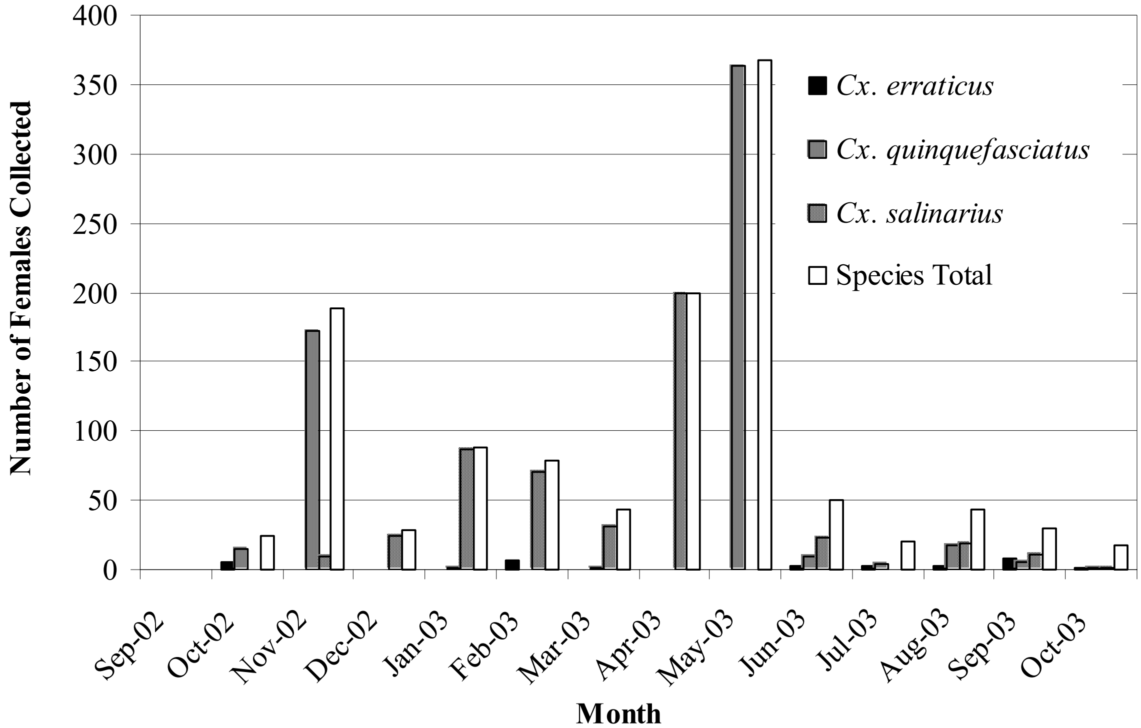

Figure 2. Three Most Abundant Mosquito Species Caught at Mosquito Magnet® Site in Slidell, LA

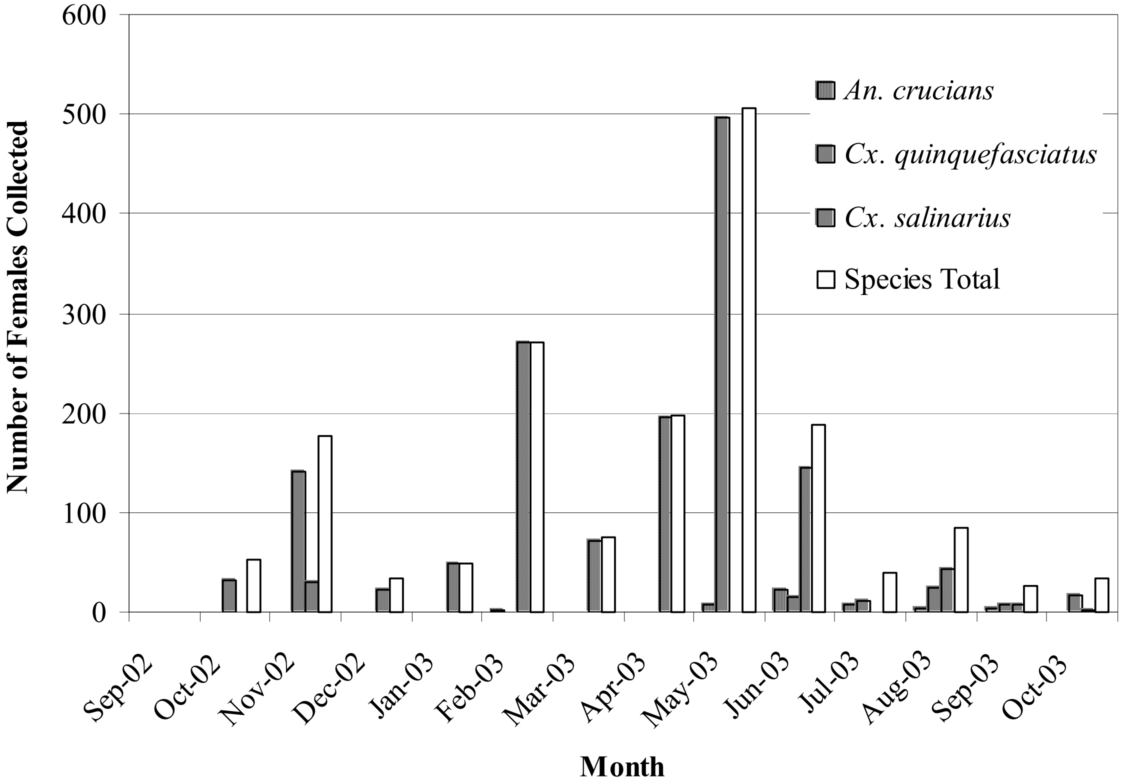

Figure 3. Three Most Abundant Mosquito Species Caught at Dragonfly/Cognito® Site in Slidell, LA

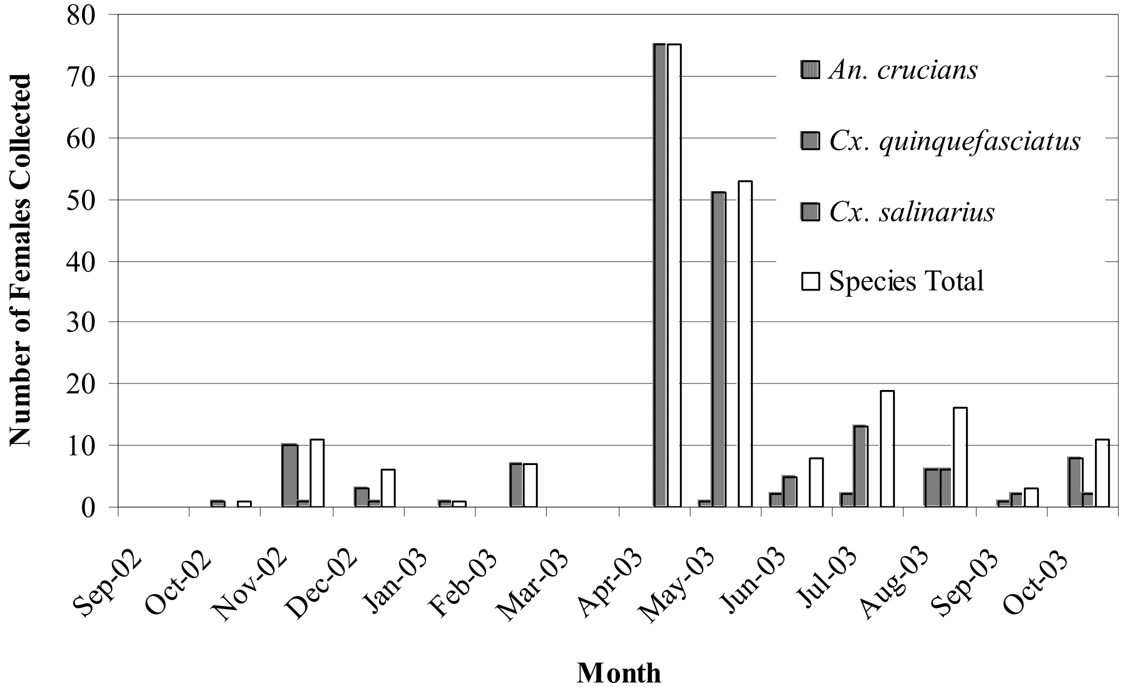

Figure 4. Three Most Abundant Mosquito Species Caught at SC Johnson OFF!® Lantern Site in Slidell, LA

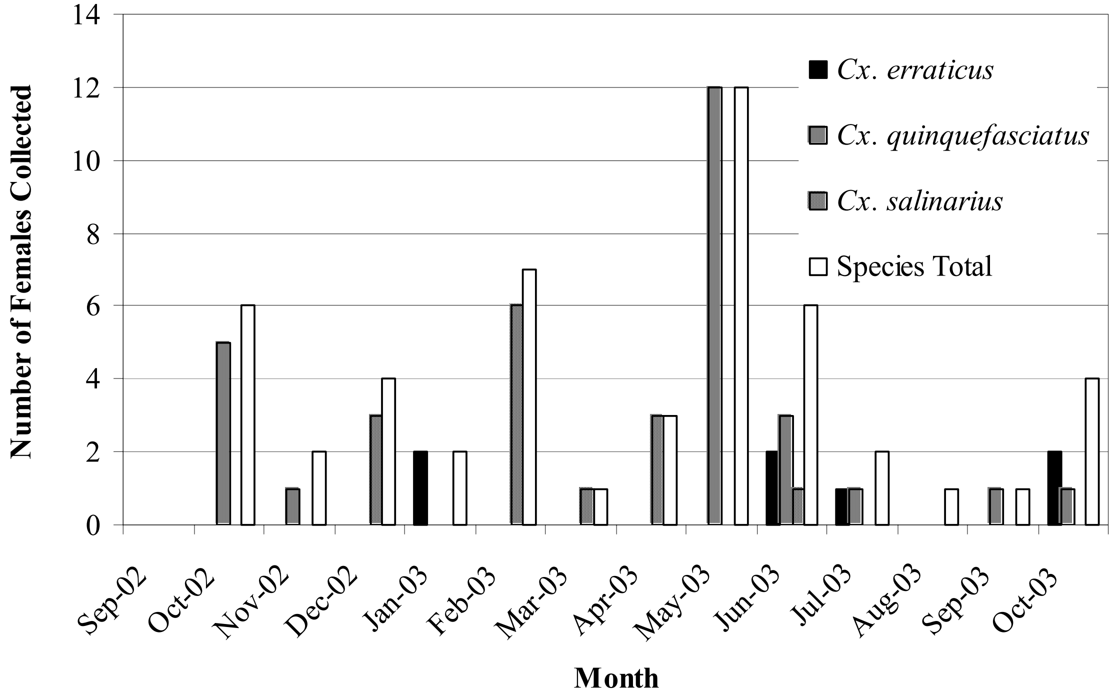

Figure 5. Three Most Abundant Mosquito Species Caught at ThermaCell® Site in Slidell, LA

indistinguishable taxonomic characteristics. Of the 23 species captured by the ABC traps, *Cx. salinarius* and Cx. *quinquefasciatus* comprised 47.8% and 37.3% respectively, or 85.1% of all the species caught. At the Slidell, LA location a total of 3577 mosquitoes representing 19 species were caught. The ABC trap at the Dragonfly®/Cognito® treatment site captured the most specimens (1731), followed by the Mosquito Magnet® (1179), Control (405), SC Johnson OFF!® Mosquito Lantern (211) and ThermaCell® (51) (Table 1). The Dragonfly®/Cognito® had the most species represented with 15 followed by the Mosquito Magnet® (13), Control (13), SC Johnson Off!® Mosquito Lantern (10) and ThermaCell® (9). Monthly totals of ABC trap collections for each treatment and control site at Slidell, LA indicated that *Cx. quinquefasciatus* and *Cx. salinarius* are the most abundant (Figures 1-5). Of the 19 species caught, *Cx. quinquefasciatus, Cx. erraticus, Cx. salinarius,* and *An. crucians* were the most abundant, comprising 94.1% of the total with the remaining 15 species only represented by 5.9%. No mosquitoes were collected for the month of September 2002 due to Hurricanes Isidore and Lili. The ABC trap at the SC Johnson OFF!® Lantern site in January 2003 caught zero specimens (Figure 4).

