

2009 Annual Report of the Fire Island National Seashore (FIIS) Mosquito Surveillance and Management Program

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ABSTRACT

The Fire Island National Seashore (FIIS) Mosquito Surveillance and Management Program was first implemented in 1998 in response to public concern over Eastern Equine Encephalitis (EEE), and continued due to prevalence of West Nile Virus (WNV). From 2000-2009 (except in 2007), WNV has been detected within the park in at least one sample pool (up to 50 mosquitoes) each year. Although in the past 9 years there have been relatively continual isolations of WNV in two areas (Watch Hill/Davis Park and Saltaire), there has not been a strong consistency as to where on FIIS WNV has been found. Mosquito sampling for the 2009 trapping season began on June 8th and the last traps were set on September 29th. At the beginning of the season, a total of 18 traps were maintained throughout the park in seven different surveillance sites. Two types of traps were used: CO₂-baited light traps and gravid traps. Typically, the light traps yielded a significantly greater amount of mosquitoes than the gravid traps. For 2009, the highest number of mosquitoes collected in a light trap during one trap night (approx. 16 hrs) was an estimated 79,611 mosquitoes, which was collected on September 8th at the Wilderness Visitor Center. The highest yield from a gravid trap this year was 1,517 mosquitoes on September 8th from a collection obtained from the Wilderness Visitor Center. In 2009, there were two WNV-positive mosquito pool detected within Fire Island National Seashore. One positive pool was near the Wilderness Visitor Center just west of Smith Point County Park on August 26th. The second was collected from Sailor's Haven on September 22, 2009. As a result, an additional light trap was set up and monitored during the week of September 8th to the week of September 21th near the Wilderness Visitor Center location to increase the sensitivity of the mosquito surveillance. Because the positive pool of WNV at Sailor's Haven happened so late in the season, FIIS staff, with consultation from experts from United States Geological Survey (USGS) and Suffolk County Vector Control (SCVC), decided not to continue trapping for mosquitoes or the need for additional traps.

Key words: Flanders Virus, Culex spp., Eastern Equine Encephalitis, gravid trap, light trap, Ochlerotatus sollicitans, West Nile Virus.

INTRODUCTION

Fire Island is a 32-mile long barrier island characterized by saltmarsh, dune grassland, dune shrubland, interdunal swale and forest/shrubland habitat (Klopfer et al. 2002) and is situated off the south shore of Long Island, New York. A unit of the National Park Service, Fire Island National Seashore (FIIS) comprises 26 miles of this narrow barrier island, plus the historic 613-acre William Floyd Estate (Public Law 89-244, 1965). Created in 1964, FIIS is maintained and operated by the National Park Service, under Department of the Interior regulation and jurisdiction. According to the FIIS Enabling Legislation (Public Law 88-587, 1964), FIIS was established "for the purpose of conserving and preserving for the use of future generations certain relatively unspoiled and undeveloped beaches, dunes, and other natural features..."

Within the boundaries of the park lie the Otis G. Pike High Dune Wilderness Area, park facilities, such as, Sailors Haven and Watch Hill, as well as 17 private resort communities. All of FIIS falls within the boundaries of Suffolk County, Long Island. At the west end, FIIS is bounded by the Robert Moses State Park. On the east end, Smith Point Suffolk County Park falls within the Park's jurisdictional boundaries, but is managed by the county (Figure 1, pg 20).

In 1998, FIIS implemented a mosquito surveillance and management program in response to concerns that Eastern Equine Encephalitis (EEE), a mosquito-borne virus, could potentially occur within the park and affect public health. When another mosquito-borne virus, West Nile Virus (WNV), was discovered in the New York region in 1999, mosquito surveillance and management efforts were subsequently expanded within the park to appropriately address this new disease concern. Every year from 2000-2009 (except 2007), WNV has been detected at various locations within FIIS. In 2000, WNV was detected in the community of Saltaire (at the time, this trap was maintained by a village employee). In 2001, it was detected at Watch Hill. In 2002, it was detected in both Watch Hill (near the border of the Davis Park community) and in the federally-designated Wilderness Area. In 2003, it was detected at the William Floyd Estate and in a dead bird collected from the community of Cherry Grove. In 2004, both WNV and Flanders or Flanders-like virus, another mosquito-borne virus (not previously detected in the park), was found at the William Floyd Estate. This virus has not been found to be harmful to humans. In 2005, WNV was detected in several sites: the community of Saltaire, the Lighthouse Tract, the Sunken Forest and the Wilderness Area. In addition, Flanders or Flanders-like virus was again found at the William Floyd Estate in 2005. In 2006, only a single WNV-positive mosquito pool was detected within the FIIS jurisdictional boundaries—a collection isolated from the Watch Hill employee residence area. In 2007, there were no WNV-positive mosquito pools detected within the FIIS jurisdictional boundaries. In 2008, a WNV-positive mosquito pool was detected in the federal land west of the Fire Island Pines. In 2009, WNV was detected near the Wilderness Visitor Center and at Sailor's Haven.

The FIIS mosquito program relies on two important documents, the Mosquito Surveillance and Management Protocol and the Mosquito Action Plan (MAP). These are updated annually in collaboration with county, state and federal organizations, including Suffolk County Vector Control (SCVC), Suffolk County Department of Health Services and United States Geological Survey (USGS). These documents contain specific criteria for varying levels of alert and action, as well as the procedures for handling dead birds, the management of freshwater sources and equipment requirements.

Approximately 40 mosquito species have been documented in Suffolk County, Long Island (Guirgis 1984). Approximately 25 of these species have been recorded throughout FIIS (table 1; Lussier 2003), with *Aedes sollicitans* (= *Ochlerotatus sollicitans*¹), *Ae. vexans*, *Culex pipiens*, *Cx. restuans*, and *Cx. salinarius* being the most common. Of these species, the FIIS Mosquito Surveillance and Management Program focuses on mosquitoes of the genus *Culex*, which are known to have a higher estimated transmission rate (ETR) for WNV than other mosquitoes found in FIIS. In our area, the primary epidemic or bridge vector that is responsible for transmission of WNV to people is *Cx. salinarius*, with *Ae. sollicitans* and *Ae. vexans* possibly also being WNV bridge vectors in the Northeast.

WNV is maintained in the Northeast in an enzootic cycle by *Cx. pipiens*, and *Cx. restuans*, with many bird species such as corvids (*Corvidae* spp) and robins (*Turdus migratoris* spp) acting as reservoirs. The preferred habitats of these mosquito species are areas that contain standing freshwater with high organic content (Crans 2004). This could be natural areas such as woodland pools or artificial containers such as barrels, discarded tires and wells (Means 1987). The breeding of both species is continuous throughout the summer months. Breeding in *Cx.*

1. Recent papers (Reinert 2000, Reinert et al. 2004) have suggested that several subgenera exist within the *Aedes* genus. The validity of this, however, has yet to be resolved. Thus, in this report we use the original classification of *Aedes*, as is used by the *Journal of Medical Entomology* (2005. *J. Med. Entomol.* 42: 511).

pipiens peaks in July and early August (Means 1987, Andreadis et al. 2005), while in *Cx. restuans* the peak is in June and early July (Andreadis et al. 2005). These two species are both primarily bird feeders (ornithophilic) that are known to only occasionally bite mammals.

Cx. salinarius breeds in a wide range of habitats, but is exceptionally abundant in freshwater marshes in Suffolk County (Means 1987). In contrast to *Cx. pipiens* and *Cx. restuans*, however, *Cx. salinarius* also lays eggs in brackish water and has a broader host range, including mammalian species.

Ae. sollicitans, also known as the white-banded saltmarsh mosquito, are also abundant in the saltmarshes of Suffolk County (Means 1979). They are multivoltine breeders (Crans 2004), with adults emerging by mid-May to produce successful generations into late September and even October (Means 1979). Eggs are normally deposited on bare moist soil in saltmarsh depressions which are regularly flooded, particularly by lunar tides, producing broods at approximately two week intervals. Storm tides and heavy rains can also trigger additional broods (Crans 2004). The natural landscape found within FIIS, especially in the Otis G. Pike Wilderness Area in the eastern portion of Fire Island, supports healthy populations of *Ae. sollicitans*. However, research has found that the Great South Bay acts as a migration barrier for mosquitoes and only a small percentage (< 1% - 6% in differing emergences) of *Ae. sollicitans* produced in the Otis G. Pike Wilderness Area migrate across to the neighboring communities of Mastic Beach and Shirley (Ginsberg 1986). Moreover, of those that do migrate across the bay, it was suggested that they are primarily newly-emerged mosquitoes (Ginsberg and Rohlf, 1985) and are thus not likely to transport arboviruses across to Long Island. This is based on the understanding that WNV has not been suggested to be transferred transovarially among local mosquito species.

METHODS

Trapping Methods and Equipment

Two types of traps were used for the collection of mosquitoes: CDC Gravid traps (John W. Hock Company model #1712) and CO₂-baited CDC Miniature Light Traps (John W. Hock Company model #512). In most trap locations, light and gravid traps were paired together (within several meters of each other) in order to help facilitate possible future epidemiological research by USGS. The exception to this design is two isolated light traps: one within the Watch Hill employee residence area, and the second a few meters south of the Sailors Haven concessions building and east of the Park Visitor Center. Each surveillance site had at least one set of paired light and gravid traps.

Gravid Trap

The gravid trap consists of 3.5"-wide PVC tubing that has a basic motor fan secured inside and a net on the top. The fan is powered by a sealed 6-volt battery. Held up vertically by aluminum cross beams, the PVC tubing rests on top of a plastic bin with measurements of 7" x10" x14" (height, width, and length, respectively). The bin contains a fermented mixture of rabbit feed and water, which acts as a high-organic material bait. The fermented mixture amount is adjusted so that the base of each tube sits approximately 1 inch above the surface of the mixture. The trap functions by pulling the mosquitoes up into the net via the PVC tubing, by the

force of the fan, as gravid mosquitoes approach the fermented mixture to deposit their eggs (figure 2, pg 21).

The gravid traps are designed to attract and collect gravid (egg-bearing) mosquitoes of species with larvae that thrive in freshwater with high organic content, which in FIIS are predominately *Culex pipiens* and *Culex restuans*. However, these traps can occasionally collect non-gravid foraging females of other species, especially those which are typically low-flying such as *Ae. sollicitans*. Gravid *Culex* spp. mosquitoes are the preferred specimens for WNV testing. Gravid mosquitoes have already fed and are therefore more likely to be infected with the virus compared to those mosquitoes that have not yet fed. For that reason, along with the ecology and biology of *Culex* mosquitoes, it is argued that gravid traps are likely to be more sensitive in detecting WNV and other mosquito-borne diseases than light traps.

Light Trap

As with the gravid traps, the light trap consists of 3.5"-wide PVC tubing with a basic motor fan run by a sealed 6-volt battery secured inside and a collection container that hung from the tubing. As a bait, a 6" cube of dry ice is hung in a canvass bag adjacent to the trap. Dry ice is purchased in larger blocks and has to be chipped into smaller pieces. Carbon dioxide gas given off during sublimation of the dry ice attracts mosquitoes to the vicinity of the trap. It is claimed that once baited, an incandescent light located at the top of the tubing acts as a focal point and draws the mosquitoes to the suction of the fan, upon which they are pulled inside the bottom of the collection container via the tubing (figure 3, pg 21).

