Environmental Influences on Mosquito Adult and Larvae Abundance

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Introduction:

Mosquitoes are very important as vectors of disease and as pests of many organisms on the Earth, especially humans. The ability of mosquitoes to transmit diseases and parasitic organisms is well documented, and many control strategies have been devised to eliminate mosquito populations in order to control or curb the spread of disease. Many of these control strategies focus on the behavior of the mosquito, both in larval and adult forms. Certain chemical and biological agents are used to eliminate adult and larval mosquitoes in specific habitats under specific environmental conditions. Control strategies for the mosquito focus on eliminating mosquito populations when they are most active and controlling larval populations in habitats where mosquitoes are most likely to breed. Mosquitoes can be affected by a number of different environmental factors (Platt, 1957), and one of the chief of these is temperature (Love, 1957). Temperature not only affects where the mosquitoes breed (Platt, 1957), but also how long it takes for them to develop and how active the adults will be (Platt 1957, Love 1957). It is intuitively obvious that mosquitoes are more active in the times around dawn and dusk, as these are cooler times of the day, but adult mosquitoes also respond to small differences in temperature change, even as low as $2^{o}C$ (Platt, 1957). Mosquitoes have been shown to have a marked increase in activity with just a small increase in temperature, but very little response to other factors (Platt, 1957). In this study, the temperature variability was compared to the number of mosquitoes caught, and other factors were also examined in order to see if wind speed, wind direction, solar radiation, or rainfall had an effect on the population of mosquito adults. Larvae from three different sites were also examined to determine the relative abundance of larvae and pupae at each site, and compared to water temperatures taken at each habitat. These habitats were chosen to imitate similar habitats that are found around human habitations, specifically temporary water habitats with differing amounts of vegetation and temperature properties. From these results, a good idea may be given as to the most likely times to find a large abundance of adult and larval mosquitoes and perhaps to devise a control strategy to reduce the number of mosquitoes that serve as pests and disease transmitters.

Materials and Methods:

Larvae: Three temporary habitats were chosen to compare larval abundance and water temperature effects on development. The first of these was a temporary pool which was heavily vegetated, mostly by reeds and other aquatic plants. It was approximately 55 m in circumference, and dipping sites were chosen at ten equidistant points around the perimeter of the pool (Morrison 1992, Gilardi). The site was dipped only at the edge, as this is where the majority of mosquito larvae reside (Morrison). Temperature was also taken at each of these dipping sites. Five dips were taken per dipping site, with the number of larvae and pupae recorded. Larvae were captured and placed into 70% ethanol for transport to lab for identification. The second habitat was a temporary pool with sparse vegetation, mainly tree saplings. Ten equidistant points were made around the circumference of 41 m, and again each site was dipped at the edge and temperature was taken at each dipping site, with the larvae stored and transported back to lab. The third habitat was a roadside ditch caused by tire ruts. It was approximately 42 m in length, so ten equidistant points were dipped within the habitat and temperature taken at each point.

The larval habitats were sampled on June 2, 6, and 9, and each site took approximately an hour to complete. Sampling usually began in the early afternoon and finished before 5 pm. There was a noticeable decrease in water level between each sampling day, with the ditch most affected by the lack of rain and the open vegetation pond most affected. The heavily vegetated habitat was able to withstand the lack of water much better than the other two. The vegetated site faced west, the open site faced south, and the ditch ran north to south.

Unfortunately, by the second week of June, all three temporary habitats had dried up. These were most likely snowmelt induced habitats, making them very important for the breeding of Anopheles and Culiseta species, being the earliest breeding genera present on property, but hard to study once the summer begins to dry them out. There was also a significant lack of rain, reducing the habitats' chances of replenishing themselves. Each habitat was examined after 3 days to allow growth of the larvae, as some species can pupate and hatch within a week (Barr et al), but with the short duration of the habitats no real data can be examined as to how the varying temperatures of the habitats affect the relative rates of development in these temporary habitats. There was some data of interest, however, in the amount of larvae and pupae per habitat type and relation to temperature, showing that mosquitoes may prefer one habitat type to the others.

Adults: Adult mosquitoes were captured with a New Jersey light trap, which is a metal cylinder with a fan and a light bulb, and stored in 70% ethanol until counted. The trap was set up from 5 pm every day to around 10 am the next morning, from June 23 to July 16. The trap was located outside the student research lab, on the north side of the building, and was the only light on that side of the building during trapping. Mosquitoes were counted each day and stored in glass jars of 70% ethanol until being scored for genus on July 16-17. The adults were identified to genus using Barr and Merritt et al. There are three days of data missing during the trapping period for the adults captured. One of these days was due to the trap becoming plugged when a large moth was shredded very early in the fan and plugged the cone, preventing other insects from falling into the trap. The other two days were due to the use of the trapping area to clean and skin a bear and deer.

Weather Data: Weather data was obtained through the use of weather stations set up on the UNDERC property near the trapping station at the lab. Two weather stations were used, one that made measurements daily and one that made measurements hourly. The data recorded included air temperature, soil temperature, wind speed, wind direction, humidity, solar radiation in kJ, solar energy in W/m^2, daily rainfall and hourly rainfall.

Identification:

Barr et al. and Merritt et al. were primarily used to identify the adults and larvae to genus. I have devised an UNDERC key to the genera captured, which may be useful to future capture studies based on similar methods to my own. In cases where species identification is needed, Barr is vastly superior to any other resource encountered.