At the Baton Rouge, LA location a total of 1684 mosquitoes representing 14 species were collected. The ABC trap at the Mosquito Magnet® treatment site collected the most species with 11, followed by the Dragonfly®/Cognito® (10), Control (9), SC Johnson Off!® Lantern (7), and ThermaCell® (6). The ABC trap at the Mosquito Magnet® site caught the most specimens (835), followed by the Dragonfly/Cognito® (572), Control (161), SC Johnson OFF!® Mosquito Lantern (90), and ThermaCell® (26). Monthly totals of ABC trap collections for each treatment and control sites at Baton Rouge, LA indicated that *Cx. quinquefasciatus* and *Ae. vexans* were the most abundant (Figures 6-10). Of the 14 species caught in Baton Rouge, *Ae. vexans, Cx. quinquefasciatus, Cx. salinarius,* and *Cx. erraticus* composed 95.4% with the remaining 10 species made up only 4.6%. Except for the

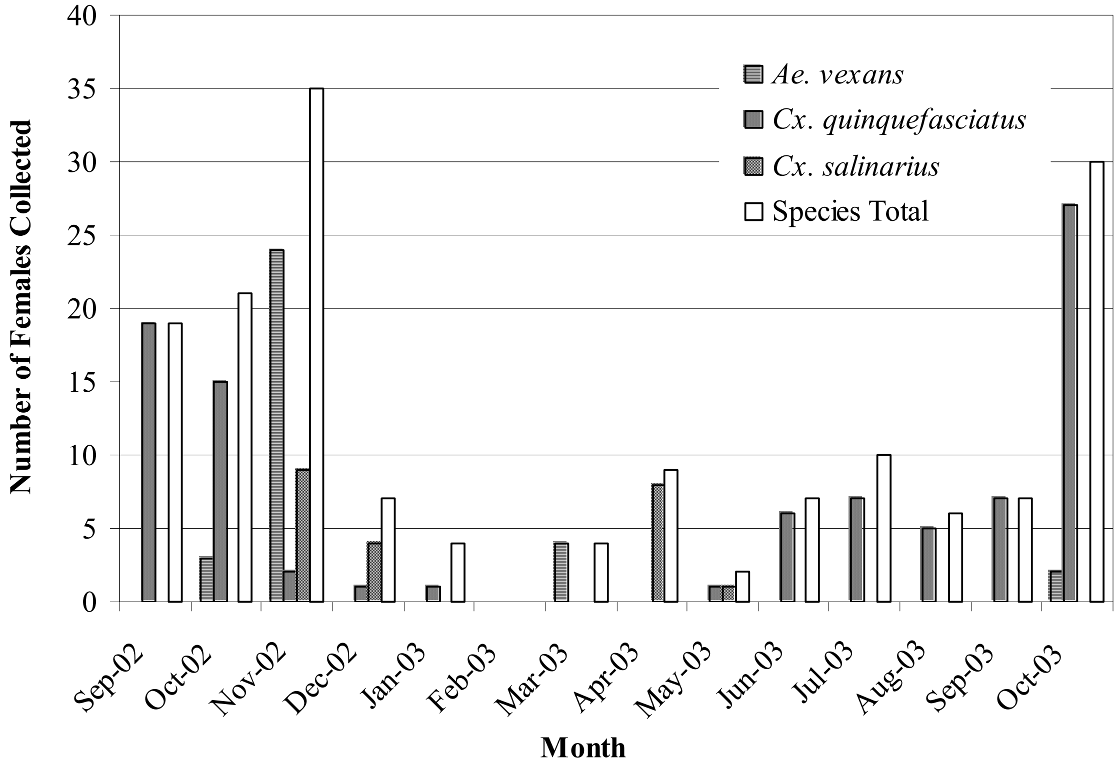

Figure 6. Three Most Abundant Mosquito Species Caught at Control Site in Baton Rouge, LA

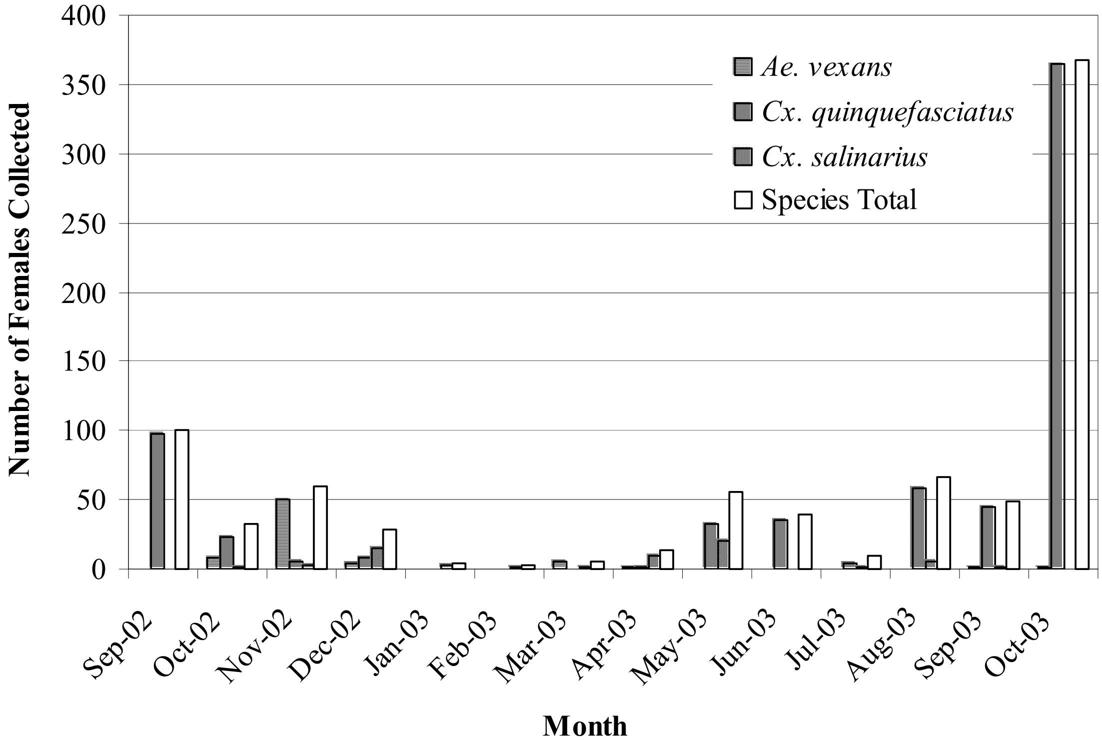

Figure 7. Three Most Abundant Mosquito Species Caught at Mosquito Magnet® Site in Baton Rouge, LA

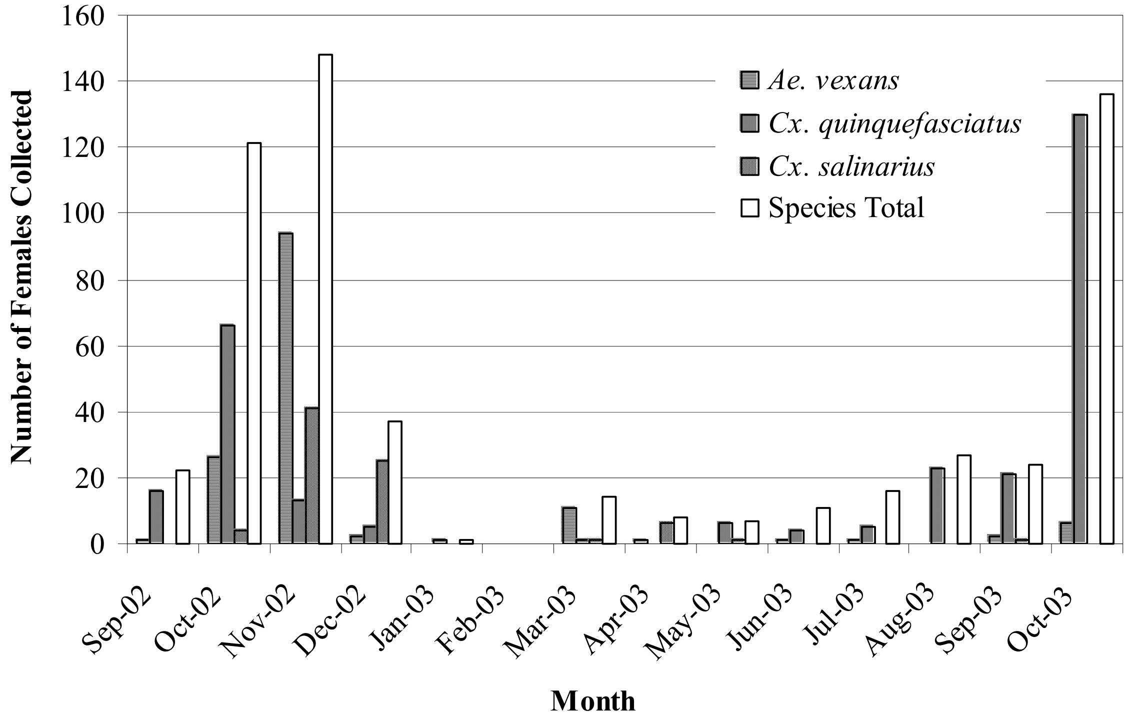

Figure 8. Three Most Abundant Mosquito Species Caught at Dragonfly/Cognito® Site in Baton Rouge, LA

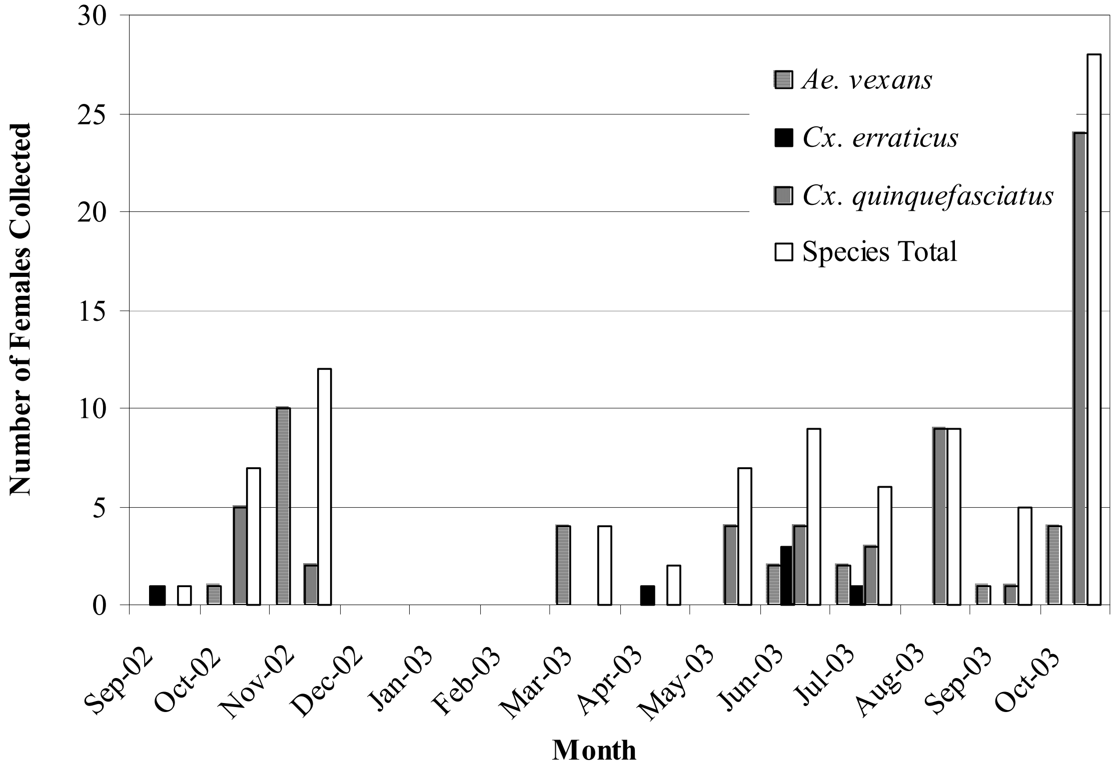

Figure 9. Three Most Abundant Mosquito Species Caught at SC Johnson OFF!® Lantern Site in Baton Rouge, LA

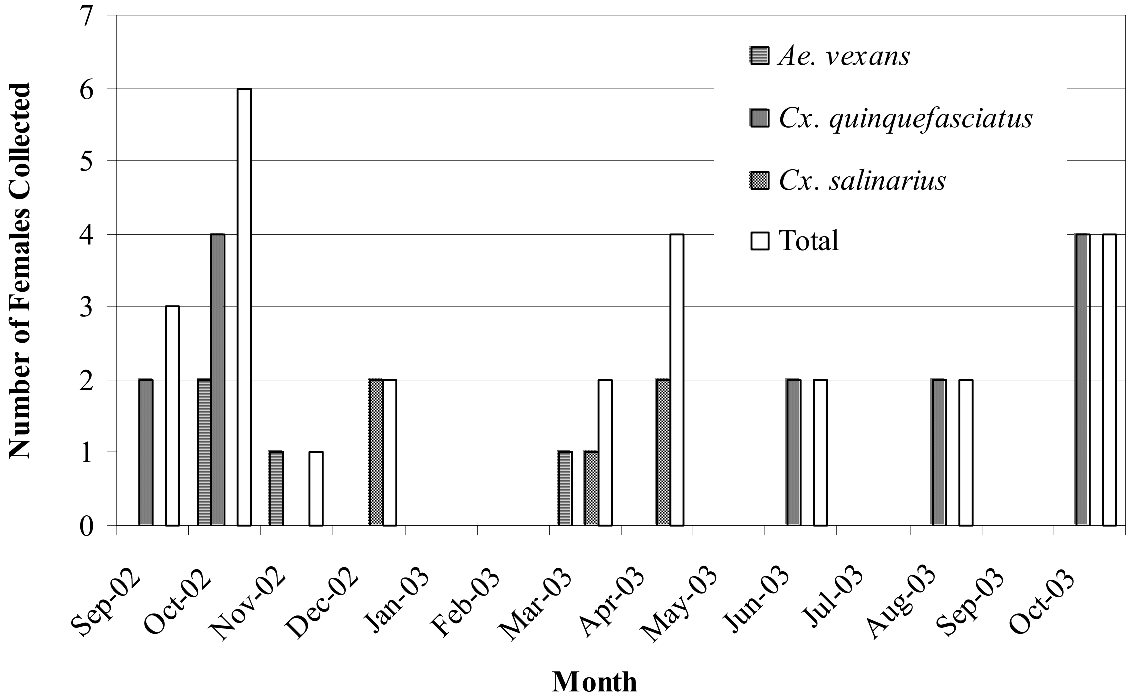

Figure 10. Three Most Abundant Mosquito Species Caught at ThermaCell® Site in Baton Rouge, LA