The CO₂-baited light traps are designed to attract and collect host-seeking adult female mosquitoes. Research has shown, however, that these traps do not attract all species equally (Lussier et al. 2006). For example, some studies have found that certain bird feeding species were not strongly attracted to CO₂. Considerable variation among species has also been found in the degree that mosquitoes are attracted to light (Service 1976). Nonetheless, CO₂-baited light traps are generally known to yield larger collections, with a greater diversity of mosquitoes as compared to gravid traps (Lussier et al. 2006). Therefore, this trap may be a slightly stronger gauge for qualitatively measuring species abundance and, to a certain extent, diversity in each of the surveyed areas.

Surveillance Sites

A total of seven areas were used as surveillance sites, which were selected in consultation with Dr. Howard S. Ginsberg of the USGS. The sites established were 1) the Lighthouse Tract, 2) the Village of Saltaire, 3) Sailor's Haven, 4) Fire Island Pines, 5) Watch Hill, 6) the Otis G. Pike Wilderness Area, and 7) the William Floyd Estate (from west to east).

The Fire Island Lighthouse Tract is located on the western most area of FIIS. The Lighthouse Tract is characterized by northern dune shrubland, maritime deciduous scrub forest, brackish meadow, reedgrass marsh, highbush blueberry shrub forest and northern beach grass dune vegetation (Klopfer et al. 2002). Kismet Pond is also located here, which is a permanent, freshwater inland pool. This pond is a productive breeding site for dragonflies and damselflies, representing the "most diverse and robust fresh water pond in FIIS" in terms of odonate species

(Briggs and Sones, 2005). The Lighthouse Tract is bordered by the town of Kismet to the east and Robert Moses State Park to the west.

The Village of Saltaire is a boardwalk community that is characterized by northern dune shrubland, maritime deciduous scrub forest, and northern beach grass dune vegetation (Klopfer et al. 2002). The village is heavily fragmented by houses, and much of the original vegetation profile has changed. A high percentage of ornamental and exotic plantings occur around houses, and a high abundance of *Phragmites* is present in wetland areas. Saltaire has a high water table and often has standing fresh to brackish water under the boardwalks and houses. This standing water provides excellent breeding areas for several mosquito species, especially *Culex* spp.

Sailors Haven is an area within Fire Island National Seashore that consists of a public marina, a visitor center, and hiking boardwalks and trails. The Sunken Forest is the central feature of Sailors Haven and predominantly consists of maritime holly forest, maritime deciduous scrub forest, acidic red maple swamp, northern dune shrubland, highbush blueberry forest, shadbush and sassafras (Klopfer et al. 2002). Sailors Haven is bordered by the community of Cherry Grove to the east and a relatively long strip of privately-owned land, which encompasses six communities, to the west.

Although one of our surveillance sites is labeled as Fire Island Pines, traps were not located in this community. Rather, traps were placed approximately 100 meters west of the federal-private lands border in a small tract of federal land, unofficially called the Carrington Tract. Although this landscape is predominately characterized by a maritime deciduous forest and maritime holly forest, it also has features of reedgrass marsh, highbush blueberry shrub forest and northern salt scrub (Klopfer et al. 2002). There is also a nearby permanent, freshwater inland pond. This federal tract bisects two strips of privately-owned land: Cherry Grove to the west and Fire Island Pines to the east.

Watch Hill is an area of Fire Island National Seashore consisting of a public marina, visitor center, campgrounds, Park employee housing and maintained hiking trails and boardwalks. This site is characterized by northern dune shrubland, northern beach grass dune, pitch pine dune woodland, maritime deciduous scrub forest, highbush blueberry shrub forest, beach heath dune, northern salt shrub vegetation. On the bay side (north) there are features of reedgrass marsh, brackish meadow and low and high saltmarsh (Klopfer et al. 2002). Watch Hill is bordered by the community of Davis Park on the west and by the federally-designated Otis G. Pike High Dune Wilderness Area to the east.

The Otis G. Pike High Dune Wilderness Area is the only federally designated Wilderness Area in the state of New York and one of only a few in the Northeastern U.S. It is characterized by very similar habitat as Watch Hill, but has a more extensive saltmarsh and reedgrass marsh network (Klopfer et al. 2002), which has been historically ditched for mosquito abatement. These mosquito ditches still have a strong presence in the marshes and are clearly visible in recent aerial photographs. The Wilderness Area is bordered on the east by Smith Point County Park and is bisected by a very small seasonal recreational beach facility owned by the village of Bellport. Bellport Beach consists of a few amenities including a dock, rest room, and small concession facility.

Though not located on the barrier island, the historic William Floyd Estate is also managed by FIIS. The estate consists of 613 acres and is located in Mastic Beach, NY on Long Island. It is dominated by coastal oak-heath forest and also characterized by cultivated pastures, pitch pine-oak forest, maritime deciduous scrub forest, acidic red maple basin swamp forest and northern salt shrub vegetation to the north; and on the south side bordering the bay, reedgrass

marsh and low and high saltmarsh are dominant features (Klopfer et al. 2002). There are also two or more inland freshwater pools. The Estate is surrounded by the fairly densely-populated community of Mastic Beach.

In addition to the two kinds of mosquito traps found in the seven locations on FIIS, Suffolk Dept of Health Services and the Park have set up a New Jersey light trap on FIIS land at the Wilderness Visitor Center. Maintenance of the New Jersey trap is taken care of by Suffolk County.

Trapping Schedule and Placement

The mosquito trapping season began the week of June 8, 2009 and ended the week of September 28, 2009. The season began with a total of 18 traps established at seven surveillance sites (Table 2, pg 25). Exact locations of each trap were selected based on various factors such as vegetative indicators, proximity to residential communities, the degree of staff and visitor use, visibility of trap (to avoid vandalism), mosquito productivity, canopy cover (for light traps) and either the presence of standing water or indications of water table surfacing (for gravid traps). Traps were typically set in the afternoon, left overnight and then collected the following morning. Care was taken to not leave the traps out for longer than 16 hours in order to avoid excessive mortality and subsequent degradation of viruses, and damage to morphological characteristics necessary for accurate identification. Weather-permitting, each trap was set once per week. GPS coordinates of each trap location were recorded using a Trimble GeoXT™. Multiple traps were maintained at each of the surveillance sites. In most trap locations, light and gravid traps were paired together, within several meters of each other, in order to help facilitate possible future epidemiological research. There were only a few exceptions to this layout.

The Lighthouse Tract surveillance site had a total of two traps; a paired light trap and gravid trap. These traps were located just east of the Kismet pond and northeast of the Kismet Fire Station (Figure 4, pg 21).

Saltaire's surveillance site contained a light trap and a gravid trap separated by several hundred feet. The gravid trap was located on West Ave. at the west end of Saltaire, and the light trap was positioned on Neptune Ave. near the center of Saltaire (Figure 5, pg 22).

The Sailor's Haven surveillance site consisted of three traps: a paired light trap and gravid trap within the Sunken Forest and a lone light trap positioned behind the concessions building adjacent to the public marina of Sailor's Haven. (Figure 6, pg 22).

The Fire Island Pines site had a total of one light trap and one gravid trap, which were also paired. Although labeled as Fire Island Pines, traps were not located within this community. Rather, traps were placed approximately 100 meters west of the federal-private lands border in a small tract of federal land unofficially called the Carrington Tract (Figure 7, pg 23). This parcel of land does not have any Park-maintained facilities.

A total of three traps were placed at Watch Hill for the entire trapping season. A paired light trap and gravid trap were set approximately 50 meters east of the Davis Park community border; this area was referred to as Watch Hill West. One light trap was situated a few meters west of employee house unit #2 and was referred to as Watch Hill Residence (Figure 8, pg 23).

The Wilderness Area contained paired traps; one light trap and one gravid trap were maintained approximately 150 meters west of the Otis G. Pike High Dune Wilderness Visitor Center (Figure 9, pg 24).

A total of four traps were maintained at the William Floyd Estate. A paired light trap and gravid trap were located in the forest on the western border, referred to as William Floyd Estate West. A seconded paired light and gravid trap were placed near the visitor entrance to the Estate. This location is referred to as William Floyd Estate Entrance (Figure 10, pg 24).

Protective Equipment and Other Materials

Personal protection equipment was a necessity for the field work executed for the mosquito program monitoring effort. A white, disposable TyvekTM suit with a hood and elastic wrists and ankles was worn for protection against ticks and mosquito bites, and a hoop-ring headnet and leather gloves were also occasionally worn for mosquito protection. Permethrin, DEET, and/or herbal-based insect repellents were also applied to clothing as extra precautionary measures. Rubber boots were worn when hiking in wet areas and also provided a smooth surface that inhibited ticks from grasping on to clothing.

Dry ice for the light traps was purchased from Ice Cream Depot Corp, located in Holbrook, NY. Fresh dry ice was purchased in the beginning of every week for that week's trapping. Dry ice was stored in a cooler placed in a top-loading freezer to minimize the rate of sublimation.

Transportation

Fire Island is a unique barrier island in that it does not have a paved road along its entirety, making the beach the main access road for full sized and off-road vehicles. There are restrictions for traveling on the beach during piping plover (*Charadrius melodus*) nesting season, which overlaps with most of the mosquito season, therefore, not all traps could feasibly be reached by a full-sized vehicle. Consequently, the traps located at Sailors Haven, Fire Island Pines, and Watch Hill were reached by boat during the majority of the season. This method of transportation was highly weather-dependent, therefore, trapping schedule varied each week according to the forecast. During inclement weather (i.e. small craft advisories and heavy thunder storms), traps that needed to be set by boat could sometimes not be set, so incomplete data was recorded for that particular week. At the conclusion of the plover nesting season, all traps located on the island were accessible by Polaris or ATV; this occurred from mid August to the week of September 28th, the end of the 2009 mosquito trapping season.

Adult Mosquito Sampling and Analysis

After being established at a particular location, most of the trap equipment remained at that trap site until the end of the season. The only equipment and materials that were removed and reset each week were the batteries, the collection nets, fermented water mixture and dry ice. In cases of damage or malfunction, traps were brought back to the lab for repair and reset the next trapping cycle, or if possible, repaired in the field. Immediately after being picked up in the mornings, the collection containers were placed in a cooler with dry ice to preserve the

specimens and keep them immobilized for later analysis. Several layers of newspaper were placed between the containers and the dry ice so as to reduce damage to the specimens.