Adults:

1. Maxillary palpi about as long as proboscis; scutellum rounded; thorax and abdomen few or no scales________________________*Anopheles*
1. Maxillary palpi less than half as long as proboscis; scutellum tri-lobed; thorax and abdomen densely covered with scales________________2

2. Post-notum with tuft of setae________________________*Wyeomyia*
2. Post-notum without tuft of setae_____________________________3
3. Cerci evident; abdomen pointed__________________________*Aedes*
3. Cerci concealed; abdomen rounded__________________________4
4. Spiracular bristles present; post-spiracular bristles absent____*Culiseta*
4. Spiracular bristles absent; post-spiracular bristles absent___________5
5. Wing scales dark______________________________________*Culex*
5. Wing scales conspicuously dark and light intermixed; hind tarsi with pale rings at bases of segments only; proboscis with definite pale ring ____*Mansonia*

Larvae:

1. Siphon absent____________________________________*Anopheles*
1. Siphon present____2
2. Siphon with pecten____4
2. Siphon without pecten_______________________________________3
3. Siphon triangular and attenuated; head wider than long_____*Mansonia*
3. Siphon elongate with many single hairs: head at least as long as wide; anal brush tuft a long, single hair______________________*Wyeomyia*
4. Air tube with ventral hair tuft at base____________________*Culiseta*
4. Air tube without ventral hair tuft at base______________________5
5. Many hair tufts or hairs on siphon, none between spines of pecten____*Culex*
5. Single pair of large hair tufts on siphon, usually close to or associated with pecten____*Aedes*

Pupae:

Unfortunately, no reliable source exists to identify pupae. Instead, only absolute counts of pupae captured were taken.

Results:

The analysis of the results relied on mostly regression analysis of the amount of mosquitoes captured to the environmental variables encountered. Among the variables studied, the ones deemed most relevant to mosquito ability to breed and feed were temperature, wind speed, and daily rainfall. Mosquitoes are very delicate insects, so air temperature has a large effect on feeding habits, and likewise anything that influences air temperature should be important in determining when mosquitoes are most likely to feed. Thus, wind speed can cool the air as well as prevent adults from flying far in search of a bloodmeal, and daily rainfall can also cool the air temperature as well as increase the amount of water on the ground, perhaps increasing feeding and mating to regenerate the population. Solar radiation and wind direction were also examined, as solar radiation can affect temperature and wind direction may aid mosquitoes in reaching the trapping station from a certain habitat and prevent others in other habitats. Averages were taken of hourly measurements from 1700 h at night to 1000 h the next morning. The figures for temperature and wind speed and direction were averaged because only a total nightly count was done, not an hourly trapping count. The rainfall and solar radiation counts were taken as a daily amount, recorded at 2400 h each night. Larval abundance and pupal abundance were examined in relation to both temperature at each site on each day and between sites. Temperature readings taken at each dipping site were averaged for the whole pond, and then compared between the ponds. Temporary habitats were compared to examine if any temperature difference exists between them which would enable one habitat to be more advantageous in breeding.

When doing a regression analysis of the data, only temperature was found to significantly influence the number of adult mosquitoes caught (Fig. 1), both in total number caught ($P < 0.001$) and for the two most abundant species caught (Fig. 2), which were *Mansonia peturbans* ($P = 0.038$) and *Aedes* species ($P = 0.027$), especially *Aedes vexans*. The mosquito populations were found to be very sensitive to air temperature, with increased or decreased activity with only a $2^{o}C$ change in average nightly temperature. Wind speed and direction were not found to play a significant role in the number of adults caught (Fig. 4), surprising considering that mosquitoes are an aerial species but understandable as the average wind speeds were relatively low and could easily be overcome by an adult. Wind direction also was insignificant, eliminating the possibility that one habitat was at an advantage in producing mosquitoes that reached the trapping station. Solar radiation was also found to not have any significant relation to the number of adult mosquitoes caught (Fig. 3), also surprising as this is the main source of temperature fluctuation. Mosquitoes in previous studies have been shown to not respond significantly to white light fluctuations, however, and do not respond to different wavelengths of light either (Platt). Thus, the energy level of light and any environmental effects due to light, such as temperature effects, are inconsequential to mosquito feeding habits. A regression analysis of the temperature and solar radiation per day, however, also found no significant relationship. Thus, the air temperature, while dependent on solar radiation, is affected by other factors as well, most likely humidity. Humidity has been found in previous studies to influence mosquito behavior (Platt), so this may be the case in this study as well. However, when doing a regression of the average nightly humidity to total number of adults captured, no significant relationship was found ($R^2 = 0.0018$). There was a very large variability in the hourly humidity, however, leading to the question of whether adult capture was thus variable as well at these humidities.

When examining the larval data, the temperatures between the habitats did not differ significantly, nearly overlapping for each day examined (Fig. 6). Any variability in the numbers of larvae and pupae caught must be due either to some other environmental influence or adult breeding preference. When looking at the numbers captured in each habitat, the all three had lowered numbers as the weeks went by (Fig. 6). The greatest change in number was in the open habitat, perhaps showing that this habitat is quicker at regenerating populations of mosquitoes because a dropoff would indicate that the larvae had pupated and adults had laid more eggs, leading to a decrease in larval abundance. A dropoff could also be a sign of increased mortality. However, the larval population in the vegetated habitat had the greatest correlation to temperature, not the open habitat (Fig. 5). This shows that if the open habitat regenerated faster than the vegetated site, it was not due to increased temperature, but to some other factor in the water.

If temperature is really the most influential of aquatic environmental factors, which previous studies have shown (Love), mosquitoes may prefer to breed in highly vegetated or debris-laden water, not open or ditch water. This makes sense as mosquito larvae feed on bacteria and microorganisms, which would be more abundant in debris-laden water. Also, vegetation or debris provides shelter from predators, leading to a greater survival of mosquito larvae and a greater population of adults. Vegetation also provides a cooling effect to the water, very important as larvae are very sensitive to high temperatures (Love), which they are more likely to experience in open water, and especially in a shallow roadside ditch. Adults also prefer to rest in shady places (Platt), which would be more likely in a vegetated habitat, thus leading to a greater possibility of mating and breeding. Pupae were very strongly correlated to temperature (Fig. 5), as the populations in each habitat showed a significant relationship (Veg: $R^2 = 0.8386$, Open $R^2 = 0.6181$, Ditch $R^2 = 0.8514$). Pupae have been previously shown to be more sensitive to temperature fluctuations (Love), so a habitat that provides a shady resting place from the heat of the day is more likely to have a higher survival rate of pupae than a habitat with little vegetation or little water. Thus, it is interesting to note that in the vegetated habitat, pupae abundance went up with increasing temperature, but went down in the open habitat. The ditch habitat, while statistically significant, can be ignored as only one pupa was captured in this habitat.