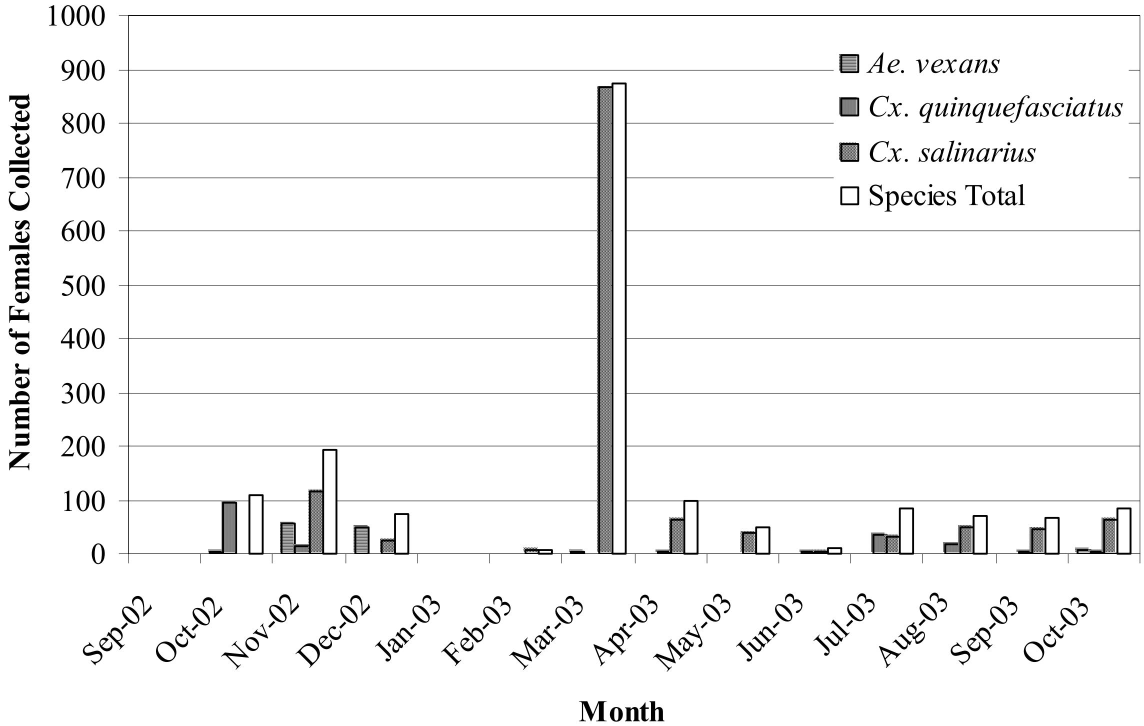

Figure 11. Three Most Abundant Mosquito Species Caught at Control Site in Lake Charles, LA

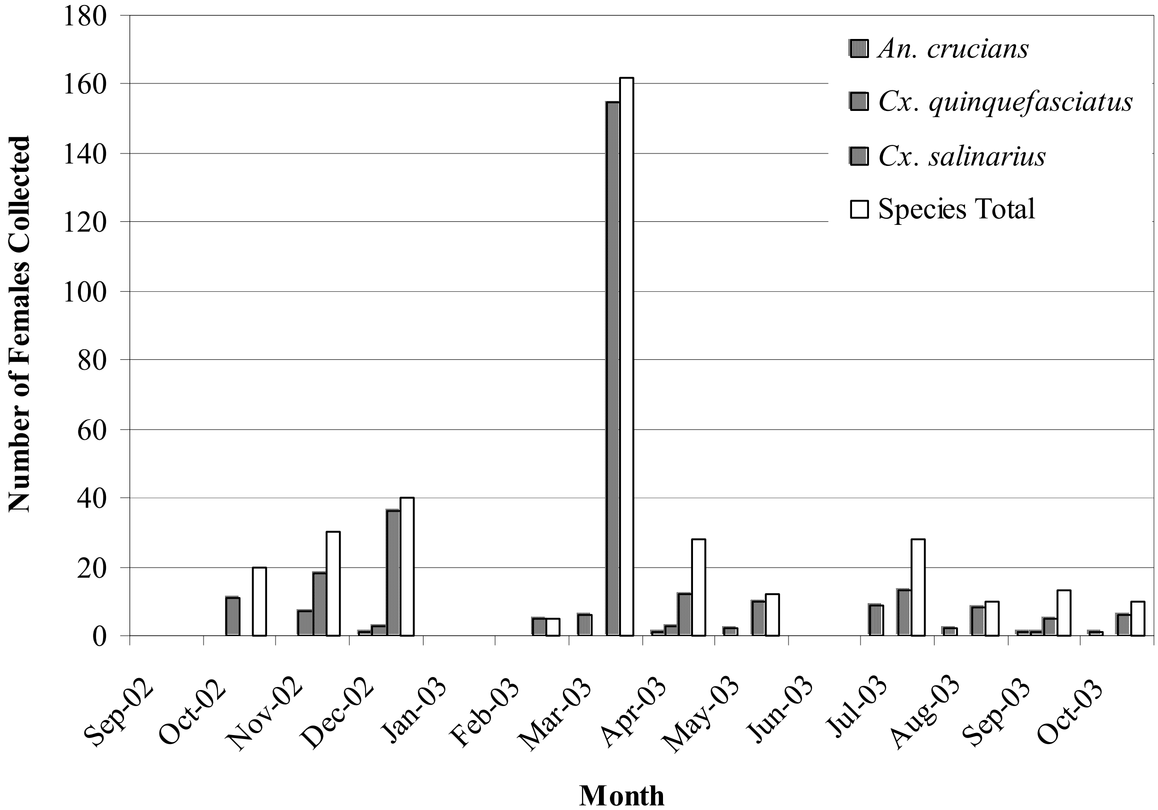

Figure 12. Three Most Abundant Mosquito Species Caught at Mosquito Magnet® Site in Lake Charles, LA

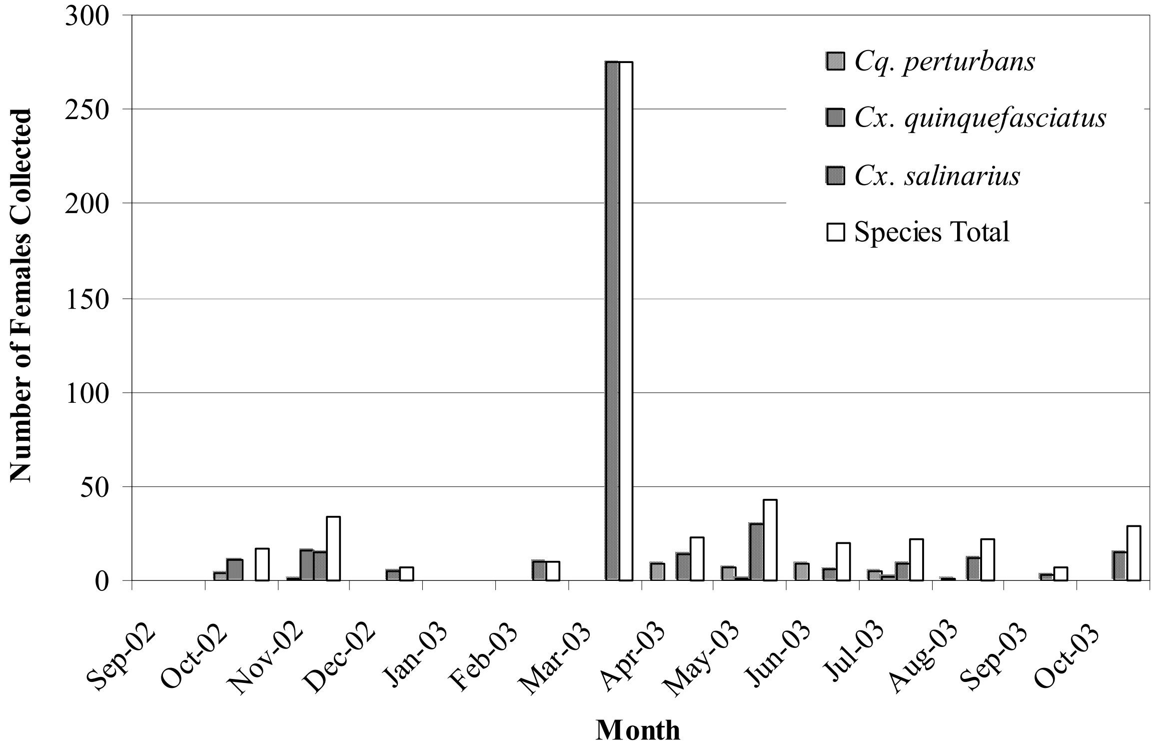

Figure 13. Three Most Abundant Mosquito Species Caught at Dragonfly/Cognito® Site in Lake Charles, LA

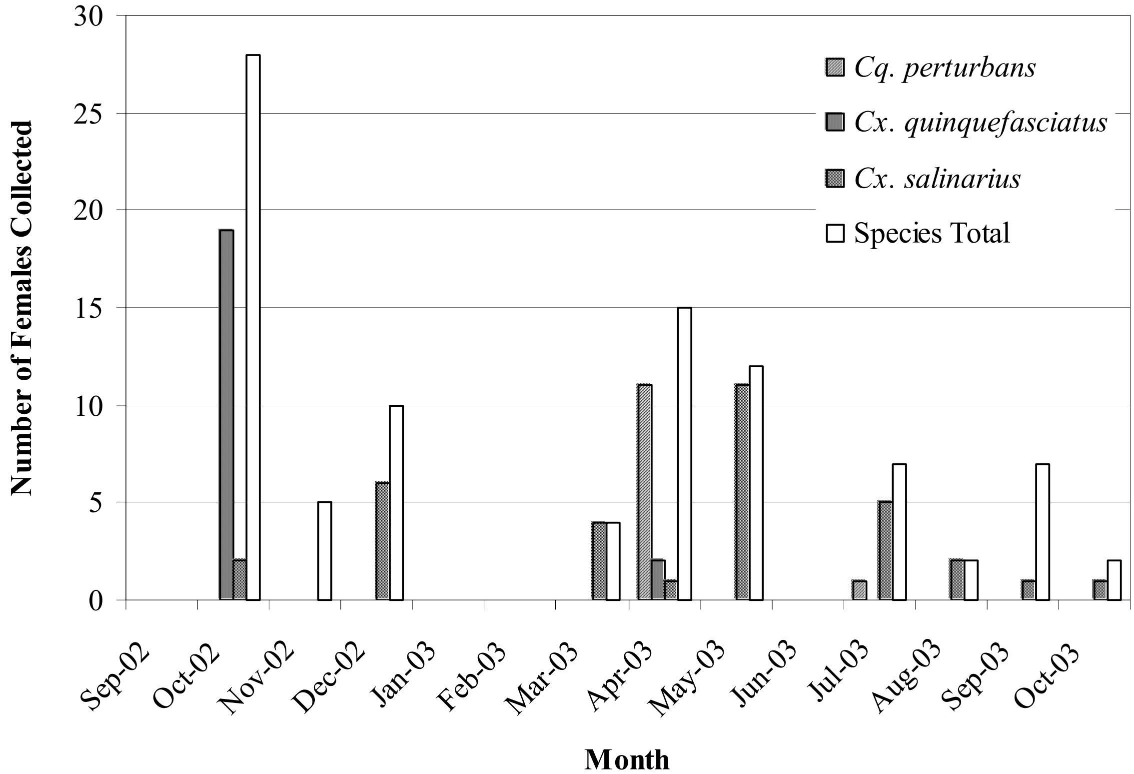

Figure 14. Three Most Abundant Mosquito Species Caught at SC Johnson OFF!® Lantern Site in Lake Charles, LA

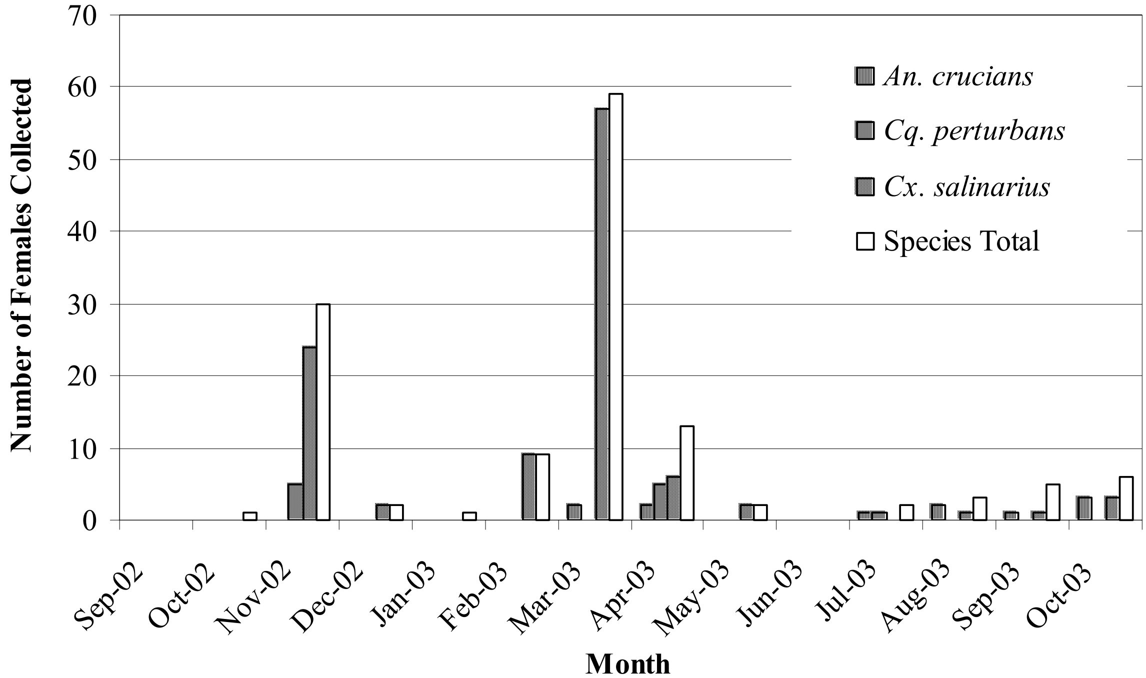

Figure 15. Three Most Abundant Mosquito Species Caught at ThermaCell® Site in Lake Charles, LA

Dragonfly®/Cognito® site in Baton Rouge, no other site caught mosquitoes for the month of February 2003. There were no mosquitoes collected for the months December 2002, January 2003 for the SC Johnson OFF!® Mosquito Lantern or for the month of January 2003 for the ThermaCell®.