The analysis of mosquito populations involved determining the total number of mosquitoes caught per trap, the numbers of *Culex* spp., *Ae. sollicitans*, *Ae. taeniorhynchus*, *Ae. vexans*, and *Coq. perturbans* caught per trap night, and the isolation of mosquito pools that were sent for arbovirus testing. Mosquitoes were sorted into six taxonomic groups: 1.) *Culex* spp. 2.) *Ae. sollicitans* 3.) *Ae. taeniorhynchus* 4.) *Ae. vexans* 5.) *Coq. perturbans* and 6.) unknown/other. For traps that contained relatively few mosquitoes, all individual mosquitoes were individually counted to determine the total number caught and the totals of each taxonomic group. For traps that contained high numbers of mosquitoes, the total number was estimated using sample size and mass ratios. The contents of the entire trap were weighed using an ADAM ACB Plus – 150™ (max:150g, d=0.005g) digital scale, and the resulting mass was compared to the mass of a known sub-sample size (100 mosquitoes). In order to account for differences in condensation and moisture content between each, a sub-sample size was extracted from each large trap night sample. The following formula was used for this calculation:

$$T = (\# \text{ of mosquitoes in sub-sample}) \times (\text{mass of all mosquitoes}) \div \text{mass of sub-sample}, \text{ where}$$

$$T = \text{the total number of mosquitoes in a single trap night.}$$

For traps that collected high numbers of mosquitoes, the number of each taxonomic group was also estimated. This was done by determining the proportion of each species in a known, randomly-extracted sub-sample and then multiplying that proportion by the estimated total number of mosquitoes. For example, to estimate the total number of *Ae. sollicitans* in a single trap night the same formula was used: (Solve for X)

$$\frac{X (\text{Proportion of Ae. Sol.})}{\text{Estimate total number in trap night (done by weight)}} = \frac{\text{Number of Ae. Sol. In sub-sample}}{100 (\text{sub-sample size})}$$

Then, solve for T_{sol} , where T_{sol} is the estimated number of *Ae. Sollicitans* in a trap night.

$$T_{sol} = X (\text{Proportion of Ae. Sollicitans}) \times \text{Total number in trap night} / 100$$

Individual *Culex* spp. were always pulled out of traps and, when possible, *Ae. sollicitans* were also pulled out to form pools. A pool consisted of 10 to 50 mosquitoes of the same species collected from the same trap during the same trap night. Pools were placed in petri dishes, secured with rubber bands and labeled with the type of trap (gravid or light), the trap location, the date set and the contents of the pool (# of mosquitoes and species). Pools were then stored on dry ice until they could be transported to Suffolk County Vector Control entomology laboratory. Once there, they were stored at -70°C in a top-loading freezer. Specimen identifications and counts were confirmed by laboratory staff and then later sent to the New York State Department of Health Wadsworth Center in Albany for arbovirus testing. The turnaround time for getting the results of the laboratory testing was approximately two weeks.

Data

After the mosquito data was gathered each week, it was entered into an Excel spreadsheet. From this, data graphs (Graphs 1-12, pg 26-32) were generated in Excel to depict trends in the mosquito numbers for each species and weather patterns throughout the season. The maps of

surveillance sites (Figures 4-10, pg 21-24) were created using ArcGIS™ (Geographic Information System).

RESULTS

Light Traps

For 2009, the total numbers of mosquitoes caught in light traps exhibited a multi-modal curve (Graph 1, pg 26), as is typical in previous seasons. Overall, samples obtained in light traps were larger and represented greater species diversity than gravid traps. Light traps yielded low to moderate numbers at the start of the season and throughout July, followed by a population increase in the first few weeks of August, followed by a short decrease. A spike occurred in late August/early September that lasted a few weeks with populations tapering off at the end of September.

The highest trap total was obtained from the Wilderness Visitor Center extra light trap that was set up in response to a positive WNV on 9/15/08, with an estimated 79,611 mosquitoes. The Lighthouse Tract light trap averaged 364 mosquitoes (with a high of 1,772), the Saltaire light trap averaged 43 mosquitoes (with a high of 160), the Sunken Forest light trap averaged 2,893 mosquitoes (with a high of 7,620), the Sailors Haven light trap averaged 3,328 mosquitoes (with a high of 14,353), the Fire Island Pines light trap averaged 656 mosquitoes (with a high of 1810), the Watch Hill West light trap averaged 1,506 mosquitoes (with a high of 3,234), the Watch Hill Residence light trap averaged 1,878 mosquitoes (with a high of 11,506), the Wilderness Visitor Center light trap averaged 8,751 mosquitoes (with a high of 35,784), the William Floyd Estate Entrance light trap averaged 204 mosquitoes (with a high of 502), the William Floyd Estate West light trap averaged 666 mosquitoes (with a high of 2,040), and the additional light trap, 14.1-WVC-L, at the Wilderness Visitor Center averaged 29,747 (with a high of 79,611) during the 2009 season.

Culex spp. in Light Traps

The total numbers of *Culex* spp. caught in the light traps also exhibited a multi-modal curve (Graph 2, pg 27). The highest total was obtained from the Wilderness Visitor Center light trap on 6/29/09 with an estimated total of 3,733. Although the numbers were high during this week, it does not represent the proportion of *Culex* spp. that occurred in the light traps overall, some areas have a higher volume of mosquitoes than others. The Lighthouse Tract light trap averaged 76 *Culex* spp., Saltaire light trap averaged 5, the Sunken Forest light trap averaged 192, the Sailors Haven light trap averaged 110, the Fire Island Pines light trap averaged 91, the Watch Hill West light trap averaged 190, the Watch Hill Residence light trap averaged 245, the Wilderness Visitor Center light trap averaged 968, the William Floyd Estate Entrance light trap averaged 48, the William Floyd Estate West light trap averaged 236, and the additional Wilderness Visitor Center light trap averaged 84 *Culex* spp. during the 2009 season.

NOTE: the average of a certain species found in a trap does not always portray the proportion of that species typically found in that trap. For example, the highest proportion of *Culex* spp found in light traps was obtained from William Floyd Estate West and the lowest was obtained from Wilderness Visitor Center (Graph 4, pg 28). The difference in average number of *Culex* spp

found in the light trap is more due to the difference in overall adult mosquito population. This will be a theme throughout the results section when comparing the average amount of species in all traps. Refer to Graph 4 on page 28 or 8 on page 30 when comparing average proportions of certain species found in a trap not the average number found in each trap.

Aedes sollicitans in Light Traps

The total numbers of *Ae. sollicitans* caught in the light traps exhibited a multi-modal shaped curve as well (Graph 3, pg 27). The highest total was obtained from the additional Wilderness Visitor Center light trap on 9/8/09 with an estimated total of 65,980. The highest overall proportion of *Ae. sollicitans* was obtained from the Wilderness Visitor Center light trap and the lowest was obtained from Fire Island Pines and the Lighthouse Tract (Graph 4, pg 28). The Lighthouse Tract light trap averaged 7 *Ae. sollicitans*, the Saltaire light trap averaged 4, the Sunken Forest light trap averaged 21, the Sailors Haven light trap averaged less than 186, the Fire Island Pines light trap averaged 3, the Watch Hill West light trap averaged 309, the Watch Hill Residence light trap averaged 479, the Wilderness Visitor Center light trap averaged 4,494, the William Floyd Estate Entrance light trap averaged 7, the William Floyd Estate West light trap averaged 73, and the additional light trap at the Wilderness Visitor Center averaged 23,427 *Ae. sollicitans* during the 2009 season.

Aedes taeniorhynchus, *Aedes vexans*, and *Coq. perturbans* in Light Traps

The highest average proportion of *Ae. taeniorhynchus* in the light traps was found in the William Floyd Estate Entrance light trap while the lowest average proportion was found in the Lighthouse Tract light trap.

The highest average proportion of *Ae. vexans* in the light traps was found in the Fire Island Pines light trap. Both the Wilderness Visitor's Center light traps had the lowest average proportion.

The highest average proportions of *Coq. perturbans* in the light traps were found in the Lighthouse Tract and Fire Island Pines light traps. The Lighthouse Tract and Fire Island Pines light traps was the only traps that caught a significant amount *Coq. perturbans*, the other light traps caught an average of 0.20% or lower of *Coq. perturbans* (Graph 4, pg 28).

NOTE: Our foci for this surveillance were *Culex* spp. and *Ae. sollicitans*. The species mentioned in this section were only sorted when time allowed. Therefore, they were not sorted every week, especially during the weeks when there was a high volume of mosquito captures.

Gravid Traps

The total numbers of mosquitoes caught in gravid traps exhibited a similar trend to light traps throughout the season. The highest total was obtained from the Wilderness Visitor Center gravid trap on 9/8/09, with an estimated 1,517 mosquitoes. The Lighthouse Tract gravid trap averaged 6 mosquitoes, the Saltaire gravid trap averaged 25 mosquitoes, the Sunken Forest gravid trap averaged 16 mosquitoes, the Fire Island Pines gravid trap averaged 31 mosquitoes, the Watch Hill West gravid trap averaged 205 mosquitoes, the Wilderness Visitor Center gravid trap averaged 183 mosquitoes, the William Floyd Estate Entrance gravid trap averaged 7 mosquitoes, the William Floyd Estate West gravid trap averaged 17 mosquitoes during the 2009 season (Graph 5, pg 28).

Culex spp. in Gravid Traps

The total numbers of *Culex* spp. caught in the gravid traps also exhibited a multi-modal curve (Graph 6, pg 29). The highest total number was obtained from the Fire Island Pines gravid trap on 8/11/09 with a total of 120. The highest proportion of *Culex* spp. was obtained from Lighthouse Tract and Saltaire gravid traps and the lowest was obtained from the Wilderness Visitor Center gravid trap (Graph 8, pg 30). The Lighthouse Tract gravid trap averaged 4 *Culex* spp., the Saltaire gravid trap averaged 19, the Sunken Forest gravid trap averaged 4, the Fire Island Pines gravid trap averaged 17, the Watch Hill Gravid trap averaged 5 mosquitoes, the Wilderness Visitor Center gravid trap averaged less than 1, the William Floyd Estate Entrance gravid trap averaged 2, and the William Floyd Estate West gravid trap averaged 2 *Culex* spp. during the 2009 season (Graph 6, pg 29).

Aedes sollicitans in Gravid Traps

The total numbers of *Ae. sollicitans* caught in the gravid traps exhibited a multi-modal shaped curve as well (Graph 7, pg 29). The highest total of *Ae. sollicitans* was obtained from the Wilderness Visitor Center gravid trap on 9/8/09 with an estimated total of 1,411. The highest average proportion of *Ae. sollicitans* was obtained from Wilderness Visitor Center and the lowest was collected from Saltaire and Fire Island Pines traps (Graph 8, pg 30). The Lighthouse Tract gravid trap averaged 0 *Ae. sollicitans*, the Saltaire gravid trap averaged 0, the Sunken Forest gravid trap averaged 1, the Fire Island Pines gravid trap averaged less than 1, the Watch Hill West gravid trap averaged 114, the Wilderness Visitor Center gravid trap averaged 153, the William Floyd Estate Entrance gravid trap averaged 1, and the William Floyd Estate West gravid trap averaged 11 *Ae. sollicitans* during the 2009 season (Graph 7, pg 29).

Aedes taeniorhynchus, *Aedes vexans*, and *Coq. perturbans* in Gravid Traps

The highest average proportion of *Ae. taeniorhynchus* in the gravid traps was found in the Sunken Forest trap while the lowest average proportions were found in the Lighthouse Tract, Saltaire, Fire Island Pines, and Wilderness Visitor's Center traps.

The highest average proportion of *Ae. vexans* in the gravid traps were found in the Sunken Forest trap while the lowest average proportion was found in the Wilderness Visitor Center gravid traps.

All the gravid traps had an average of 0.00% *Coq. perturbans* (Graph 8, pg 30).

NOTE: Our foci for this surveillance were *Culex* spp. and *Ae. sollicitans*. The species mentioned in this section were only sorted when time allowed. Therefore, they were not sorted every week, especially during the weeks when there was a high volume of mosquito captures.

Arbovirus Testing

West Nile Virus was isolated from one pool of *Culex* spp. which was found in the light trap at the Wilderness Visitor Center. This pool was obtained from a sample collected on August 26, 2009. The park was notified about this detection by SCVC on September 4, 2009. As per the park's Mosquito Surveillance and Management Protocol and Mosquito Action Plan, surveillance was intensified in the Wilderness Visitor Center area. One additional light trap was set close to the Wilderness Visitor Center traps to increase surveillance after the positive result was announced.