Discussion:

Environmental influences are very important to the development and breeding of mosquito populations, and chief among these is temperature. Temperature can be influenced by the amount of solar radiation, humidity, wind, and cloud cover which may induce rainfall. Water temperature can influence larval development (Haufe, 1956) and can lead to a greater regeneration of populations as insect metabolism is increased with increasing temperature (Sayle). Water temperature is influenced by many things, especially solar radiation and cloud cover (Morrison, Haufe). Also, rainfall can influence water temperature if it is cooler than the ground water. However, the results of this study seem to show that even if water temperature influences metabolism, it has a minimal effect on larval population survival and mosquito population regeneration. It is significant to pupae survival, meaning that the population of mosquitoes can be influenced by small changes in temperature only when they have reached the critical pupae stage. Since this stage lasts only a couple of days of the approximately 15 it takes to fully develop from egg to adult, temperature can be regarded as a minimal factor influencing mosquito population regeneration. There must be other environmental influences of breeding site water at UNDERC that play a larger role in larval development periods, most likely nutrient levels and predator populations of the habitats.

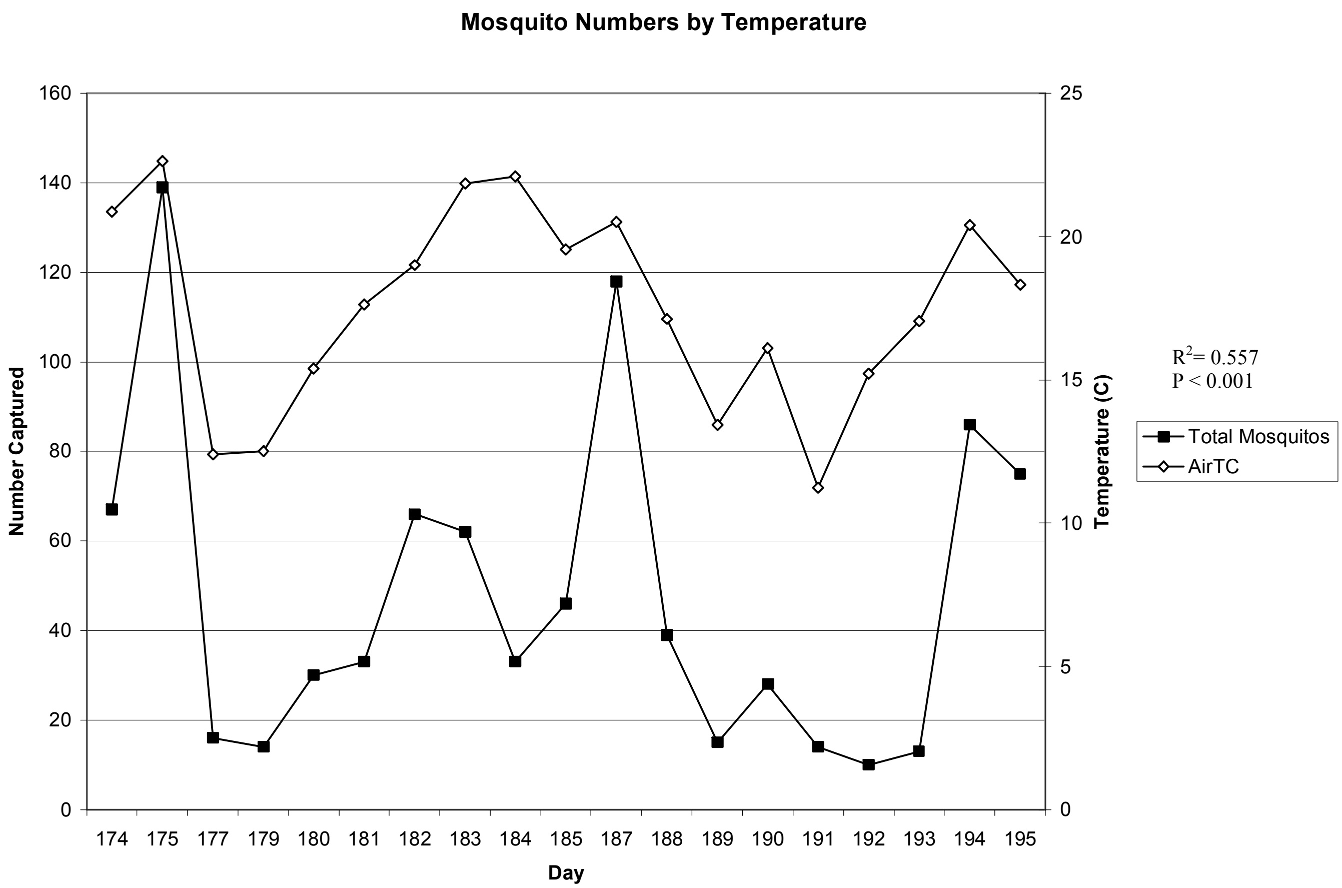
The habitats chosen for this study were specifically chosen to represent similar breeding habitats which may occur near human habitations. From the results, it appears that the greatest threat from the mosquito population lies in breeding sites that are heavily vegetated. These temporary water sites occur in many cities and areas, usually in the form of run-off pools, small depressions, and refuse-filled holes. These habitats provide ample cover from both predators and temperature fluctuations, and would lead to a greater survival rate of larvae and pupae, leading to a larger population of adult mosquitoes. Open water habitats would also be more likely to breed, but the larvae would be at a greater risk to predation and desiccation if the pool dries up quickly. Ditches are not ideal either, as the water level is very variable and they are more likely to have larger temperature fluctuations, leading to a higher mortality of the larvae and especially pupae. Thus, control strategies for immature mosquitoes should be focused on debris-laden temporary water as well as more permanent sites, as these present the best breeding and survival situations for the mosquito population.