At the Lake Charles, LA location, a total of 2799 mosquitoes were collected with 20 species represented. The ABC trap at the Control site caught the most specimens (1707), followed by Dragonfly®/Cognito® (509), Mosquito Magnet® (358), ThermaCell® (133), and SC Johnson OFF!® Mosquito Lantern (92). The ABC trap at the Dragonfly®/Cognito® and control sites caught the most species (13) followed by Mosquito Magnet®, SC Johnson OFF!® Mosquito Lantern (10), and ThermaCell® (8). Monthly totals of ABC trap collections for each treatment and control sites at Lake Charles, LA shows that *Cx. quinquefasciatus* and *Cx. salinarius* are the most abundant (Figures 11-15). Of the 19 species of mosquitoes collected, *Cx. salinarius*, *Cx. quinquefasciatus*, *Ae. vexans*, *Cq. perturbans*, and *An. crucians* comprised 97.4% with the remaining species making up 2.6%. No mosquitoes were collected for the month of September 2002 due to Hurricanes Isidore and Lili. Except for the ABC trap at the ThermaCell® site which caught 1 *Culiseta inornata*, no other sites collected mosquitoes for the month of January 2003. No mosquitoes were caught in February 2003 in the ABC trap at the SC Johnson OFF!® Mosquito Lantern site.

Monthly means of the four treatment devices and control for mosquitoes collected by the ABC traps are shown in Figure 16. While there were no significant differences among main effects for month (ANOVA; $F=1.54$, $df=13$, $P>0.11$) and the interaction between month and treatment ($F=0.56$, $df=52$, $P>0.99$), overall treatment effect among treatments was significant between devices ($F=4.57$, $df=4$, $P<0.0017$). For treatment effects, the ABC traps at the control ($P<0.0011$), Dragonfly/Cognito® ($P<0.0001$), and the Mosquito Magnet® ($P<0.0008$) sites were significantly different from the SC Johnson OFF!® Mosquito Lantern and

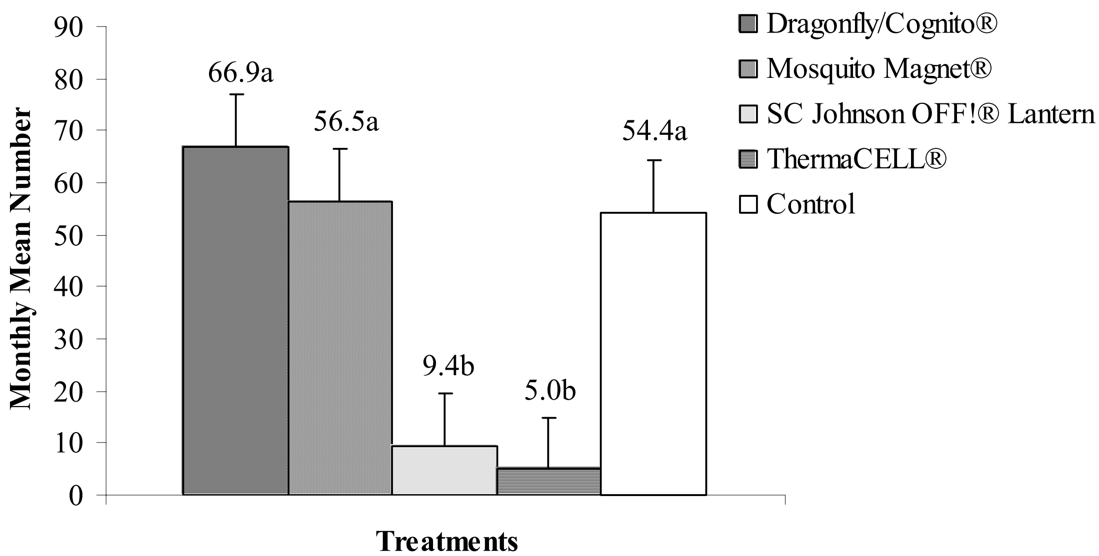

Figure 16. Mosquitoes Captured by ABC Light Traps in Louisiana

Means followed by the same letter are not significantly different (P>0.05) with Duncan's mean separation test (SAS 2002).

Table 2. Means Comparisions of Treatments vs. Control of Mosquitoes Captured by ABC Light Traps.

Treatment	Differences Between Control and Treatment	P Value
Dragonfly/Cognito®	12.6	0.512
Mosquito Magnet®	2.12	0.912
SC Johnson OFF!® Mosquito Lantern	- 45	0.020
ThermaCell®	- 49.36	0.011

Significance based on Dunnett's one-tailed test (P<0.05)

ThermaCell®. The ABC traps at the Mosquito Magnet® and Dragonfly®/Cognito® treatment sites showed no significant difference in number of mosquitoes caught when compared to the control (P>0.05). For the ABC traps at the SC Johnson OFF!® Mosquito Lantern and

ThermaCell® treatment sites there was a significant difference in the number of mosquitoes caught between these treatments and the control ($P<0.05$). When the ThermaCell® and SC Johnson OFF!® Mosquito Lantern were used as treatments, significantly fewer mosquitoes were caught in the ABC traps. When each individual treatment was compared to the control to determine if treatments were effective, mosquitoes collected in the ABC traps from the Dragonfly®/Cognito® and Mosquito Magnet® treatment sites were not significantly different from the control, but the ThermaCell® and SC Johnson OFF!® Mosquito Lantern treatment sites were significantly different than the control (Table 2). These results indicate that the SC Johnson OFF!® Lantern and the ThermaCell® repel and reduce mosquito numbers.

Temperature, relative humidity, and total number of mosquitoes caught by month for each location are shown in Figures 17-22. Wind speed and direction did not appear to be a significant factor since calm conditions usually existed at all locations when trials were conducted. There was no significant correlation between numbers of mosquitoes caught and temperature at Slidell, LA ($r = 0.032$, $P = 0.91$), Baton Rouge, LA ($r = 0.053$, $P = 0.85$) and Lake Charles, LA ($r = -0.11$, $P = 0.71$). Humidity did not have a significant effect when correlated against numbers of mosquitoes caught in Slidell, LA ($r = -0.20$, $P = 0.50$), Baton Rouge, LA ($r = -0.066$, $P = 0.82$) and Lake Charles, LA ($r = -0.11$, $P = 0.71$).