The trap was maintained for three trapping cycles and all subsequent samples tested negative for West Nile Virus.

The second positive WNV pool was collected from Sailor's Haven on September 22, 2009. Because the positive pool of WNV at Sailor's Haven happened so late in the season, FIIS staff, with consultation from experts from United States Geological Survey (USGS) and Suffolk County Vector Control (SCVC), decided not to continue trapping for mosquitoes or the need for additional traps. The low presence of visitors, as well as the colder temperatures deemed it unnecessary for increased surveillance.

DISCUSSION

Site Specific

For both light and gravid traps there was considerable difference among surveillance sites in the numbers of mosquitoes caught, though this was generally consistent for each area. For example, the Wilderness Visitor Center usually yielded the highest total number of mosquitoes, while Saltaire yielded the lowest numbers.

When comparing the differences in proportion of the identified taxonomic groups in each site, this data also demonstrated consistent trends. For example, Fire Island Pines, Lighthouse Tract, and Saltaire usually had high proportion of *Culex* spp. like many other years. However, this year the William Floyd Estate traps yielded high levels of *Culex* spp. which may be attributed to the high levels of precipitation in the beginning of the season. Watch Hill and the Wilderness Area generally yielded the highest proportion of *Ae. sollicitans*, also similar to past years (Graph 9, pg 30).

These trends could be attributed to the microhabitats in each area and the placement of the traps within these sites. Whereas Fire Island Pines, Lighthouse Tract, and Saltaire landscapes include permanent, freshwater inland ponds, Watch Hill and the Wilderness Area are predominantly characterized by brackish meadows and low and high saltmarshes. Although these trends were generally consistent there were exceptions, possibly attributable to weather parameters such as precipitation, wind, or temperature. When subjectively examining the graphs, some associations could be made between trends displayed by the mosquito data collected and the varying weather conditions throughout the season. However, because the surveillance program was designed primarily to monitor disease activity, attempts to infer any correlation between weather parameters and mosquito captures will not be made in this report.

Light Trap vs. Gravid Trap

When comparing light traps and gravid traps there was a considerable difference in the numbers of mosquitoes caught, as expected. Overall, light traps typically yielded significantly more mosquito captures and higher diversity of species than gravid traps.

WNV Detection and Subsequent Actions

All positive test results were to be communicated to the Mosquito Biological Technician, Park Biologist, Chief of Resource Management and Superintendent by Suffolk County Vector DOHS. Park staff would then notify these results via email, press release and radio transmission. Staff, visitors and residents would be advised to use personal protection and limit their exposure to areas with high mosquito densities. As per our current protocol, additional personal protection equipment was to be distributed to all Mosquito Action Plan equipment caches located throughout the park in high-visitor-use areas.

Limitations

Several trapping periods throughout the season yielded very high numbers of mosquitoes; with limited time and staff, the number of samples sorted for arbovirus testing was only a small portion of the population captured. Consequently, the proportion of mosquitoes tested, relative to the numbers caught in each of those traps was extremely small. Therefore, the sensitivity in detecting a mosquito-borne disease may have been reduced during these weeks. This is particularly true in those samples collected in light traps, which demonstrated a substantial increase in mosquito capture numbers.

A major issue affecting the FIIS mosquito program was travel to and from sites. As Fire Island has no continuous paved roads throughout the length of the island, ORVs and 4-wheel drive vehicles were necessary to access sites from the beach. Setting each trap once per week could not always be done due to inclement beach and weather conditions. Access by boat was a necessity for several locations; however, this method of transportation was not always reliable due to the weather. Often times, a trap could not be set due to inclement weather, especially after a small craft advisory had been announced. Weather was also a concern for keeping mosquito specimens in good condition, which could be potentially damaged because of the turbulence of the bay or precipitation.

Occasionally, the vessels and other forms of transportation used for trapping needed to be serviced, creating further logistical challenges and greatly affecting the trapping schedule.

Another issue associated with the FIIS mosquito program was the failure and disturbance of equipment. Often times, a trap was disturbed or failed after being set, resulting in incomplete data.

Future Recommendations

To avoid a high turnover rate, the position of Mosquito Biological Technician could be made permanent. The Technician should primarily be responsible for assisting with the mosquito program and, as a permanent employee, could assist with other Resource Management programs before and after the trapping season. This would result in a more robust and consistent mosquito program and would also relieve some of the strain on limited resources and staff.

In years past, there have been a variety of different formats in which data have been recorded. As a remedy, an Access© database has been created in order to increase the consistency of data recording between years. However, there still remains some minor fine

tuning before this can be applied. Once this is completed, all historic and recent data should be recorded using this database. This could help in comparing data from year to year, looking at various parameters and independent variables.

ACKNOWLEDGEMENTS

First, I would like to thank Jordan Raphael for his training and guidance for this program. His knowledge and efficiency facilitated the smooth start and continuation to the mosquito trapping season. I would also like to thank Dr. Scott Campbell and Dr. Howard Ginsberg for contributing their academic and technical expertise. I would like to thank everyone at Suffolk County Vector Control for their hard work and assistance. Finally, I would like to thank members of the FIIS Natural Resource team, especially Lindsay Reis for any help she provided when needed, Law Enforcement and Maintenance staff, particularly Walter Marten; without them, the surveillance program would have been considerably more challenging. Their assistance with transportation and their various supports is greatly appreciated.

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Figure 1. Map of Fire Island National Seashore with the seven study sites.

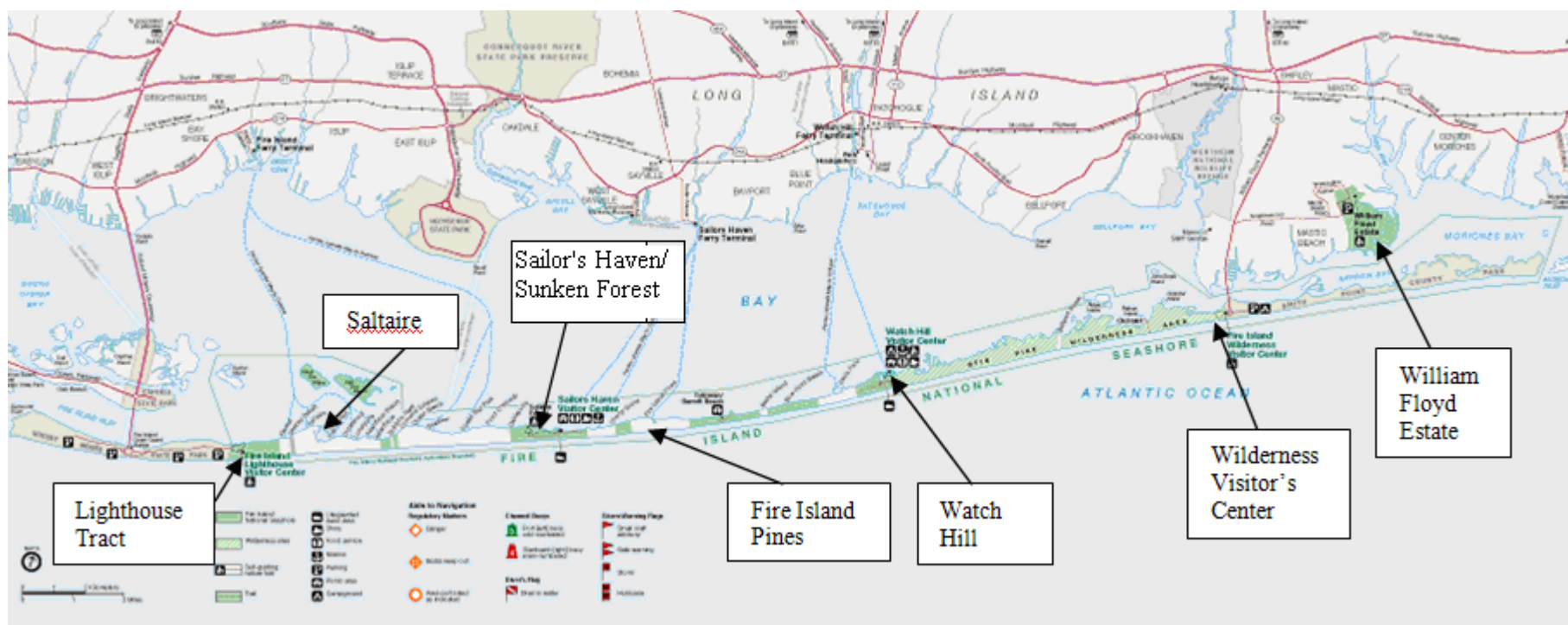


Fig. 2. Gravid trap with collection net and battery.



Fig. 3. Light trap with collection container.



Figure 4. Map of the Lighthouse Tract study site.



Figure 5. Map of Saltaire Study.

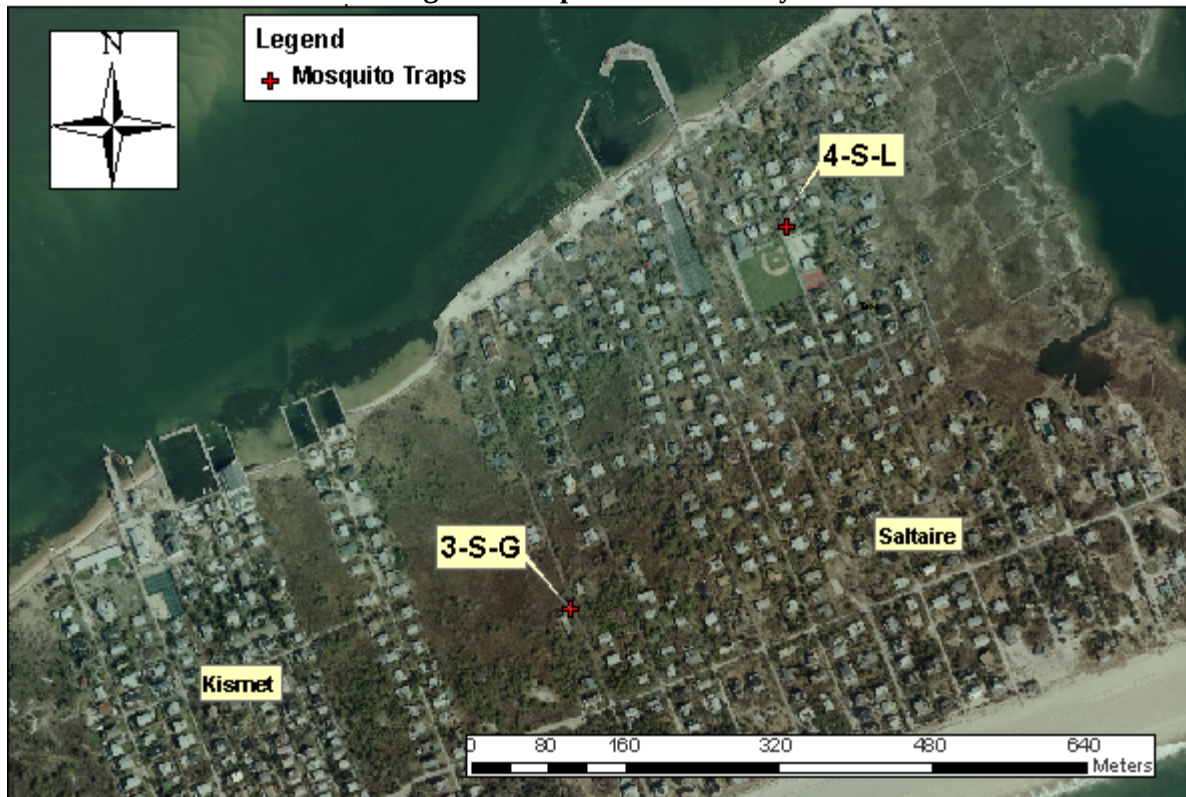


Figure 6. Map of the Sunken Forest and Sailor's Haven study site.