The adult population of mosquitoes responds well to temperature. Both the total number of adults caught and the numbers of *Aedes* and *Mansonia* species, which were the most abundant caught over the sampling period, were significantly influenced by temperature. The peaks of *Aedes* and *Mansonia* also occurred at different times during the sampling period. When the Aedes population was elevated the *Mansonia* population was depressed, and vice versa. This may reflect a cyclic pattern to development that these genera use to avoid competing with each other for resources. While temperature influenced the number of adults captured, no other factor that would influence temperature was significantly related to the number of adults captured. Solar radiation, wind speed, wind direction, humidity, and rainfall were all found to have insignificant effects on the number of adults captured. Thus, while temperature influences adult mosquito feeding habits, it cannot be boiled down to a single factor which has a greater influence than others. Humidity has been found in the past to influence adult feeding habits, but was negligible on the UNDERC property. Wind speed also was not a factor, most likely because it was relatively low and could be overcome by the flying ability of adult mosquitoes. Rainfall was surprisingly not correlated to the amount of mosquitoes captured, but peaks did seem to follow each other at approximately 15 day intervals. It would appear, then, that there is a 15 day development period for mosquito generations on the UNDERC property. Previous studies have found that at 30^{o}C development time can be as little as 7-10 days (Barr, 1958), but the temperature at the UNDERC station remained around 20^{o}C, leading to a longer development time.

While this study studied the effects of temperature on adult mosquitoes, one inherent flaw was the use of a light trap. Most mosquitoes respond to carbon dioxide and heat better than they do light, so a greater number of mosquitoes, and possibly a larger diversity of genera and species, would be caught if a trap could be used that also uses a form of carbon dioxide release such as dry ice. Also, no adults of Wyeomyia were captured in the light trap, mainly because there was no way to get the light trap close to a habitat with pitcher plants, such as a bog with sphagnum, since it was powered by an AC/DC outlet. A battery-powered trap would be much more useful and efficient in studying diversity and capturing tree-hole and bog species of mosquitoes. Another interesting study would be to examine adult capture numbers over the course of a night. It has been shown for some time, both scientifically and practically, that mosquitoes prefer to feed around dusk and dawn. However, as temperature and humidity changes over the course of the night, the adult population would also be expected to fluctuate. Wind speed also varied greatly over the course of the night, so an hourly trap count would better express adult mosquitoes' relationship and preferences concerning wind.

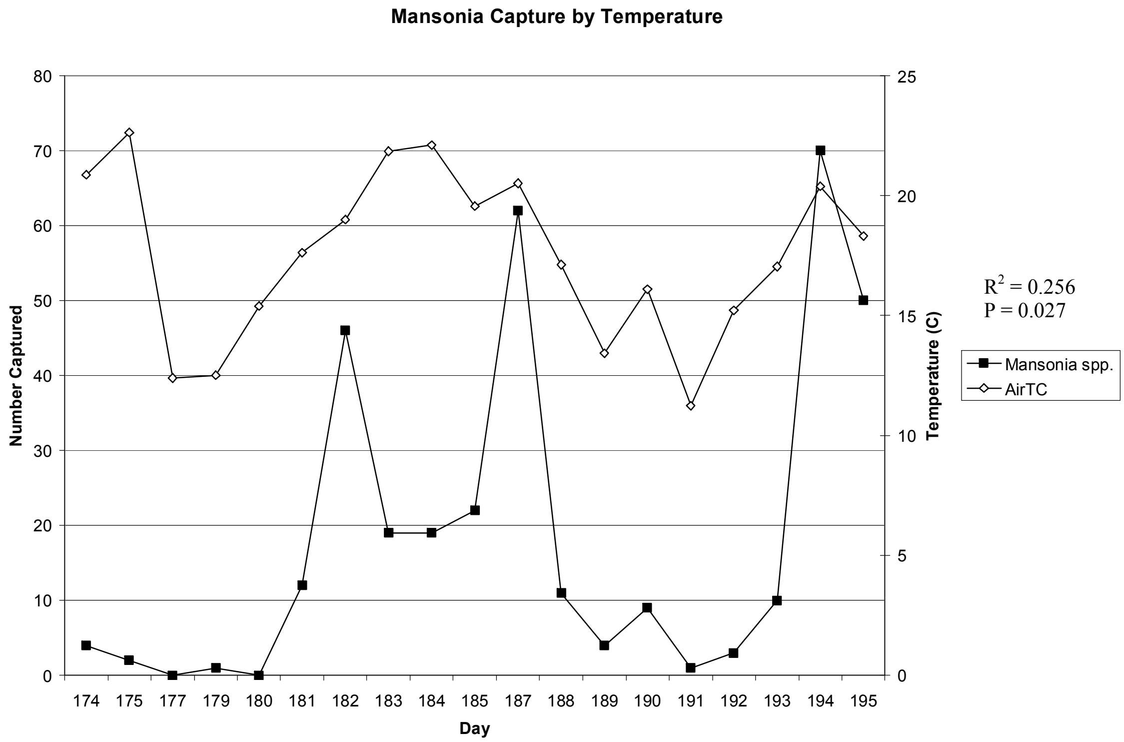
If a mosquito control program were to be devised for the UNDERC property, it would obviously need a highly integrated system of both immature and adult control, but it may be possible to concentrate the larval control efforts on highly vegetated sites and adult control on those nights where the average nightly temperature is above 20^{o}C and approximately 15 days since the last rainfall. It would be by no means easy, as there are a large amount of vegetated water sites throughout the property, but adult control may be feasible around human habitations on property on those nights ideal for feeding. More research is needed on the preferred feeding conditions throughout the night and any fluctuations in conditions which may influence hourly behavior, but with more and better trapping stations around property, perhaps an idea of the relative abundances and peaks of each area can be devised and compared, possibly leading to a more efficient strategy at controlling mosquito populations on property.