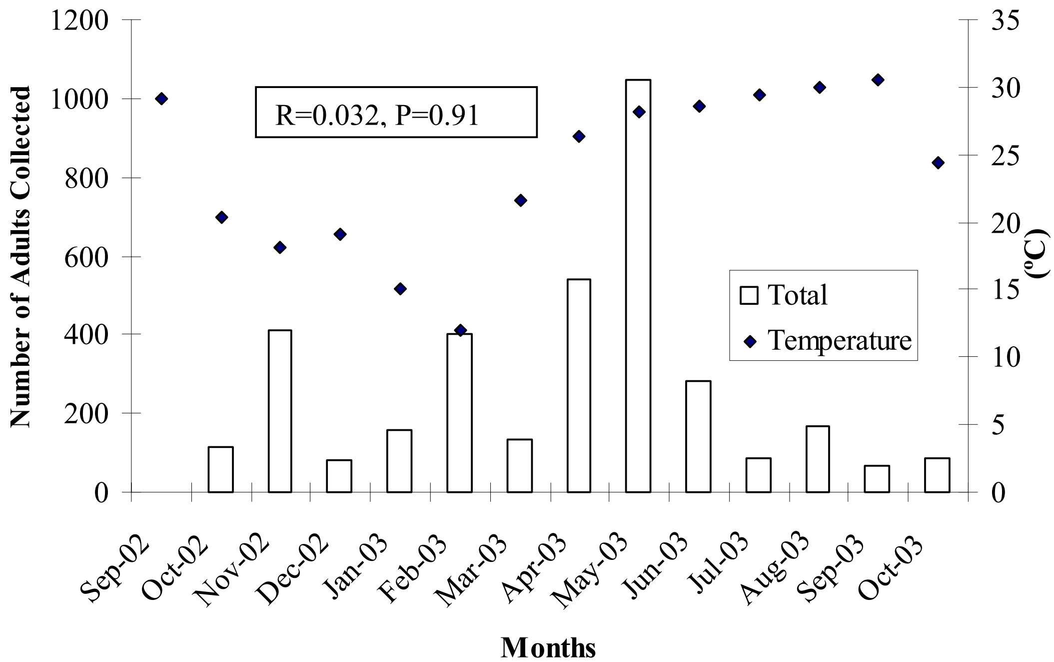

Figure 17. Temperature vs. Mosquito Population, Slidell, LA

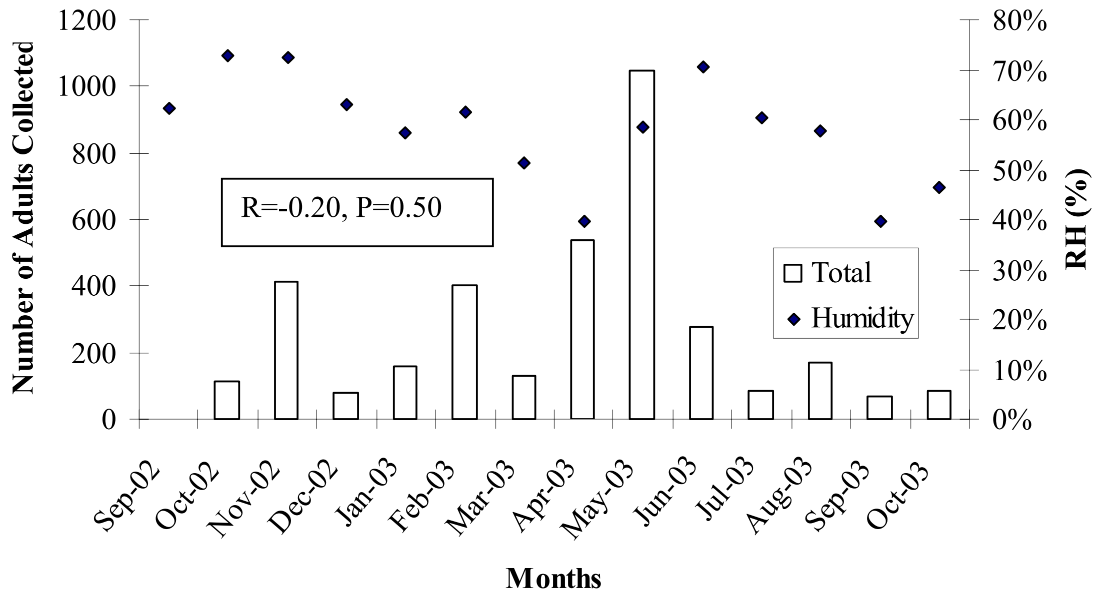

Figure 18. Humidity vs. Mosquito Population, Slidell, LA

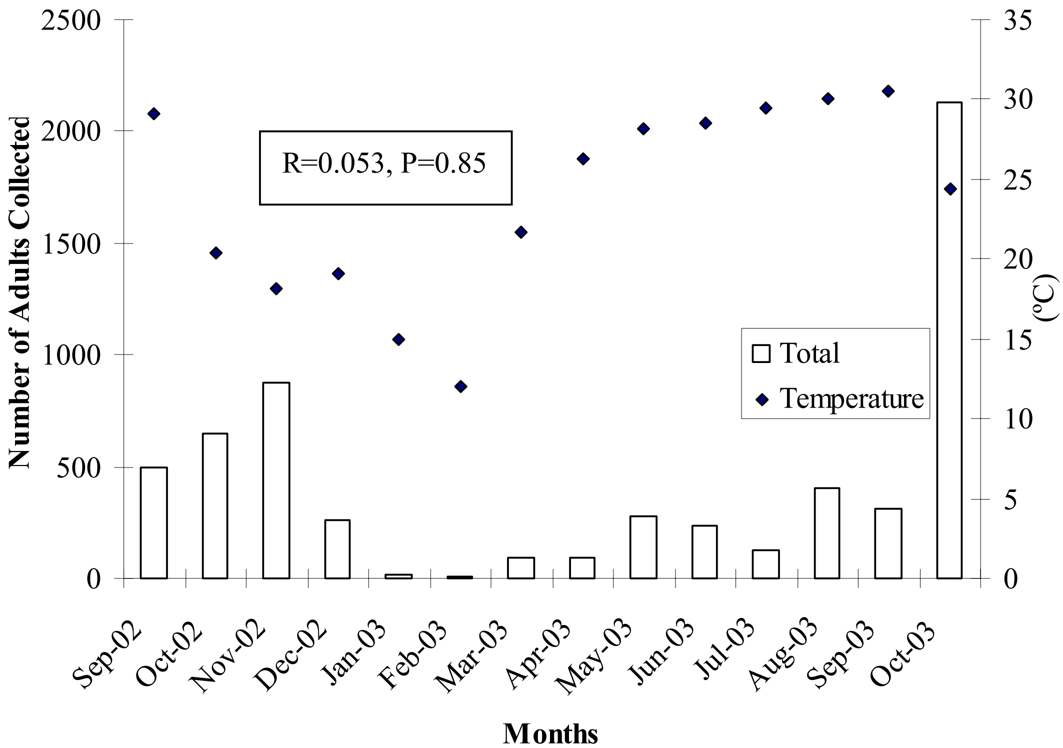

Figure 19. Temperature vs. Mosquito Population, Baton Rouge, LA

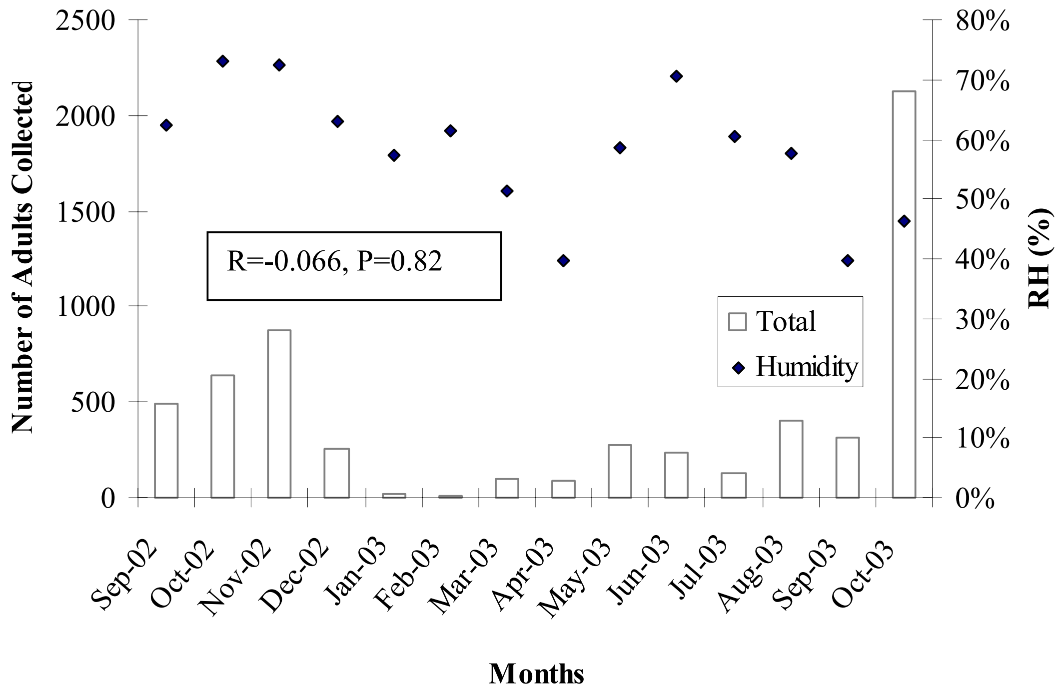

Figure 20. Humidity vs. Mosquito Population, Baton Rouge, LA

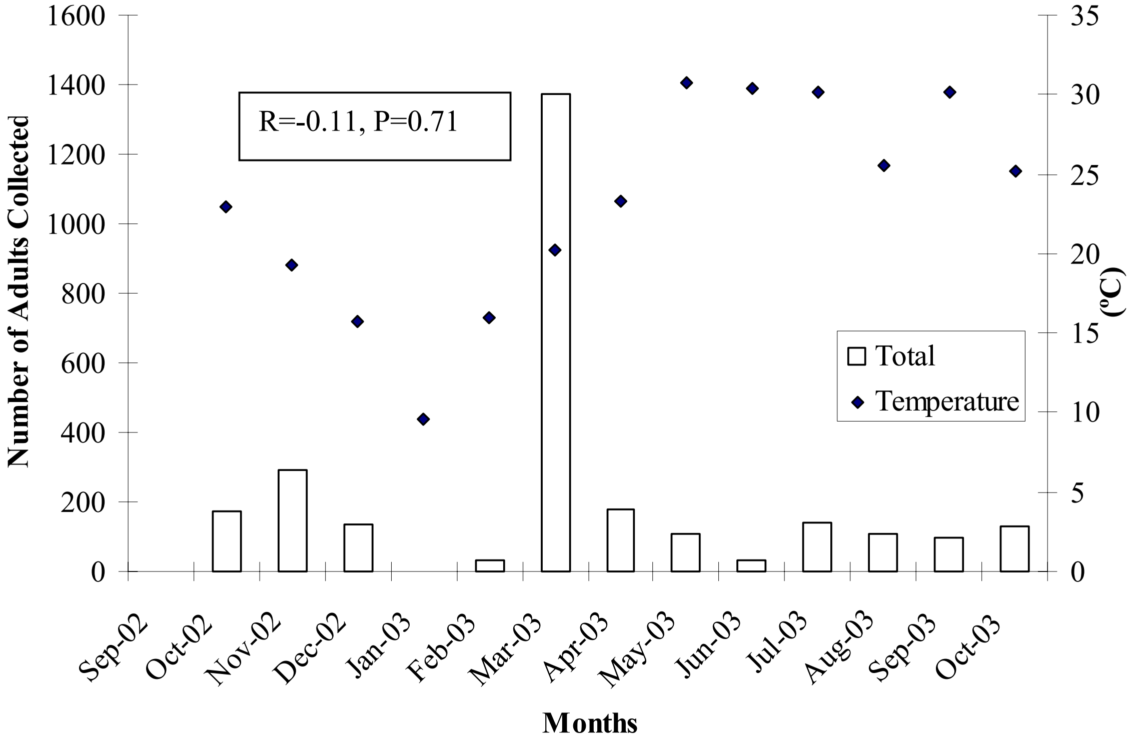

Figure 21. Temperature vs. Mosquito Population, Lake Charles, LA

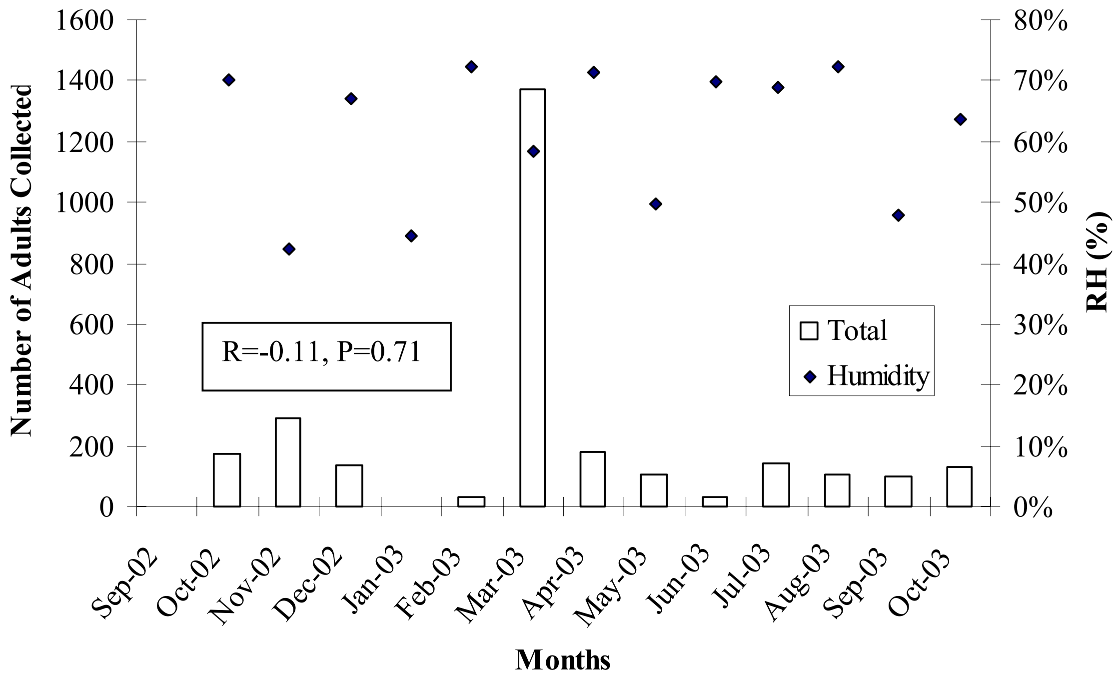

Figure 22. Humidity vs. Mosquito Population, Lake Charles, LA

CHAPTER 5

DISCUSSION

With the emergence of diseases such as West Nile virus and the abundance of nuisance mosquitoes remaining a concern in Louisiana, effective alternative control measures other than spraying with insecticides at the individual or Parish mosquito abatement level must be found and developed. Mosquitoes are vectors of malaria, yellow fever, dengue fever, filariasis, and numerous other diseases that cause many millions of people to become sick or die each year worldwide (Olkowski 2001). High numbers of common biting arthropods in Southern Louisiana such as *Cx. salinarius, Cx. quinquefasciatus, Cq. perturbans, Ae. vexans, An. crucians* and others often constitute a significant nuisance to homeowners who wish to conduct activities in their yards. The data reported in this study indicate that the ThermaCell® and SC Johnson OFF!® Mosquito Lantern can repel mosquitoes from a given area. In a previous study, when the ThermaCell® was evaluated as an area repellent system against phlebotomine sand flies and nuisance mosquitoes in Cunpolat, Turkey, significant protection was achieved with repellent efficacy ranging from 87.5 to 97.7% (Alten et al. 2003). For this study, based on the numbers of mosquitoes caught in the ABC traps at the SC Johnson OFF!® Mosquito Lantern and ThermaCell® sites at all three locations, the SC Johnson OFF!® Mosquito Lantern was 44.1 to 94.6% effective in repelling mosquitoes and the ThermaCell® was 83.9 to 92% effective. While there was no significant difference between these two devices as far as numbers of mosquitoes caught, the ABC traps at the SC Johnson OFF!® Mosquito Lantern treatment sites overall collected 53.4% more mosquitoes than the sites treated with the ThermaCell®. At the Lake Charles location, the ABC traps at the SC Johnson OFF!® Lantern site caught 69.2% fewer mosquitoes than the ABC trap at the ThermaCell® site. However, at the Slidell and Baton Rouge locations, the ABC trap at the ThermaCell® site caught 75.8 to 71.1% fewer mosquitoes, respectively, than the SC Johnson

OFF!® Mosquito Lantern sites. Both repellent devices use a similar impregnated pad treated with 21.9% cis-trans allethrin, but while the SC Johnson OFF!® Mosquito Lantern uses a candle as a heat source to disperse the repellent the ThermaCell® uses a disposable butane cartridge. Because the design of the ThermaCell's heating element allows even heating of the impregnated repellent pad, the repellent may evaporate more effectively and disperse more efficiently and thus be more effective in repelling mosquitoes. Often during trials at all three locations, the SC Johnson OFF!® Mosquito Lantern was more vulnerable to weather effects in which the flame on the candle would go out due to precipitation. Wind effects were negligible since most properties used in the study had fences or sufficient vegetation to act as a wind barrier. During this study, 3 ThermaCells (one at each location) had to be replaced due to faulty ignition. Because of the simple design of the SC Johnson OFF!® Mosquito Lantern, none of these devices had to be replaced. One significant limitation that the SC Johnson OFF!® Mosquito Lantern and ThermaCell® have is that they are limited in their range of protection. Both devices only protect 4.6m x 4.6m or $21.2m^2$ (Appendix A pages 55 and 57) as opposed to the Dragonfly/Cognito® system and Mosquito Magnet® which claim (Appendix A, pages 58 and 61) to protect an area from ½ to 1 acre respectively.

Both the Mosquito Magnet® and Dragonfly/Conito® devices use CO_2 and octenol (1-octen-3-ol) as olfactory attractants to capture mosquitoes and remove them from the environment. Carbon dioxide has long been used as an attractant for mosquitoes and other biting arthropods. It is one of the most important olfactory cues and is the primary cue that initiates flight of the female mosquito (Gillies 1980). Since it is a gas, it is considered a long-range cue, for it can disperse from the emitting host and travel far down wind until picked up by the mosquito. Kellogg (1970) reported finding a class of neurons in the capitate sensilla on the ventral-medial aspect of the maxillary palpi of female *Ae. aegypti* that are sensitive in a dose-dependent manner to levels of CO_2 found in exhaled human breath. With these sensilla, a mosquito may be able to detect and guide itself toward the host. Since higher forms of life including mammals, birds, and reptiles exhale CO_2 from their respiratory systems, it is no wonder that the mosquito keys in on this compound. It is interesting to note that these cells exhibit phasictonic responses to fluctuations in CO_2 and logarithmic sensitivity to stimulus detecting changes in CO_2 levels as low as 0.01% (Bowen 1991). In comparison, the breath of a human is about 4.0% CO_2 (Bowen 1991). This alone makes CO_2 not only a behaviorally important kairomone, but also an important attractant.

Another compound that both the Mosquito Magnet® and Dragonfly/Cognito® utilize to attract mosquitoes and is used as an olfactory cue is octenol (1-octen-3-ol). Isolated from ox breath, it has been reported as an attractant for the tsetse fly, *Glossina morsitans* Westwood (Vale and Hall 1985). It is an effective attractant for mosquitoes in the field when used in addition to other attractants such as CO_2 (Kline 1994). For mosquitoes, octenol has been demonstrated to attract certain species in the field (e.g., *Aedes taenorhynchus* (Weid) and *Culex salinarius*) but not others (e.g., *Ae. aegypti*) (Kline 1994). Some species of mosquitoes react differently according to what phase of the gonotrophic cycle they are in. *Culex salinarius*, for example, has been shown to be attracted regardless if it is gravid or not. This was made abundantly evident when at the end of each trial the Mosquito Magnet® and Dragonfly®/Cognito® had *Cx. salinarius* resting on the top, sides, and gas lines of the traps. This resting behavior was also noted at times on the ABC traps at these sites and the ABC trap at the control, but not on the SC Johnson OFF!® Mosquito Lantern or ThermaCell® treatment sites.

Though the Mosquito Magnet® and Dragonfly®/Cognito® use CO_2 and octenol to attract mosquitoes, the way they operate and function is different. The Mosquito Magnet® uses the principle of counterflow technology™, a catalytic combustion unit to convert propane to CO_2, heat and water vapor, and a thermoelectric generator, which allows it to be selfsustaining (American Biophysics Corp. 2004). The Dragonfly®/Cognito® utilizes a 20-pound CO_2 gas cylinder and must rely on an AC power source to operate (Appendix A page 62). Unlike the Mosquito Magnet®, The Dragonfly®/Cognito® releases CO_2 every 5 or 10 seconds depending on the desired setting to simulate respiration (Appendix A page 63). The Dragonfly®/Cognito® system also utilizes a thermal lure and electrostatic panels to attract and capture mosquitoes (Appendix A page 62). In addition, the Dragonfly® system uses a pair of Cognito® dispensers that emit Conceal™ inhibitor which blocks the olfactory sensory of the mosquito (Appendix A page 69). According to the manufacturer, the Dragonfly® attracts and captures mosquitoes while the Cognito® dispensers' block the mosquito's ability to pick up olfactory signals. Even though the Mosquito Magnet® devices were maintained according to manufacturer's specifications, each Mosquito Magnet® at each location had a power pack failure in which the device would wear out and fail to keep operating. This in turn caused significant breaks in the continuous operation of the treatment device of up to 19 days until a new or rebuilt unit could be ordered, shipped, received, and installed. At no time during the study did the Dragonfly® system have a malfunction or failure. However, the Cognito® dispenser was vulnerable to moisture and high humidity. Due to constant operation, Cognitos® at Lake Charles and Slidell, LA had to be replaced due to corrosion of the battery connections and electric motor failure. One Cognito® was replaced in Baton Rouge due to corrosion. To ensure that the Cognito® dispensers were in constant operation, batteries were exchanged every 2 weeks when the inhibitor was due to be changed.