Figure 7. Map of the Fire Island Pines study site.



Figure 8. Map of the Watch Hill study site.



Figure 9. Map of the Wilderness study site.



Figure 10. Map of the William Floyd Estate study site.



Table 1. Mosquito species isolated from FIIS (Lussier 2003).

<i>Aedes (Ochlerotatus) canadensis</i>	<i>Culex pipiens</i>
<i>Aedes (Ochlerotatus) cantator</i>	<i>Culex restuans</i>
<i>Aedes cinereus</i>	<i>Culex salinarius</i>
<i>Aedes (Ochlerotatus) excrucians</i>	<i>Culex territans</i>
<i>Aedes (Ochlerotatus) riparius(?)</i>	
<i>Aedes (Ochlerotatus) sollicitans</i>	<i>Coquillettidia perturbans</i>
<i>Aedes (Ochlerotatus) sticticus</i>	
<i>Aedes (Ochlerotatus) taeniorhynchus</i>	<i>Culiseta impatiens</i>
<i>Aedes (Ochlerotatus) triseriatus</i>	<i>Culiseta incidens</i>
<i>Aedes (Ochlerotatus) trivittatus</i>	<i>Culiseta melanura</i>
<i>Aedes vexans</i>	
	<i>Psorophora ciliata</i>
<i>Anopheles sp.</i>	<i>Psorophora ferrox</i>
<i>Anopheles punctipennis</i>	
<i>Anopheles quadrimaculatus</i>	<i>Uranotaenis sapphirina</i>

NOTE: Recent papers (Reinert 2000, Reinert et al. 2004) have suggested that several subgenera exist within the *Aedes* genus. The validity of this, however, has not been resolved. Thus, in this report we use the original classification of *Aedes*, as is used by the *Journal of Medical Entomology* (2005. *J. Med. Entomol.* 42: 511).

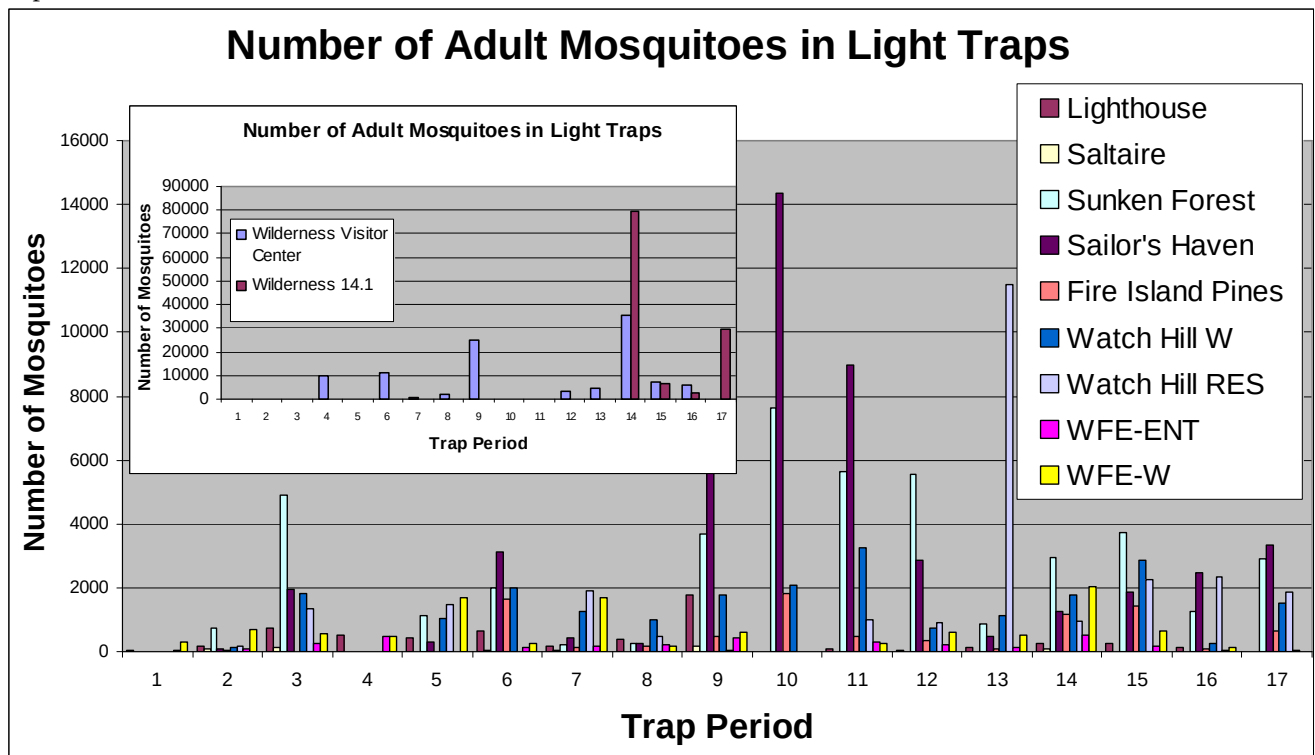
Table 2. Trap placement in 2009

Study Area	Study Site	Site Code	Trap Type	Trap Code	Trap UTM's		Trap No.
					EW	NS	
Lighthouse Tract	Lighthouse Tract-Kismet	K	Gravid	K-G	651590	4499790	1
			Light/CO2	K-L	651612	4499748	2
Saltaire	Saltaire	S	Gravid	S-G			3
		S	Light/CO2	S-L			4
Sailors Haven	Sunken Forest	SF	Gravid	SF-G	662459	4503111	5
	Sailors Haven Concessions	SH	Light/CO2	SF-L			6
			Light/CO2	SH-L	660258	4502407	7
Fire Island Pines	Fire Island Pines/Carrington Tract	FIP	Gravid	FIP-G			8
			Light/CO2	FIP-L	662490	4503085	9
Watch Hill	Watch Hill West	WH-W	Gravid	WH-W-G	669279	669280	10
	Watch Hill Residents	WH-R	Light/CO2	WH-W-L			11
			Light/CO2	WH-R-L	669827	4506289	12
Wilderness Area	Wilderness VC	WVC	Gravid	WVC-G			13
			Light/CO2	WVC-L	680062	4511193	14
			Light/CO2	WVC-L			14.1
William Floyd Estate	William Floyd Estate Entrance	WFE-Ent	Gravid	WFE-Ent-G			15
	William Floyd Estate West	WFE-W	Light/CO2	WFE-Ent-L			16
			Gravid	WFE-W-G	683535	4514710	17
			Light/CO2	WFE-W-L			18

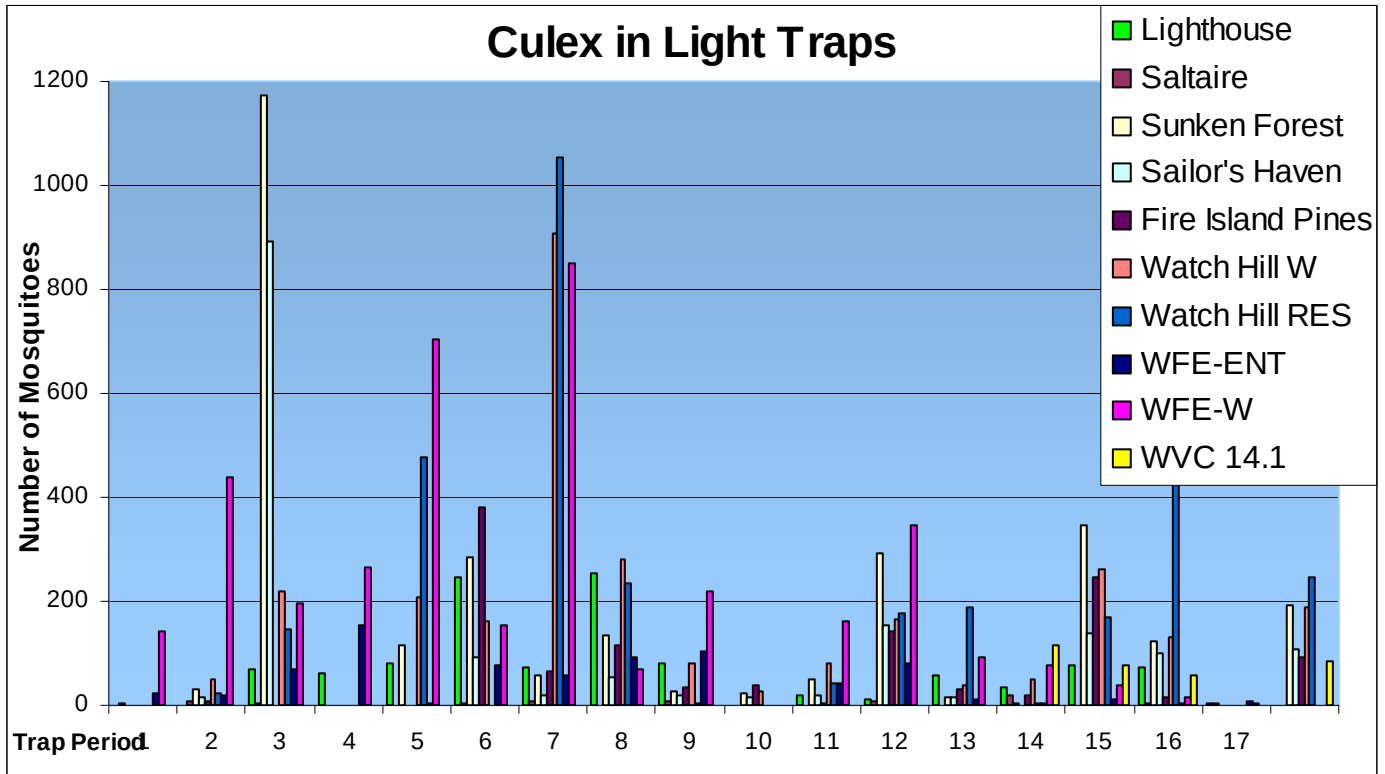
Table 3. This table should be referenced to understand the chronology of some of the following graphs.