Fig. 1: Total number captured vs. average temperature



R^2= 0.557
P < 0.001

Fig. 2: Mansonia and Aedes numbers captured vs. temperature



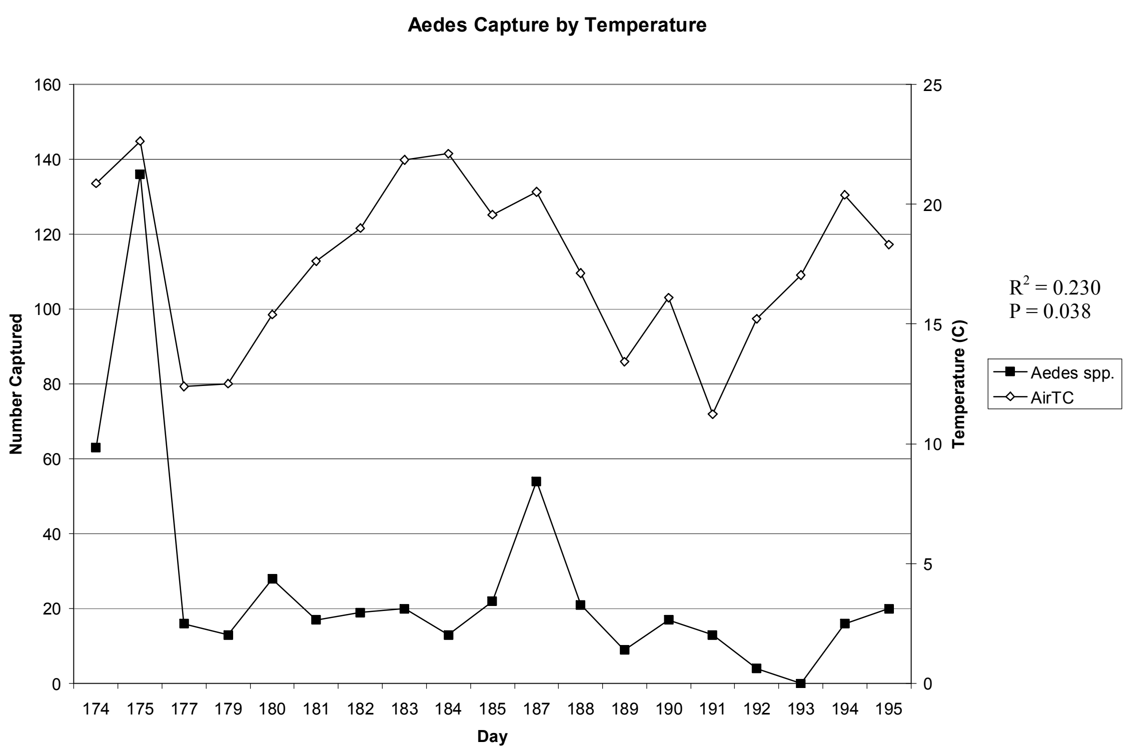
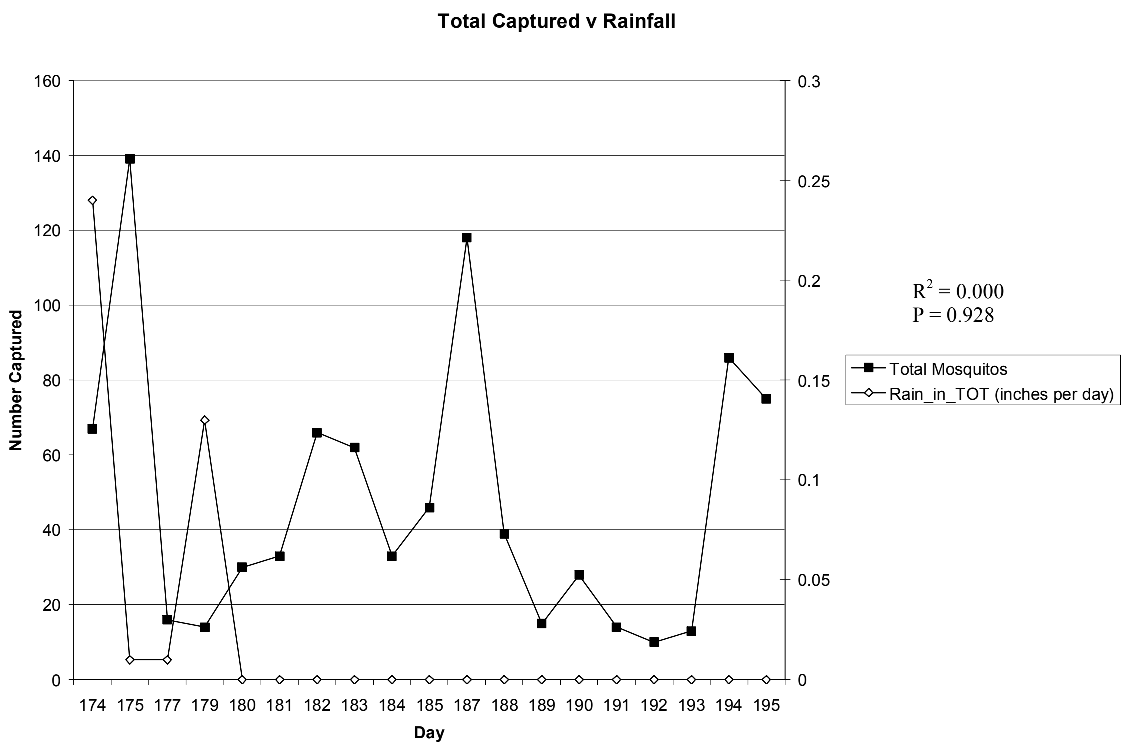
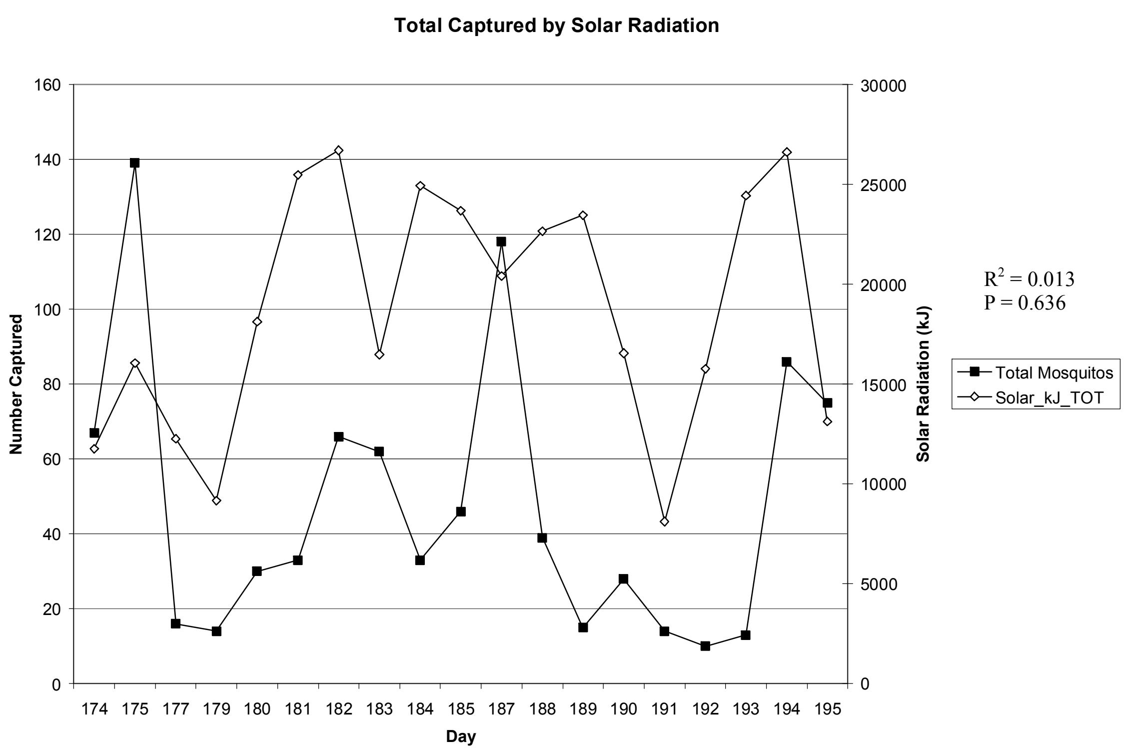