Besides olfactory stimuli, mosquitoes use physical cues to locate their hosts when they are in a host-seeking mode (Davis and Bowen 1994). For this study, temperature and humidity were looked at to determine if there was a correlation between number of mosquitoes captured and physical effects. Even though there was no correlation between temperature, humidity and number of mosquitoes caught, both effects must be considered. In addition to using CO_2 and octenol, the Dragonfly®/Cognito® emits heat with which to further attract female mosquitoes (Appendix A page 62). Temperature is an important physical signal associated with animals that mosquitoes and other vector organisms use to detect, orient toward, and locate the host (Davis and Bowen 1994). Next to olfactory sensing, this is considered one of the main attractants used by mosquitoes to isolate their host when they are close proximity (Takken 1996). A rapid temperature change of 0.05^{o}C will cause a change in spike frequency of 4 impulses/sec in both the warm and the cold thermoreceptors for a total response of 8 impulses/sec/0.05 ^{o}C (Davis and Bowen 1994). This suggests that there is a high degree of sensitivity to temperature change, which allows the female mosquito to detect slight temperature differences from the natural background. Humidity also has been identified as a stimulant for mosquitoes (Davis and Bowen 1994). It has been determined that mosquitoes prefer warm moist air as opposed to warm dry air (Davis and Bowen 1994). The reason for this may be that mosquitoes can detect temperature differences in moist air more acutely than in dry air. Most of the mosquito's receptors are moisture dependant and work best when there is sufficient humidity (Davis and Bowen 1994). As with most insects, dehydration is a main threat to mosquitoes because of their small size and lack of water storage capability.

The treatment devices used in this study vary greatly in their price. Purchase price, maintenance costs, and supplies must be considered by the consumer before buying. Depending on which vendors a customer uses, purchase price, supplies, and maintenance will vary. In this study, the Mosquito Magnet® Pro Model was used at all three locations. Of the 4 treatment devices evaluated, the Mosquito Magnet® was the most expensive costing $1296.00, but less costly models are currently available (American Biophysics Corp. 2004). Since the Mosquito Magnet® did not come with a propane tank, a 5-pound propane tank ($39.44, Wal-Mart, Bentonville, AR) had to be purchased for each device. Propane gas (cost

$7.95 – $11.25) purchased every three weeks is required for operation. Depending on where Mosquito Magnet® supplies are purchased, a pack of 5 octenol cartridges, which last up to 15 weeks, can cost $24.99. Due to environmental conditions, the net (3-pack, $79.98) must also be replaced every three months.

The Dragonfly® system with the Cognito® dispensers is a cheaper alternative. A Dragonfly® with a pair of Mosquito Cognito® dispensers can cost up to $795.00 (BioSensory, Inc. 2004). To power the Cognito®, 2 AA batteries (cost $ 3.97) are required to effectively operate up to 30 days. The inhibitor cartridges for the Cognito® (cost $14.97) are required for operation and need to be replaced every 2 weeks. A 5 pound CO_2 cylinder of gas can costs approximately $10.00 per fill depending on where the gas is purchased. Depending on the mode of operation, a cylinder of gas could go from 30 to 120 days. The biting insect lure (octenol cartridge, $5.00) has a life expectancy of 30 to 60 days depending on environmental conditions and mode of operation (Appendix A page 65). Gas cylinders can be bought or rented by month depending on which vender the customer uses.

The SC Johnson OFF!® Mosquito Lantern costs $14.99 (Appendix A page 55) and comes with a candle and repellent pad. Since one device protects only 21.1m^2, 2 or more devices may be required for greater area of protection (Appendix A page 55). SC Johnson OFF!® Mosquito Lantern refills (3 candles and 3 repellent pads) are easily obtainable and range from $3.00 – $4.62 depending on location of purchase. Each candle and repellent pad last up to four hours. This device is the least expensive evaluated.

The ThermaCell® is slightly more expensive (cost $21.99) (Appendix A page 57) than the SC Johnson OFF!® Mosquito Lantern, but uses the same repellent and provides the same area of protection. Each device comes with a butane cartridge and 3 repellent pads. Refills can be obtained for approximately $4.99.

CHAPTER 6

CONCLUSION

This study has shown that the SC Johnson OFF!® Mosquito Lantern and ThermaCell® repellent systems effectively reduce catches of mosquitoes. With the availability of mosquito treatment devices increasing due to the demand for alternatives to pesticide use, and the public becoming increasingly aware, the use of alternative treatment devices such as attractant-baited traps and repellent devices will continue to rise. Even though this study evaluated four treatment devices, there are more products coming out and being made available to the public for private use. Although this study shows promise that repellent devices provide protection from mosquitoes, more research must be done regarding long-term effects. Further studies must also be done as new devices become available on the market so that the consumer will be more informed as what does or does not work.

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APPENDIX A

EQUIPMENT INSTRUCTIONS

SC Johnson OFF!® Mosquito Lantern Instructions

Mosquito Protection for areas up to 15 feet by 15 feet.
Assembles to 5 Feet High.

Contains:

- 1 Reusable Hanging Lantern
- 3 Pole Segments
- 1 Mosquito Repellant Pad
- 1 Candle

Advanced Pad Technology: Effective Protection for up to 4 hours. Pads are designed to release repellent when heated by candle.

Refillable: Works with OFF!® Mosquito Lamp Refills or OFF!® Mosquito Lamp & Lantern Refills.

Helpful Hints:

- Use one OFF!® Hanging Mosquito Lantern in an area as large as 15' by 15'. Use two or more in larger areas.
- Allow time for candle to heat mosquito repellent pad.
- When candle is used up, replace both candle and pad.
- Place product upwind for maximum protection.

The Pad Contains Bitrex® - Pad is designed to taste bitter to help prevent ingestion. Be sure to wash hands after handling. Bitrex® is a trademark of Macfarlan Smith, Ltd.

Directions:

For Use:
It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

1. Completely assemble pole segments.
2. Insert pole into stable ground.
   Test to ensure pole does not tip easily.
3. Remove lantern base.
4. Remove enclosed contents.
5. Make sure candle cup is secured onto base post.
6. Remove repellent pad being careful not to cut, bend, or alter pad shape.
7. Gently slide narrow end of pad in top of lantern.
8. Light candle.
9. Reinstall lantern base.

10. Carefully twist base until it snaps in place.

When finished using, carefully remove lantern base and blow out flame. Pad is designed to last as long as candle.

Note: Move lantern only when cool and not in use. To remove pole from ground, grasp pole at bottom. Be sure all pole segments are removed from ground.

To Replace Pad / Candle Combination: When candle is used up, replace both candle and pad.

1. Remove lantern base.
2. Make sure flame is extinguished and lantern is cool before changing pad.
3. Pull out used pad and slide in new pad. Wash hands.
4. Remove used candle cup and insert a new cup and candle.
5. Light candle.
6. Reinstall lantern base. Carefully twist base until it snaps in place.

Cleaning Instructions: Before cleaning lantern, extinguish flame and let lantern cool. Wash with a wet cloth only. Note: To avoid damaging product, be careful not to move or bend metal bar inside of lantern when cleaning.
Storage: Prolonged storage of repellent pads in outdoor conditions may decrease effectiveness. Store unused pads in an area inaccessible to children and pets.
Disposal: Securely wrap exhausted pad in newspaper and place in trash. After allowing exhausted candle to cool, securely wrap exhausted candle in newspaper and place in trash.

Ingredients:

Active Ingredients: D-cis/trans allethrin (21.97%)

Inactive Ingredients: Inert Ingredients (78.03%)

Company Address:

SC Johnson
1525 Howe Street
Racine, Wisconsin 53403-5011
USA

Telephone: 1.800.494.4855

Website: www.scjohnson.com

ThermaCELL® Mosquito Repellent Device Instructions

1. Remove one ThermaCELL® Mosquito Repellent mat from wrapper. One mat lasts up to 4 hours. Mat turns from pale blue to white when active ingredient has been exhausted.

2. Make sure the 'On/Off' switch on the appliance is in the 'Off' position. Insert the mat under the appliance's black grill. To change mats, slide the 'On/Off' switch to 'Off' and allow the appliance to cool completely. Push the used mat out by inserting a fresh one.

3. Remove the appliance cover and butane cartridge cap.

4. Screw the cartridge into the opening of the appliance. Make sure the cartridge is fully inserted by turning it clockwise until it stops. Replace the appliance cover. One ThermaCell® butane cartridge lasts 8 to 12 hours. If your appliance fails to heat, it may be out of fuel. Check the fuel level by holding the appliance vertically and looking at the fuel gauge on the bottom. You can see the amount of butane in the cartridge. Replace if empty.

5. Slide the 'On/Off'switch to the 'On' position; the butane gas will begin to flow.

6. Wait approximately 5-10 seconds then depress the start button three to five times in rapid succession.

7. To verify the appliance is operating, pick it up and check the lens on the end of the appliance. The light at the end of the appliance glows when the appliance is heating. If the light is not glowing, check to make sure the appliance is 'On' and the cartridge is completely screwed into place; then once again depress the start button three to five times in rapid succession. Check to make sure the light is glowing.

8. Place the appliance on a flat, stable area with the grill side facing up. Do not touch the grill; it will be hot after a couple of minutes. When finished using the appliance, slide the 'On/Off' switch to the 'Off' position, and allow the appliance to cool completely. Appliance is now ready for storage.

Address:

The Schawbel Corporation
100 Crosby Drive.
Bedford MA 01730 USA

Phone: 866.753.3837 (Tollfree)

Website: www.mosquitorepellent.com

Mosquito Magnet® Instructions

Note: The Mosquito Magnet® begins catching immediately; allow 4-6 weeks to greatly reduce biting insect population.

Proper placement of your Mosquito Magnet® is crucial to its success. If placed correctly the mosquitoes will be drawn to the Mosquito Magnet® instead of you.

You should begin noticing results in 7-10 days. After 4-6 weeks of continuous use, the female mosquitoes that live in and around your yard will be captured, thereby reducing the mosquito population. After this happens you will begin to see a reduction in your mosquito catch.

For best results, use the following guidelines for proper placement:

1. Determine where the mosquitoes are breeding.
   The Mosquito Magnet must be located between the breeding areas (standing water, bushes) and the 'people areas' (patio, deck) in order to capture the mosquitoes at their source, BEFORE they get to you.
2. Place the trap 30-40 feet away from people areas.
   Place the trap as close to the breeding area and as far away from the activity as possible. 30-40 feet is enough distance from the activity so the biting insects will be attracted to the trap and not to you.
3. Place the trap upwind from the mosquito breeding area.
   Mosquitoes fly upwind looking for a blood meal (you). After a female mosquito bites a human, its weight is doubled; the mosquito will float back downwind to the resting area.
4. Place trap in an open area, not in high grass or plants.
   CO_2 is heavier than air, therefore it stays close to the ground. The mosquitoes will follow the CO_2 plume to the trap. If its placed in high grass the flow of the plume will be impeded and the mosquitoes won't find it...they'll find you!
5. Place the trap in the shade.
   Mosquitoes don't like the heat of the direct sun. As the sun sets, mosquitoes come out of their resting places.

Address:

American Biophysics Corp.
140 Frenchtown Road
North Kingstown, RI 02852
USA

Phone: 1.401.884.3500

Website: www.mosquitomagnet.com

Mosquito Cognito® Instructions

Mosquito ‘Cognito dispenser Placement

Always place Mosquito ‘Cognito dispenser where people congregate. As a rule of thumb, use one Mosquito ‘Cognito dispenser for gatherings of up to five adults. Use more for larger gatherings. Satisfactory results depend on the number of people you want to protect and the severity of the local mosquito population. Experiment to find the number of Mosquito ‘Cognito dispenser units that are right for you.

How Mosquito ‘Cognito dispenser Works

1. Mosquito ‘Cognito dispenser is activated by pulling the top and bottom halves apart until they click into the ON position. This opens the dispenser and activates a battery-powered fan that discharges Conceal™ inhibitor.
2. Push the top and bottom halves together until they click into the OFF position. This turns off the fan and seals the dispenser

Mosquito ‘Cognito dispenser Operation

Pull the top and bottom halves of the Mosquito ‘Cognito dispenser apart until they click into the ON position. See **Error! Reference source not found.**. This action opens intake and discharge vents, and activates a battery-powered fan. Air is drawn through intake vents into the dispenser where it travels vertically upward to the mouth of the cylindrical fan housing. The low velocity, upward airflow removes most dust and dirt particles from the airstream. The fan and cylindrical housing then force clean air down into the bottom half of the dispenser, where it passes over the fan motor and batteries before encountering the Conceal™ inhibitor cartridge. Bathing the motor and battery compartment with clean air prolongs the life of the electrical contacts. The airstream contacts the center of the Conceal™ cartridge and travels radially across the surface to discharge vents around the periphery. The Conceal™ inhibitor enters the airstream passing over the surface of the cartridge and is discharged with it.

Push the top and bottom halves of the Mosquito ‘Cognito dispenser together until they click into the OFF position. This action disconnects power to the fan conserving batteries, and closes the intake and discharge vents conserving Conceal™ inhibitor.

When in the OFF position the batteries and the inhibitor are protected from minor showers, however, take care to protect the ‘Cognito from heavy downpours and do not clean it with water sprays or the like.