Table 3. Dates that correspond with Trapping Periods (Cycle)	
Period 1	June 9, 2009
Period 2	June 15-17, 2009
Period 3	June 23-24, 2009
Period 4	June 29, 2009
Period 5	July 6-7, 2009
Period 6	July 13-14, 2009
Period 7	July 20- 22, 2009
Period 8	July 27-28, 2009
Period 9	Aug. 3-5, 2009
Period 10	Aug. 11, 2009
Period 11	Aug. 17-18, 2009
Period 12	Aug. 24-26, 2009
Period 13	Aug 31- Sept. 1, 2009
Period 14	Sept. 8-9, 2009
Period 15	Sept. 14-15, 2009
Period 16	Sept. 21-22, 2009
Period 17	Sept. 29, 2009

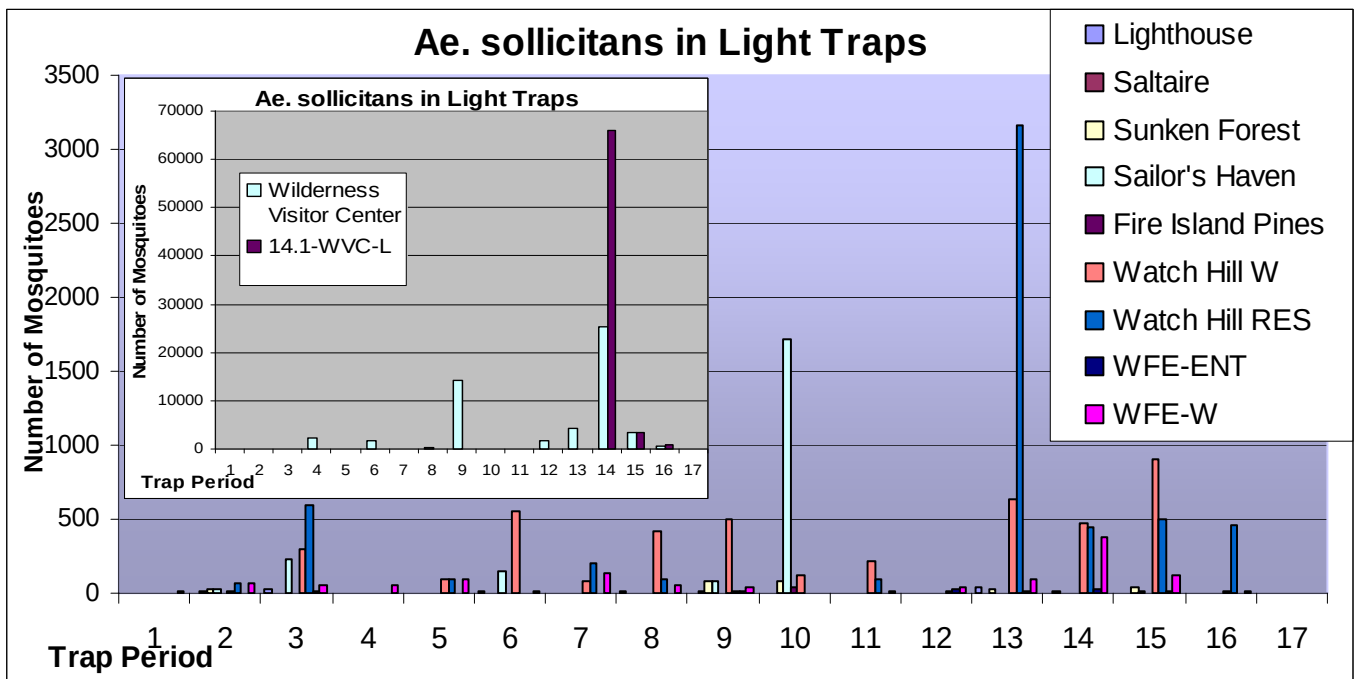
Graph 1. Total number of adult mosquitoes caught using light traps during the 2009 trapping season. Trap counts in the Wilderness Area were graphed separately because of the large difference in numbers compared to other areas. No data may indicate one of the following: no captures, a trap was not set, or a trap was disturbed/ failed.



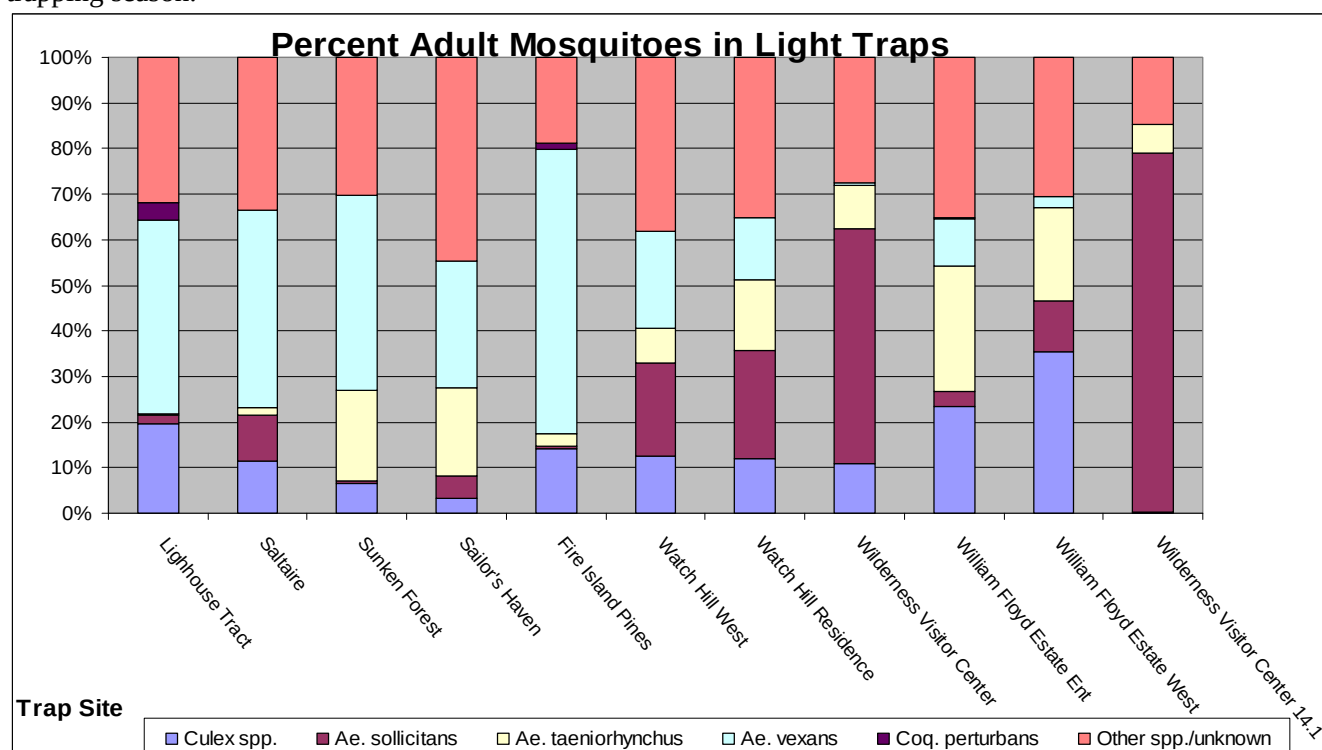
Graph 2. Total number of *Culex* spp. caught using light traps during the 2009 trapping season. Trap counts in the Wilderness Area and Watch Hill were graphed separately because of the large difference in numbers compared to other areas.



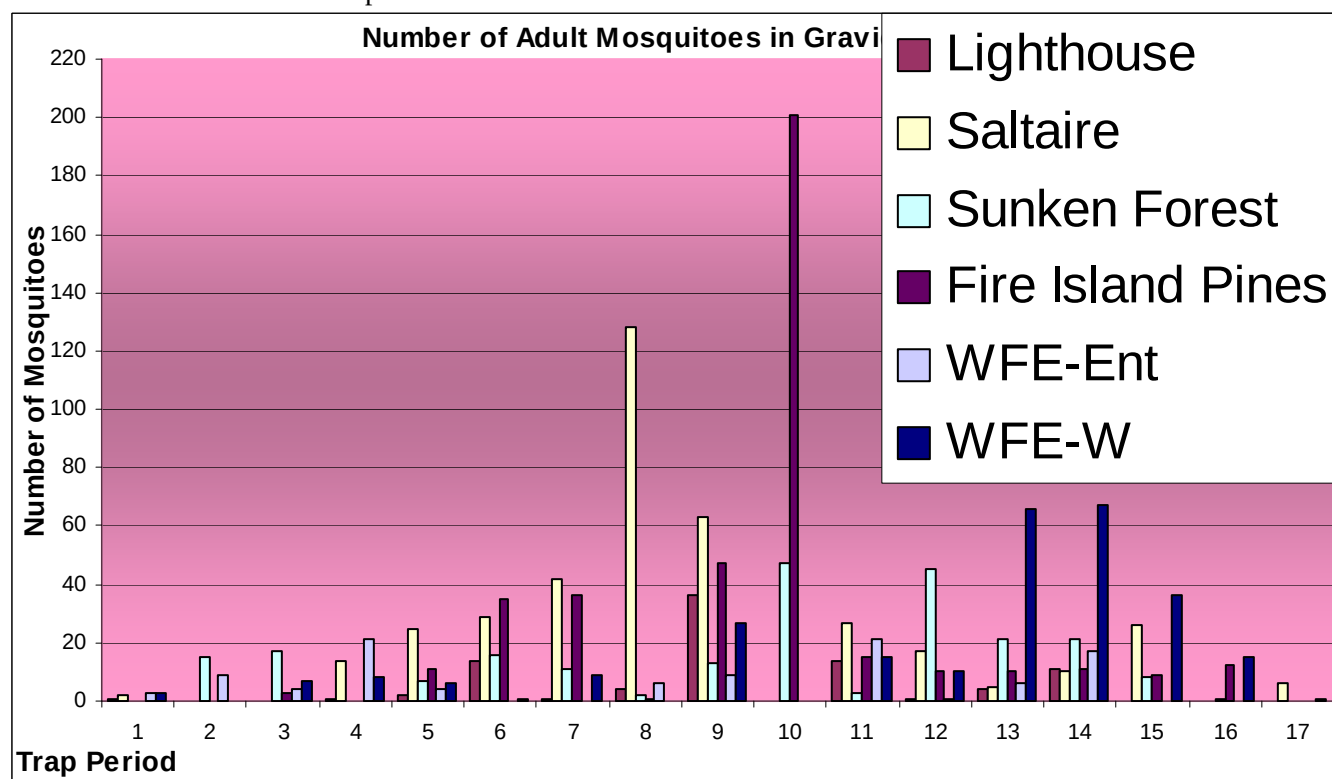
Graph 3. Total number of *Aedes sollicitans* caught using light traps during the 2009 trapping season. Trap counts in the Wilderness Area were graphed separately because of the large difference in numbers compared to other areas.