Fig. 3: Total number caught vs. daily rainfall and solar radiation

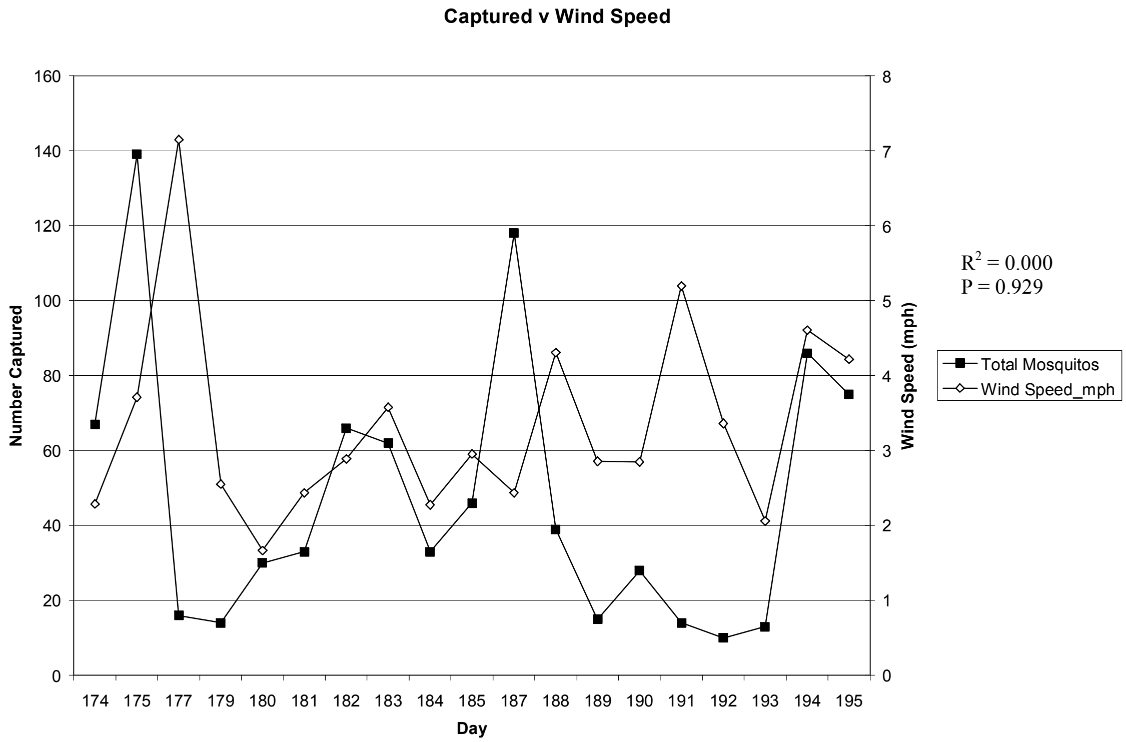


$R^2 = 0.000$
P = 0.928

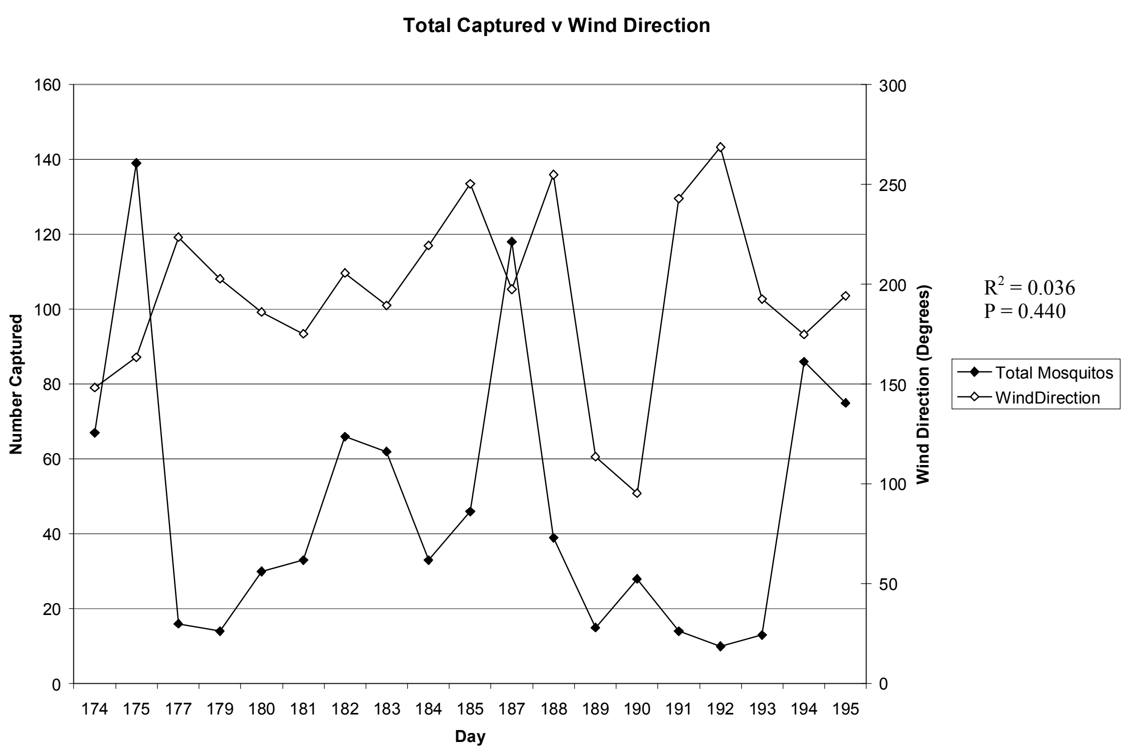


$R^2 = 0.013$
P = 0.636

Fig. 4: Total number captured vs. wind speed and direction