Replacing Conceal™ Inhibitor Cartridge

1. Push the halves of the Mosquito ‘Cognito dispenser together to snap into the OFF position.

2. Turn the Mosquito ‘Cognito dispenser on its side to gain access to the Conceal™ inhibitor cartridge in the bottom of the dispenser. Remove the old Conceal™ cartridge by grasping the finger-holds on the bottom of the cartridge and turning counter-clockwise. The cartridge will rotate a few degrees and stop. Remove finger pressure and the cartridge will fall into your hand.
3. Remove the seal from a new Conceal™ inhibitor cartridge. Insert it into the bottom half of the Mosquito ‘Cognito dispenser, aligning the locking tabs on the cartridge with the mating recess in the dispenser housing. Use the finger-holds on the bottom of the cartridge to rotate it clockwise a few degrees until it locks into place.

The Mosquito ‘Cognito dispenser is now ready for use.

Replacing AA Alkaline Batteries

1. Push the halves of the Mosquito ‘Cognito dispenser together to snap into the OFF position.
2. To gain access to the battery compartment, remove the Conceal™ inhibitor cartridge. Turn the Mosquito ‘Cognito dispenser on its side to gain access to the Conceal™ inhibitor cartridge in the bottom of the dispenser. Remove the Conceal™ cartridge by grasping the finger-holds on the bottom of the cartridge and turning counter-clockwise. The cartridge will rotate a few degrees and stop. Remove finger pressure and the cartridge will fall into your hand, exposing the battery compartment.
3. Remove the two AA alkaline batteries and replace with fresh batteries.
4. Insert the Conceal™ inhibitor cartridge into the bottom half of the Mosquito ‘Cognito dispenser, aligning the locking tabs on the cartridge with the mating recess in the dispenser housing. Use the finger-holds on the bottom of the cartridge to rotate it clockwise a few degrees until it locks into place.

The Mosquito ‘Cognito dispenser is now ready for use.

Address:

BioSensory, Inc.
322 Main Street
Willimantic, CT 06226

Phone: 1.800.423.3009

Website: www.nomorebites.com

Dragonfly® Instructions

Dragonfly Biting Insect Trap Placement

Keep the Dragonfly at least 10 m (30 ft.) away from the area you want to protect.
The Dragonfly Biting Insect Trap is a powerful mosquito attractant. The key to the Dragonfly Biting Insect Trap's extraordinary power is the way it turns the insects' keen sense of smell and poor eyesight against them. Mosquitoes and biting flies have an amazing sense of smell. They can detect the Dragonfly Biting Insect Trap's scent from up to 100 m (300 ft.) away. When they detect it they immediately fly toward it.

The visual range of mosquitoes is approximately 10 m (30 ft.), and they are attracted to the motion of people or animals within this radius. **Placing the Dragonfly Biting Insect Trap too close to people or animals creates a situation in which some insects drawn by the Dragonfly Biting Insect Trap's scent may be diverted by the motion of people or animals nearby, so keep it at least 10 m (30 ft.) away from the area you want to protect.**

That's all there is to it! Insects drawn to the Dragonfly Biting Insect Trap cannot see you because they are too far away and the Dragonfly Biting Insect Trap destroys them.

The Dragonfly Biting Insect Trap is One Part of the Dragonfly System®

The Dragonfly System® is designed to provide defense in-depth against biting insects. The first line of defense is the Dragonfly Biting Insect Trap, which draws biting insects away from you and kills them. The second line of defense is the Mosquito 'Cognito® dispenser. The Mosquito 'Cognito dispenser emits Conceal™ inhibitor, in turn, which blocks the scent-tracking ability of biting insects near you.

The Conceal inhibitor is not a repellent. Repellents simply smell bad. Insects avoid repellents and look elsewhere for prey. Conceal inhibitor is different. Insects with a nose-full of Conceal can't track down anything because their olfactory sense is impaired. Mosquitoes smell you before they see you, and if they can't smell you, they won't bite you.

Use Dragonfly Biting Insect Trap and Mosquito 'Cognito together for maximum effectiveness. Visit BioSensory on the Internet at www.nomorebites.com for more information.

How Dragonfly Biting Insect Trap Works

1. With an audible clicking sound, CO_2 is released every 5 or 10 seconds simulating the "breath" of a small animal. CO_2 is the most powerful attractant for mosquitoes and biting flies. The unit measures the amount of CO_2 released and lets you know when the bottle is getting low. Please note that the Dragonfly only functions when used with a 20-pound CO_2 bottle.

2. The thermal lure heats up, producing the infrared image of blood near the surface of the skin and the body temperature of a host animal, tricking a mosquito's body-heat sensors. Because their mouthparts cannot reach the blood supply except where it is close to the skin, and because these areas of the body are slightly warmer than other areas, insects use heat sensors to pick the best place to bite. As one entomologist aptly put it, "The Dragonfly always looks like a shaved rabbit!"

3. Activated by the heat of the thermal lure, Octenol inside the plastic lure casings evaporates out into the surrounding air. Octenol is the second most powerful attractant for mosquitoes and biting flies.

4. When biting insects attempt to land on the Dragonfly Biting Insect Trap's thermal lure, they pass through an electrostatic panel and are destroyed, falling into the collection tray below. Like a miniature lightning bolt, an arc strikes the nearby insect and destroys it instantly, but without exploding its exoskeleton and discharging fragments into the air. Mosquitoes and biting flies circling the thermal lure "sparkle" when they go near the electrostatic panels, but there is no unpleasant "zapping" sound.

Amount of carcasses in collection tray will not be indicative of total destroyed insects.

- Due to shock and flight path, 25% - 30% of insect bodies will not fall into the collection tray.

- Exoskeletons will be blown out by everyday breezes.

- Ants, wasps, and other scavenger insects will also carry out significant numbers.

Setup of Dragonfly Biting Insect Trap

The Dragonfly Biting Insect Trap requires a 20-pound CO2 bottle supplied by Praxair (visit shop.praxair.com for more details), your local independent CO2 distributor, or Pest Control Company. Pedestal accessories are also available for separate purchase. Please see www.biosensory.com/products.shtml for more details.

1. Place the Dragonfly Biting Insect Trap on its side.

2. A bayonet latch secures the collection tray. Remove the collection tray by gently pushing on the cover, rotating it counter-clockwise a few degrees until it stops, and pulling it away from the Dragonfly Biting Insect Trap.

3. To insert the Biting Insect Lure first remove it from its foil wrapper. Insert the lure through one of the two slots in the bottom of the Dragonfly Biting Insect Trap. When fully inserted, the lure can be secured with a screw. The lure is asymmetrical and will insert in only one direction so that it is always properly positioned. *Another lure can be inserted in the remaining slot for maximum effectiveness.*

4. Replace the collection tray by aligning bayonet latch cut outs with black housing pegs. Gently push tray into housing and rotate tray clockwise a few degrees until it stops and its edges are snug and flush with the rest of outside housing edges.

5. With wrench, tighten the CGA-320 connector (located at the end of the braided hose) to the valve on the CO2 bottle by turning clockwise. Take care that the Teflon® washer in the CGA-320 connector seats firmly against the mating surface on the valve. Apply soapy water around the connection to insure no leaks are occurring.

6. Open the valve on the CO2 bottle by turning counter-clockwise. Check to see if the soapy water bubbles up. If this happens, retighten CGA-320 connector.

7. Connect power cord.

8. Depress the MODE membrane switch and hold it for 3 seconds to reset the CO2 counter to zero. The STATUS indicator light will go off and then flash on, indicating that the CO2 counter has been reset.

9. Set mode (see next two pages).

Operating the Dragonfly Biting Insect Trap

The Dragonfly Biting Insect Trap control panel consists of a water resistant membrane switch to set the operating **MODE**, a **STATUS** indicator light, and a photocell **SENSOR**.

Dragonfly Biting Insect Trap Control Panel

Connecting the power cord turns the Dragonfly Biting Insect Trap on. A microprocessor constantly controls the operation of the Dragonfly Biting Insect Trap.

Six operating modes are selected using the MODE membrane switch. Press the MODE membrane switch repeatedly to toggle between SENSOR control and CONSTANT ON settings. The STATUS light (see tables on next page) will indicate which setting is currently enabled. The 500-cc/min setting attracts the most mosquitoes and uses the most CO2, while the 125-cc/min setting lasts for a longer period of time but attracts fewer mosquitoes. *Experiment to find the best setting for the mosquito population in your location.* The 125-cc/min setting is adequate for most neighborhoods. Use the 250-cc/min setting for a moderate to severe insect presence. Only for extraordinary cases of infestation is the 500-cc/min setting needed.

Operating Modes

MODE	Status Light Color	# of Status Light Flashes	CO2 cc/min	Description
Sensor	Green	1 2 3	125 250 500	**Automatic operation** - turns unit on one hour before sunset and turns unit off 5 hours later. This setting is effective against mosquitoes and conserves CO_2. In this mode the unit discharges the selected amount of CO_2, (125, 250, or 500 cc/min), activates thermal lure and emits octenol. Electrostatic panels will be on automatically.
Sensor	Dim Green	1 2 3	N/A	**Standby:** This feature of the SENSOR mode is when the Dragonfly Biting Insect Trap is waiting for optimal mosquito conditions – nightfall, and a temperature above 13º C (55º F). The unit will remain in STANDBY during daylight hours, deactivating the thermal lure and octenol and CO_2 emissions. Please note that the electrostatic panels will remain operative. Because mosquitoes are not active at temperatures below 13º C (55º F), the unit will remain in STANDBY when the temperature is too cold for mosquito activity.
Sensor	Alternating Green and Red	1 2 3	125 250 500	The CO_2 bottle needs replacement.
Constant On	Yellow	1 2 3	125 250 500	Constant ON - Unit will remain on until reset to Sensor control. In this mode the unit discharges the selected amount of CO_2, (125, 250, or 500 cc/min), activates thermal lure and emits octenol. Electrostatic panels will be on automatically.
Constant On	Alternating Yellow and Red	1 2 3	125 250 500	The CO_2 bottle needs replacement.

Replacing Biting Insect Lure

Important: Always disconnect the power supply and close the CO2 bottle valve (turn clockwise) before proceeding.

The Biting Insect Lure will last 30 to 60 days, depending on ambient temperature and operating mode.

1. Remove the Dragonfly Biting Insect Trap from its support.

2. Detach the CGA-320 connector (located at the end of the braided hose) from the CO2 bottle by turning counter-clockwise.

3. Place the Dragonfly Biting Insect Trap on its side.

4. Remove the collection tray. A bayonet latch secures the collection tray. Remove the collection tray by gently pushing on the cover, rotating it counter-clockwise a few degrees until it stops, and pulling it away from the Dragonfly Biting Insect Trap.

5. Remove the old Biting Insect Lure by removing the retaining screw.

6. Remove the new lure from its foil wrapper. Insert the lure through one of the two slots in the bottom of the Dragonfly Biting Insect Trap. When fully inserted, the lure can be secured with a screw. The lure is asymmetrical and will insert in only one direction so that it is always properly positioned. *Another lure can be inserted in the remaining slot for maximum effectiveness.*

7. Replace the collection tray by aligning bayonet latch cut outs with black housing pegs. Gently push tray into housing and rotate tray clockwise a few degrees until it stops and its edges are snug and flush with the rest of outside housing edges.

8. With wrench, tighten the CGA-320 connector to the valve on the CO2 bottle by turning clockwise. Take care that the Teflon® washer in the CGA-320 connector seats firmly against the mating surface on the valve. Apply soapy water around the connection to insure no leaks are occurring.

9. Open the valve on the CO2 bottle by turning counter-clockwise. Check to see if the soapy water bubbles up. If this happens, retighten CGA-320 connector.

The unit is now ready for use.

Replacing CO2 Bottle

Important: Always disconnect the power supply and close the CO2 bottle valve (turn clockwise) before proceeding.

Under SENSOR control, the CO2 bottle will last 30 to 120 days. When it is time to refill the CO2 bottle, the STATUS indicator will flash red.

1. Detach the CGA-320 connector (located at the end of the braided hose) from the empty CO2 bottle by turning counter-clockwise.

2. Replace empty CO2 bottle with full one.

3. With wrench, tighten the CGA-320 connector to the valve on the CO2 bottle by turning clockwise. Take care that the Teflon® washer in the CGA-320 connector seats firmly against the mating surface on the valve. Apply soapy water around the connection to insure no leaks are occurring.

4. Open the valve on the CO2 bottle by turning counter-clockwise. Check to see if the soapy water bubbles up. If this happens, retighten CGA-320 connector.

5. Return the Dragonfly Biting Insect Trap to its support.

6. Connect power cord.

7. Depress the MODE membrane switch and hold it for 3 seconds to reset the CO2 counter to zero. The STATUS indicator light will go off and then flash on, indicating that the CO2 counter has been reset.

The unit is now ready for use.

Refilling or Exchanging CO2 Bottles

CO2 bottles may be refilled or exchanged at a number of locations. Contact Praxair (shop.praxair.com for more details), or check the yellow pages for your local independent CO2 distributor or Pest Control Company.

Emptying Collection Tray

Important: Always disconnect the power supply and close the CO2 bottle valve (turn clockwise) before proceeding.

In normal use, the collection tray does not require emptying. Only empty if wet insect carcasses block drainage holes after rain.

1. Detach the CGA-320 connector (located at the end of the braided hose) from CO2 bottle by turning counter-clockwise.

2. Remove the Dragonfly Biting Insect Trap from its support.

3. Place the Dragonfly Biting Insect Trap on its side.

4. A bayonet latch secures the collection tray. Remove the collection tray by gently pushing on the cover, rotating it counter-clockwise a few degrees until it stops, and pulling it away from the Dragonfly Biting Insect Trap.

5. Empty insect carcasses.

6. Replace the collection tray by aligning bayonet latch cut outs with black housing pegs. Gently push tray into housing and rotate tray clockwise a few degrees until it stops and its edges are snug and flush with the rest of outside housing edges.

7. With wrench, tighten the CGA-320 connector to the valve on the CO2 bottle by turning clockwise. Take care that the Teflon® washer in the CGA-320 connector seats firmly against the mating surface on the valve. Apply soapy water around the connection to insure no leaks are occurring.