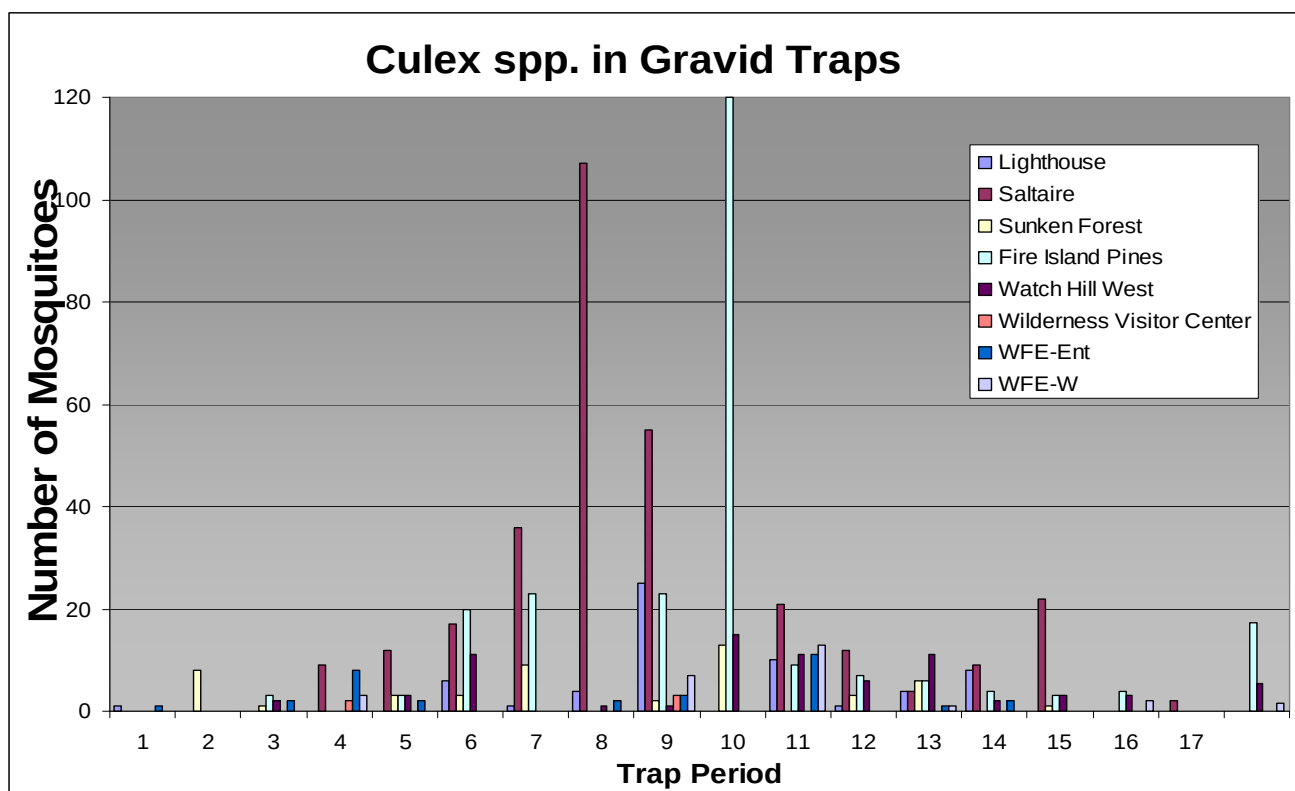
Graph 4. Overall percentage of the identified taxonomic groups for each light trap during the 2009 trapping season.



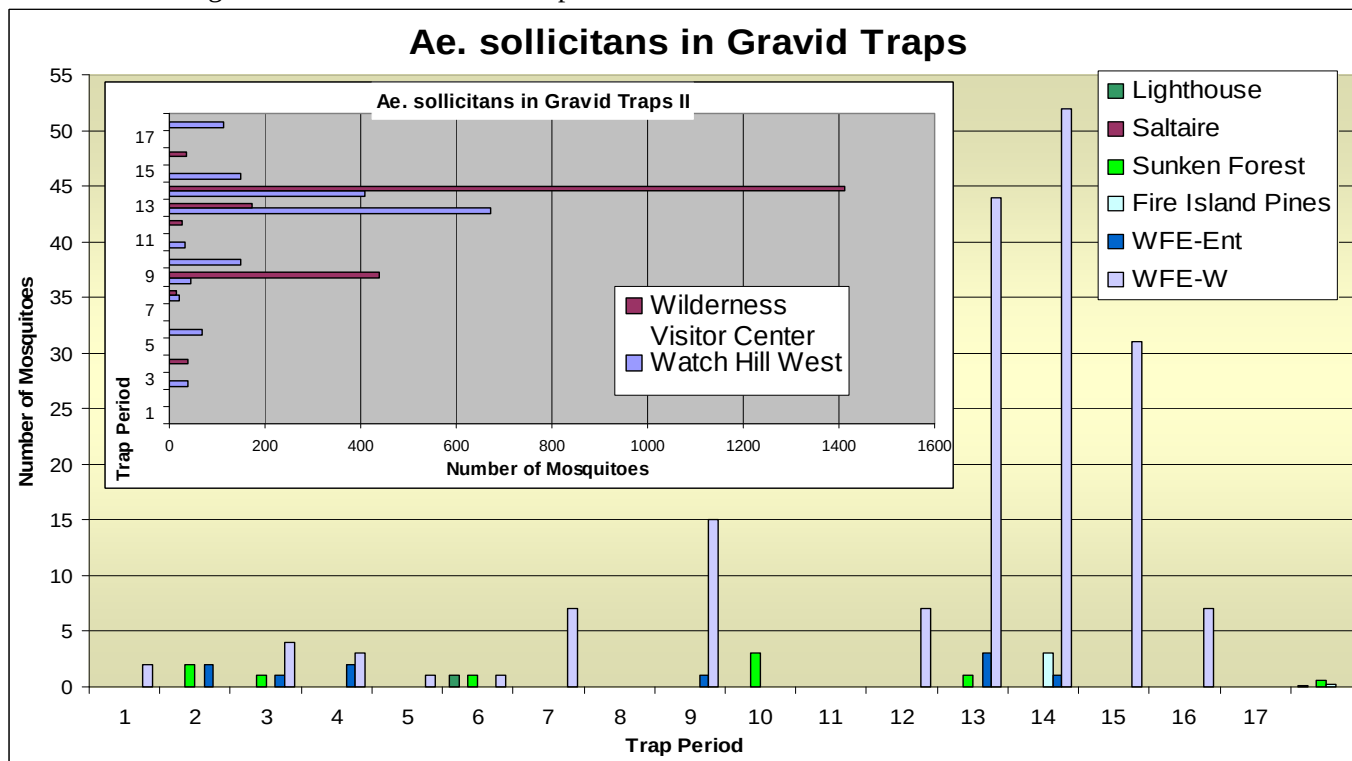
Graph 5. Total number of adult mosquitoes caught using gravid traps during the 2009 trapping season. Trap counts at Watch Hill West and Wilderness Visitor Center were graphed separately because of the large difference in numbers compared to other areas.



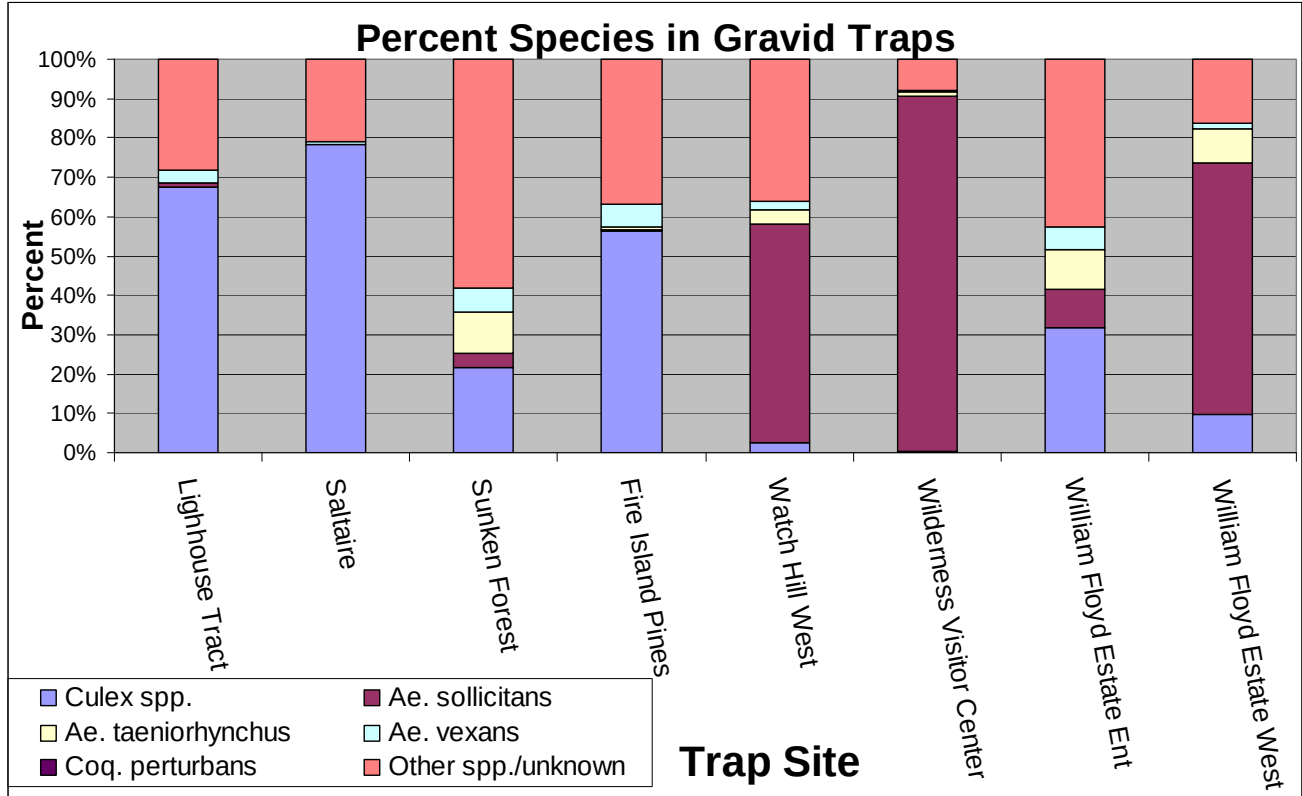
Graph 6. Total number of *Culex* spp. caught using gravid traps during the 2009 trapping season.



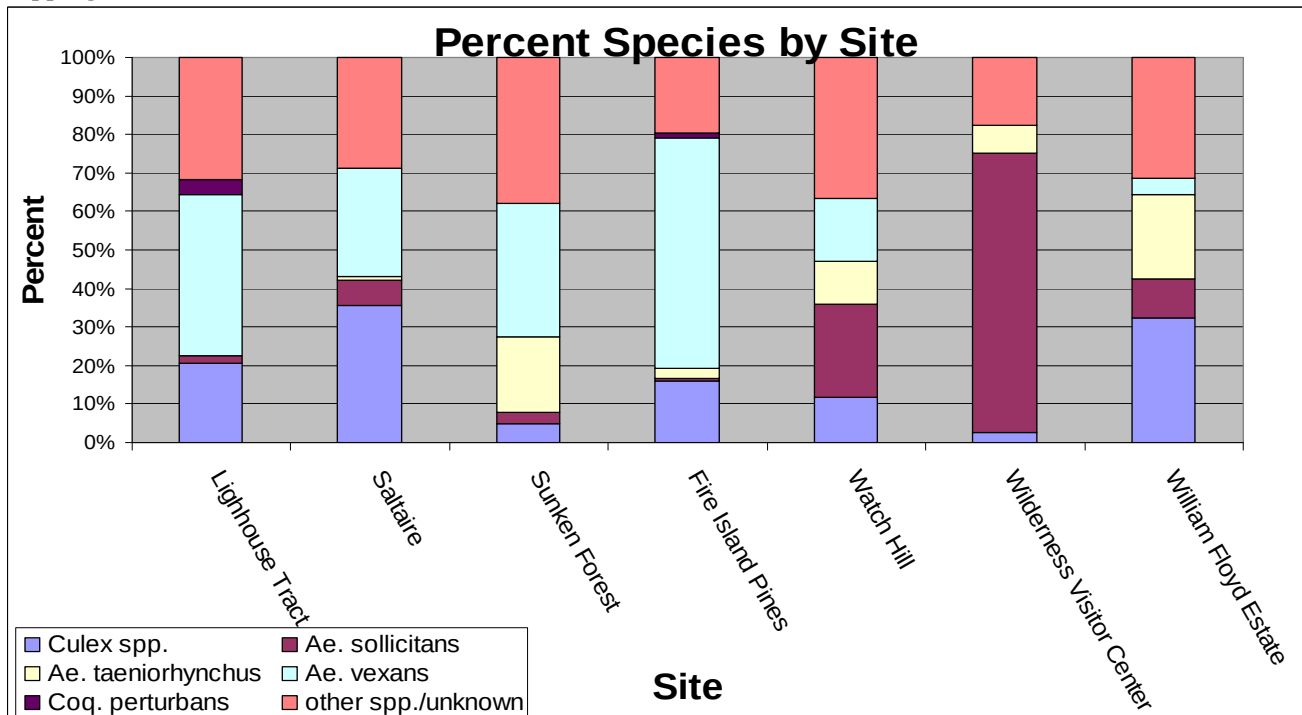
Graph 7. Total number of *Aedes sollicitans* caught using gravid traps during the 2009 trapping season. Trap counts in the Watch Hill West and the Wilderness Visitor's Center were graphed separately because of the large difference in numbers compared to other areas.



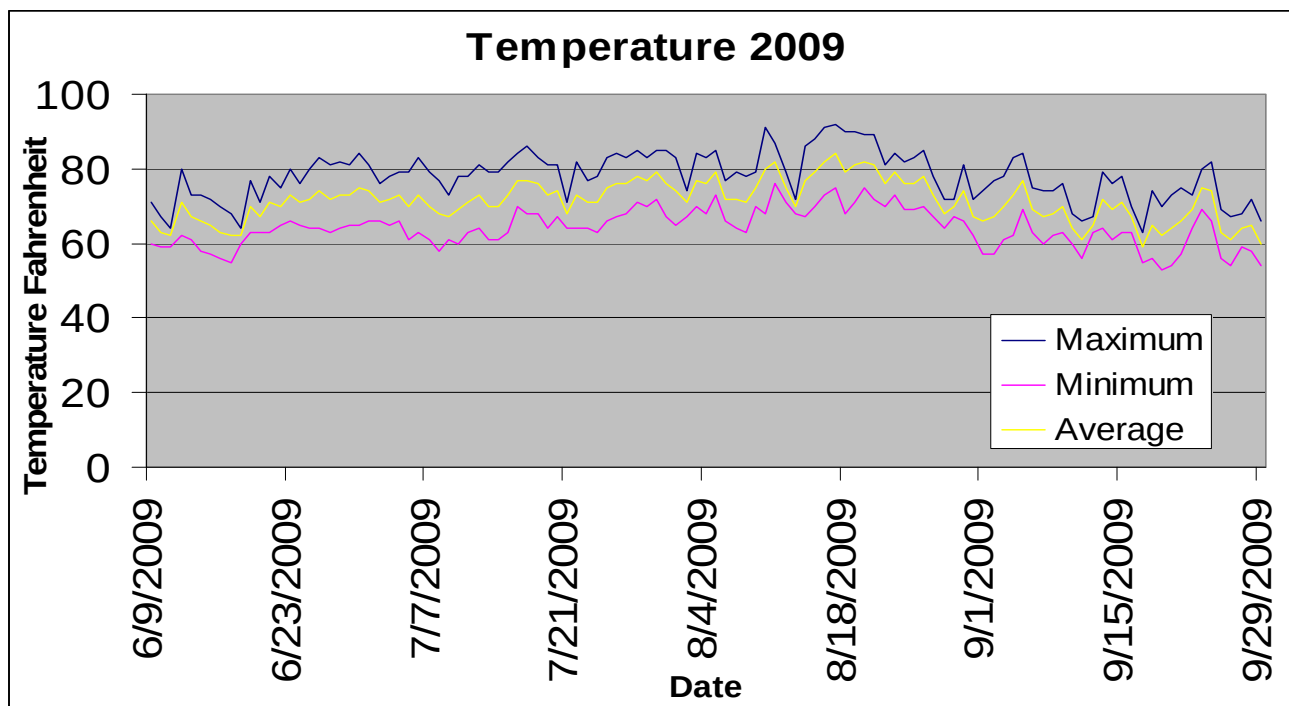
Graph 8. Overall percentage of the identified taxonomic groups for each gravid trap during the 2009 trapping season.



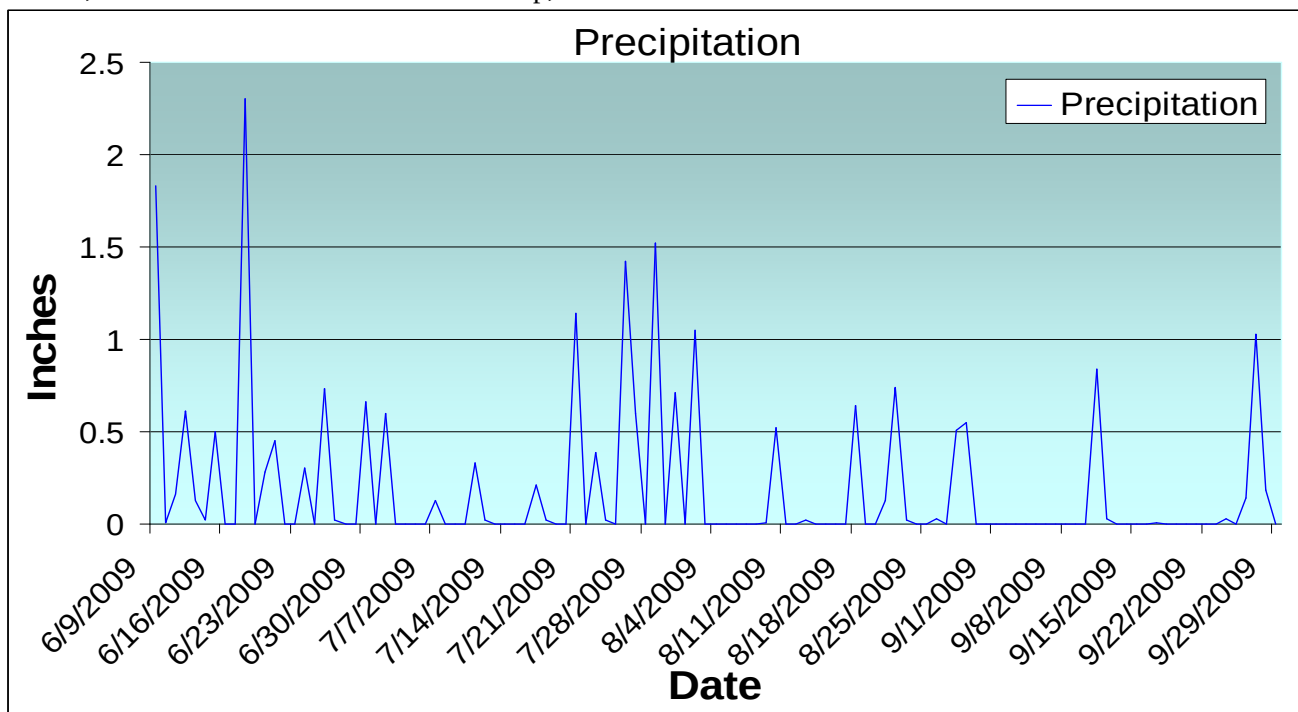
Graph 9. Overall percentage of the identified taxonomic groups for each general site during the 2009 trapping season.



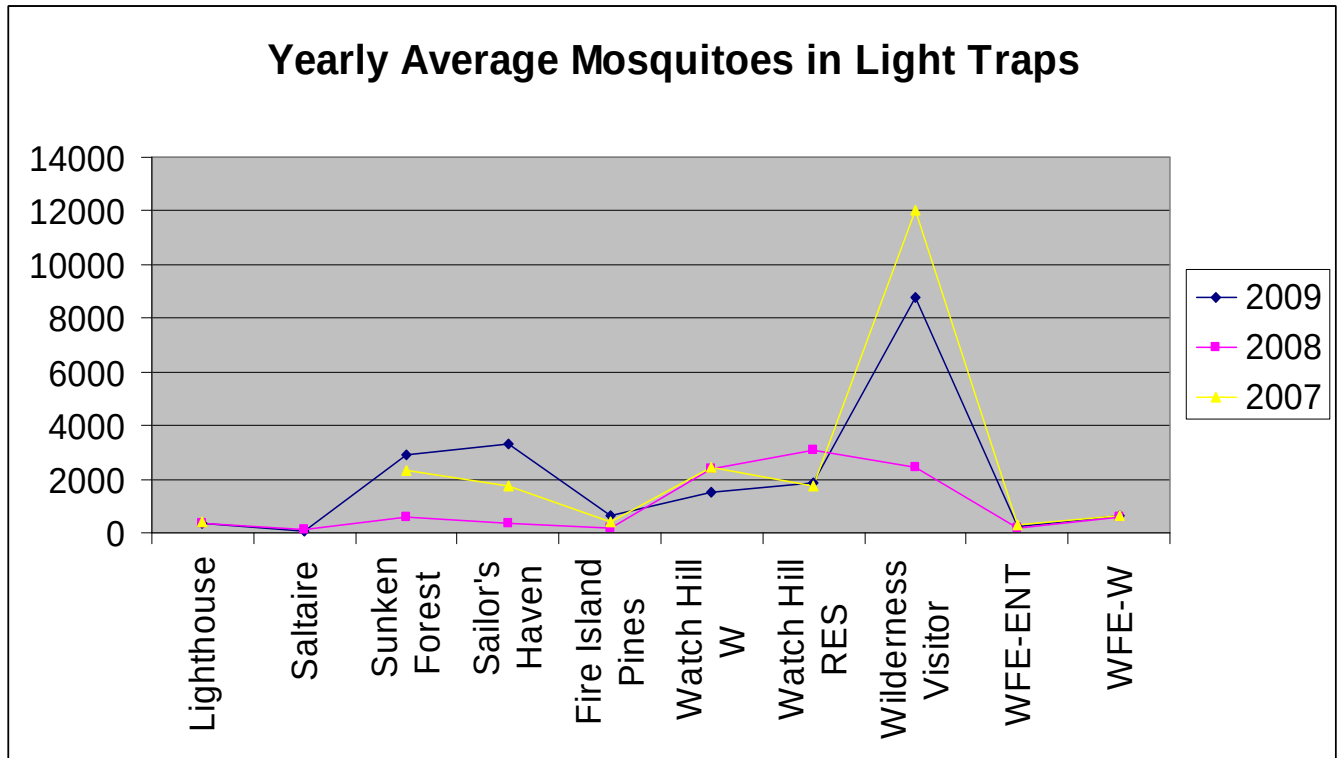
Graph 10. Daily, mean, maximum and minimum temperatures during the 2009 mosquito trapping season. Data was obtained from NOAA, National Climatic Data Center in Islip, NY.



Graph 11. Recorded precipitation during the 2009 mosquito trapping season. Data was obtained from NOAA, National Climatic Data Center in Islip, NY.



Graph 12. Comparison of average mosquitoes caught at each site in light traps from 2006-2009.



Graphs 13 and 14. Yearly averages of mosquitoes caught in gravid traps.