8. Open the valve on the CO2 bottle by turning counter-clockwise. Check to see if the soapy water bubbles up. If this happens, retighten CGA-320 connector.

9. Return the Dragonfly Biting Insect Trap to its support.

10. Connect power cord.

The unit is now ready for use.

Address:

BioSensory, Inc.
Windham Mills Technology Center
322 Main Street, Building 1 Second Floor
Willimantic, CT 06226-3149 USA

Phone: 1.860.423.3009

Website: www.nomorebites.com

APPENDIX B

NUMBER OF SPECIES COLLECTED PER MONTH FROM ALL TREATMENT SITES IN SLIDELL, BATON ROUGE, AND LAKE CHARLES, LOUISIANA

Table 1. Appendix B. Number of species collected per month from all treatment sites in Slidell, Louisiana (2002-2003).

Mosquito Magnet®

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	0	0	0	0	0	0	0	0	3	8	8	1	0	3	23
Ae. vexans	0	0	5	5	0	0	1	0	0	0	0	0	0	2	13
An. crucians	0	0	0	0	0	0	0	0	0	3	0	0	3	5	11
An. quadrimaculatus	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Cq. perturbans	0	0	0	0	0	0	0	0	0	0	0	0	2	3	5
Cx. erraticus	0	6	0	0	0	7	0	0	0	3	3	3	8	1	31
Cx. nigripalpus	0	0	0	0	0	0	10	0	0	3	0	1	0	0	14
Cx. quinquefasciatus	0	15	172	0	1	0	2	0	364	10	4	17	6	1	592
Cx. salinarius	0	0	10	24	87	71	31	199	0	23	0	19	11	2	477
Cx. spp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Oc. atlanticus/tormento	0	1	0	0	0	0	0	0	0	0	4	0	0	0	5
Oc. infirmatus	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
Oc. taeniorhynchus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Ps. ferox	0	1	0	0	0	0	0	0	0	0	1	0	0	0	2
Total per month	0	25	188	29	88	78	44	199	367	50	20	44	30	17	1179

Dragonfly®/Cognito®

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	0	2	1	0	0	0	0	0	0	1	8	3	2	5	22
Ae. vexans	0	0	2	6	0	0	2	2	0	0	0	1	0	2	15
An. crucians	0	0	0	0	0	1	0	0	8	23	7	4	4	0	47
An. punctipennis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
An. spp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Cq. perturbans	0	1	1	0	0	0	0	0	0	1	0	1	1	0	5
Cs. inornata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Cx. erraticus	0	1	0	0	0	0	0	0	0	2	7	5	4	5	24
Cx. quinquefasciatus	0	32	141	0	0	0	0	0	497	15	11	24	8	17	745
Cx. salinarius	0	0	31	23	49	270	71	195	0	145	0	44	8	2	838
Oc. atlanticus/tormento	0	3	0	0	0	0	0	0	0	0	3	0	0	0	6
Oc. infirmatus	0	4	0	3	0	0	0	0	0	0	3	0	0	0	10
Oc. sollicitans	0	2	0	0	0	0	0	0	0	0	0	0	0	1	3
Oc. taeniorhynchus	0	7	0	0	0	0	1	0	0	0	0	2	0	0	10
Oc. triseriatus	0	0	0	0	0	0	1	0	0	1	0	0	0	0	2
Ps. ferox	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Total per month	0	52	176	33	49	271	75	197	506	188	40	84	27	33	1731

Table 1. Appendix B. Number of species collected per month from all treatment sites in Slidell, Louisiana (2002-2003).

SC Johnson OFF!® Mosquito Lantern

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
Ae. vexans	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2
An. crucians	0	0	0	0	0	0	0	0	1	2	2	0	0	0	5
Cq. perturbans	0	0	0	0	0	0	0	0	1	0	0	2	0	0	3
Cx. nigripalpus	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Cx. quinquefasciatus	0	1	10	3	0	0	0	0	51	5	13	6	1	8	98
Cx. salinarius	0	0	1	1	1	7	0	75	0	0	0	6	2	2	95
Oc. atlanticus/tormento	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
Oc. infirmatus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Ur. sapphirina	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total per month	0	1	11	6	1	7	0	75	53	8	19	16	3	11	211

ThermaCell®

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Ae. vexans	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
An. crucians	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
An. quadrimaculatus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Cq. perturbans	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Cx. erraticus	0	0	0	0	2	0	0	0	0	2	1	0	0	2	7
Cx. quinquefasciatus	0	5	1	0	0	0	0	0	12	3	1	0	1	1	24
Cx. salinarius	0	0	0	3	0	6	1	3	0	1	0	0	0	0	14
Oc. atlanticus/tormento	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Total per month	0	6	2	4	2	7	1	3	12	6	2	1	1	4	51

Control

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	0	1	0	0	0	0	0	0	1	2	0	0	2	1	7
Ae. vexans	0	2	5	3	0	0	0	1	2	0	0	0	0	2	15
An. crucians	0	0	0	0	0	1	1	1	2	5	0	0	0	1	11
An. quadrimaculatus	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
Cx. erraticus	0	3	0	0	0	0	0	1	1	6	2	5	2	2	22
Cx. nigripalpus	0	0	0	0	0	0	2	0	0	0	0	0	0	1	3
Cx. quinquefasciatus	0	16	25	0	0	1	0	0	102	5	0	7	3	7	166
Cx. salinarius	0	0	4	4	17	37	10	63	0	9	0	11	0	4	159
Oc. atlanticus/tormento	0	5	0	0	0	0	0	0	0	0	3	0	0	0	8
Oc. infirmatus	0	3	2	2	0	0	0	0	1	1	0	0	0	0	9
Oc. taeniorhynchus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Oc. triseriatus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Ur. lowii	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total per month	0	30	36	10	17	39	13	66	109	28	6	24	7	20	405

Table 2. Appendix B. Number of species collected per month from all treatment sites in Baton Rouge, Louisiana (2002-2003).

Mosquito Magnet®

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	2	0	0	0	0	0	0	0	0	1	2	1	1	0	7
Ae. vexans	0	8	50	4	0	0	5	1	0	0	0	0	1	1	70
An. crucians	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
An. quadrimaculatus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
An. spp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Cq. perturbans	1	1	0	0	0	0	0	0	0	0	0	1	0	0	3
Cs. inornata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Cx. erraticus	0	0	0	0	0	0	0	1	3	3	3	0	0	1	11
Cx. quinquefasciatus	98	23	6	8	0	0	0	2	32	35	4	58	45	365	676
Cx. restuans	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Cx. salinarius	0	1	3	15	3	2	1	9	21	0	1	5	1	0	62
Ps. columbiae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total per month	101	33	59	28	4	3	6	13	56	39	10	66	49	368	835

Dragonfly®/Cognito®

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	1	0	0	0	0	0	0	0	0	0	2	2	0	0	5
Ae. vexans	1	26	94	2	0	0	11	1	0	1	1	0	2	6	145
An. crucians	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Cq. perturbans	3	25	0	0	0	0	0	0	0	1	0	0	0	0	29
Cx. erraticus	0	0	0	1	0	0	0	1	0	5	7	2	0	0	16
Cx. quinquefasciatus	16	66	13	5	1	0	1	0	6	4	5	23	21	130	291
Cx. restuans	0	0	0	4	0	0	0	0	0	0	0	0	0	0	4
Cx. salinarius	0	4	41	25	0	0	1	6	1	0	0	0	1	0	79
Oc. infirmatus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Ps. columbiae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total per month	22	121	148	37	1	0	14	8	7	11	16	27	24	136	572

SC Johnson OFF!® Mosquito Lantern

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Ae. vexans	0	1	10	0	0	0	4	0	0	2	2	0	1	4	24
Cq. perturbans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cx. erraticus	1	0	0	0	0	0	0	1	0	3	1	0	0	0	6
Cx. quinquefasciatus	0	5	2	0	0	0	0	0	4	4	3	9	1	24	52
Cx. salinarius	0	0	0	0	0	0	0	1	3	0	0	0	0	0	4
Cx. spp.	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Oc. taeniorhynchus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Total per month	1	7	12	0	0	0	4	2	7	9	6	9	5	28	90

Table 2. Appendix B. Number of species collected per month from all treatment sites in Baton Rouge, Louisiana (2002-2003).

ThermaCell®

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ae. vexans	0	2	1	0	0	0	1	0	0	0	0	0	0	0	4
Cq. perturbans	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Cx. erraticus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Cx. quinquefasciatus	2	4	0	0	0	0	0	0	0	2	0	2	0	4	14
Cx. salinarius	0	0	0	2	0	0	1	2	0	0	0	0	0	0	5
Total per month	3	6	1	2	0	0	2	4	0	2	0	2	0	4	26

Control

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	0	0	0	0	0	0	0	0	0	1	2	1	0	0	4
Ae. vexans	0	3	24	0	0	0	4	0	0	0	0	0	0	2	33
An. quadrimaculatus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Cq. perturbans	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
Cx. erraticus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Cx. quinquefasciatus	19	15	2	1	1	0	0	0	1	6	7	5	7	27	91
Cx. restuans	0	0	0	2	3	0	0	0	0	0	0	0	0	0	5
Cx. salinarius	0	0	9	4	0	0	0	8	1	0	0	0	0	0	22
Cx. spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Oc. sollicitans	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Total per month	19	21	35	7	4	0	4	9	2	7	10	6	7	30	161

Table 3. Appendix B. Number of species collected per month from all treatment sites in Lake Charles, Louisiana (2002-2003).

Mosquito Magnet®

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. vexans	0	4	4	0	0	0	1	0	0	0	0	0	2	0	11
An. crucians	0	0	0	1	0	0	6	1	2	0	9	2	1	1	23
An. quadrimaculatus	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
Cq. perturbans	0	3	0	0	0	0	0	11	0	0	3	0	0	0	17
Cx. erraticus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Cx. quinquefasciatus	0	11	7	3	0	0	0	3	0	0	0	0	1	0	25
Cx. salinarius	0	0	18	36	0	5	155	12	10	0	13	8	5	6	268
Cx. tarsalis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Oc. sollicitans	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3
Oc. taeniorhynchus	0	0	1	0	0	0	0	0	0	0	1	0	1	1	4
Ps. columbiae	0	0	0	0	0	0	0	0	0	0	2	0	1	0	3
Total per month	0	20	30	40	0	5	162	28	12	0	28	10	13	10	358

Dragonfly®/Cognito®

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. vexans	0	0	2	2	0	0	0	0	0	4	0	2	2	3	15
An. crucians	0	0	0	0	0	0	0	0	5	1	6	1	1	3	17
An. quadrimaculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
An. spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Cq. perturbans	0	4	1	0	0	0	0	9	7	9	5	1	0	0	36
Cx. quinquefasciatus	0	11	16	0	0	0	0	0	1	0	2	0	0	0	30
Cx. salinarius	0	0	15	5	0	10	275	14	30	6	9	12	3	15	394
Cx. tarsalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ms. titillans	0	0	0	0	0	0	0	0	0	0	0	5	0	0	5
Oc. infirmatus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Oc. sollicitans	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Oc. taeniorhynchus	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
Ps. columbiae	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Ur. lowii	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total per month	0	17	34	7	0	10	275	23	43	20	22	22	7	29	509

SC Johnson OFF!® Mosquito Lantern

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Ae. vexans	0	2	4	4	0	0	0	0	0	0	0	0	1	0	11
An. quadrimaculatus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cq. perturbans	0	0	0	0	0	0	0	11	0	0	1	0	0	0	12
Cx. erraticus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Cx. quinquefasciatus	0	19	0	0	0	0	0	2	0	0	0	0	0	0	21
Cx. salinarius	0	2	0	6	0	0	4	1	11	0	5	2	1	1	33
Oc. atlanticus/tormentor	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Oc. sollicitans	0	4	0	0	0	0	0	0	1	0	0	0	4	1	10

Table 3. Appendix B. Number of species collected per month from all treatment sites in Lake Charles, Louisiana (2002-2003).

ThermaCell®

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. vexans	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
An. crucians	0	0	0	0	0	0	2	2	0	0	1	2	1	3	11
Cq. perturbans	0	0	5	0	0	0	0	5	0	0	1	0	0	0	11
Cs. inornata	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Cx. quinquefasciatus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cx. salinarius	0	0	24	2	0	9	57	6	2	0	0	1	1	3	105
Oc. sollicitans	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Ps. columbiae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total per month	0	1	30	2	1	9	59	13	2	0	2	3	5	6	133

Control

Species	Sep-02	Oct-02	Nov-02	Dec-03	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Spp. Total
Ae. albopictus	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Ae. vexans	0	3	55	49	0	0	3	0	0	0	0	0	1	6	117
An. crucians	0	0	5	0	0	1	3	0	6	2	15	2	4	8	46
An. quadrimaculatus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cq. perturbans	0	9	1	0	0	0	0	29	6	0	4	0	0	0	49
Cx. erraticus	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
Cx. quinquefasciatus	0	95	15	1	0	0	0	3	0	2	34	17	4	5	176
Cx. salinarius	0	0	115	24	0	7	867	64	27	5	31	49	45	62	1296
Ms. titillans	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
Oc. taeniorhynchus	0	0	1	0	0	0	0	0	0	0	0	0	8	2	11
Ps. columbiae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Ps. ferox	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Ur. sapphirina	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Total per month	0	108	193	74	0	8	873	99	39	10	84	69	65	85	1707

VITA

Brett W. Collier, the eldest son of Warren John and Wendy Joanne Collier was born in Duluth, Minnesota, on December 06, 1962. He graduated from Denfeld High School, Duluth, Minnesota, in May, 1981 and received a Bachelor of Science degree with a major in biology and a minor in psychology from the University of Wisconsin-Superior, Wisconsin, in May 1987. In June, 2002, he was accepted by the Graduate School at Louisiana State University, Baton Rouge, Louisiana, to the Department of Entomology (Medical Entomology) under the supervision of Dr. Michael Perich. Currently, he is a candidate for a Master of Science degree in the Department of Entomology at Louisiana State University.