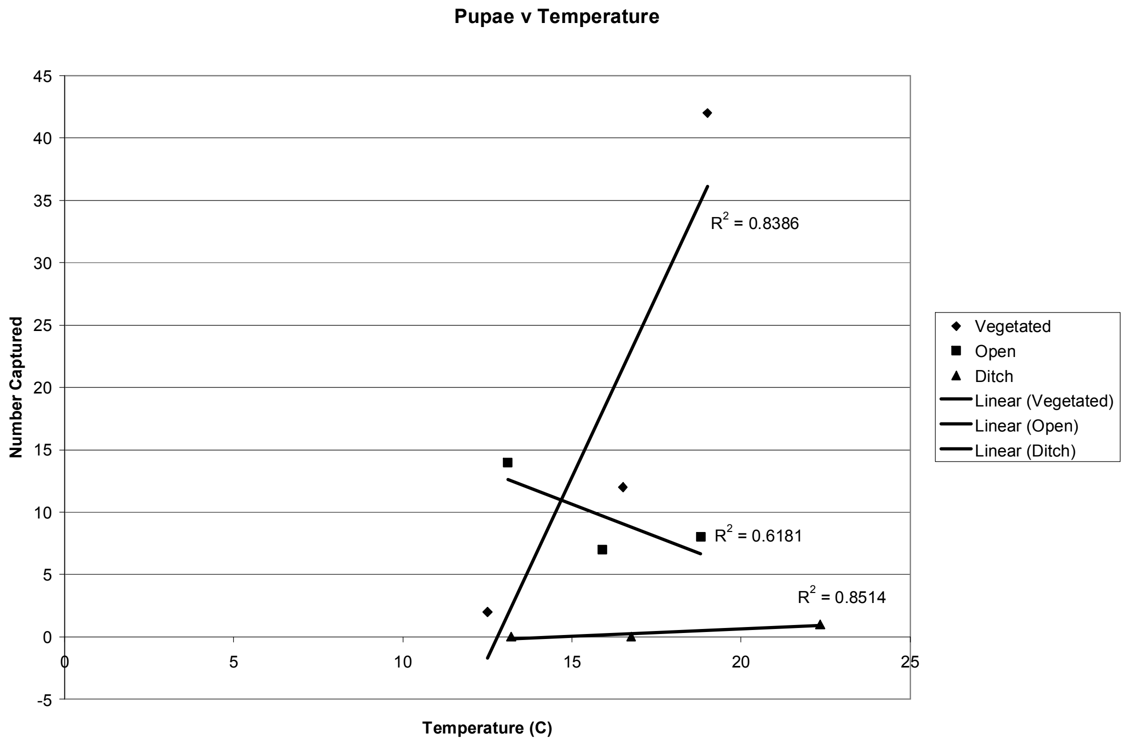


$R^2 = 0.000$
P = 0.929



$R^2 = 0.036$
P = 0.440

Fig. 5: Pupal and Larval Abundance with Temperature



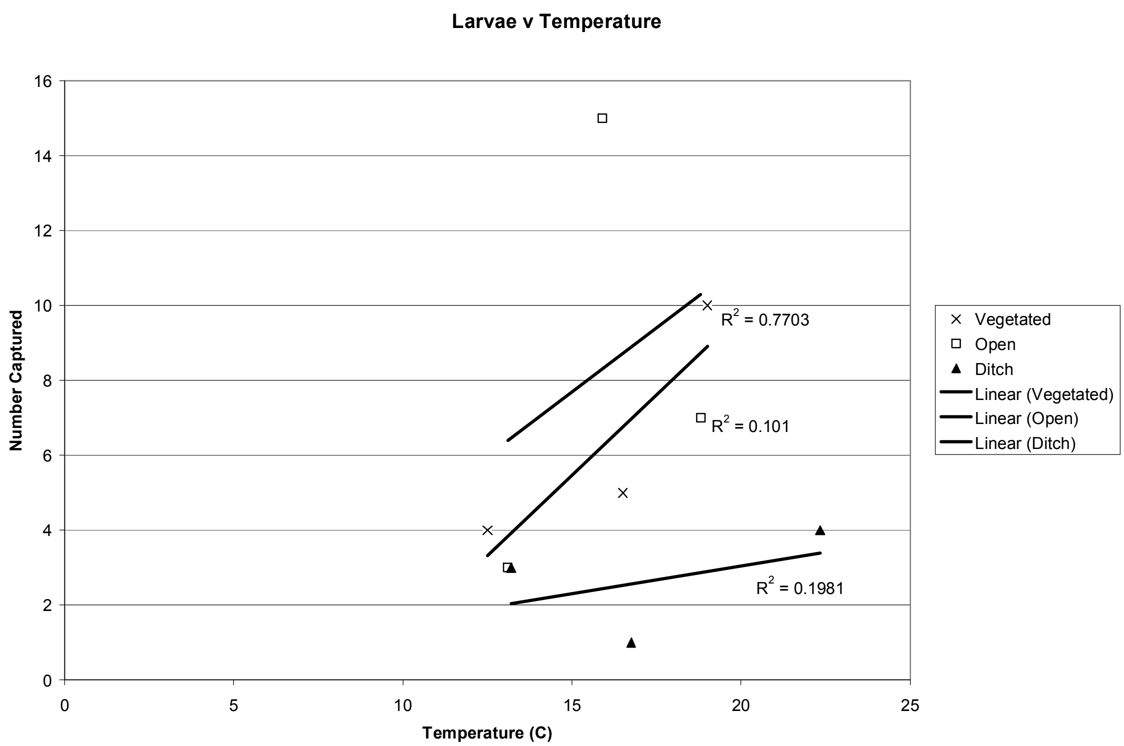
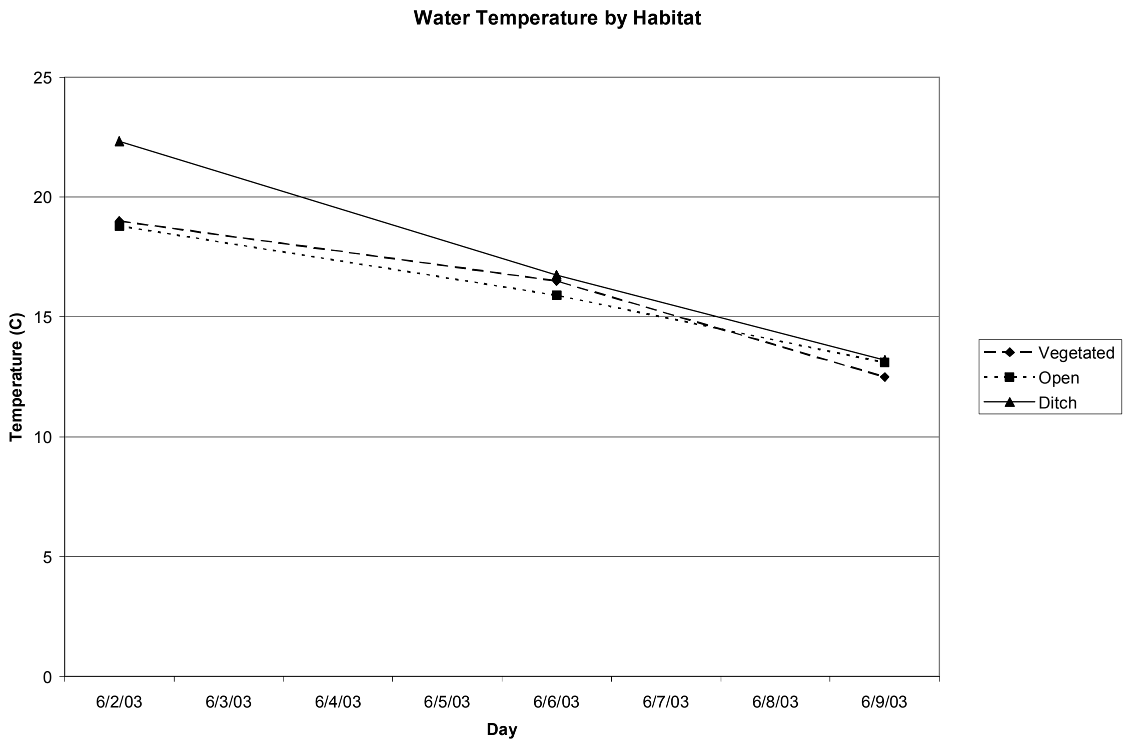
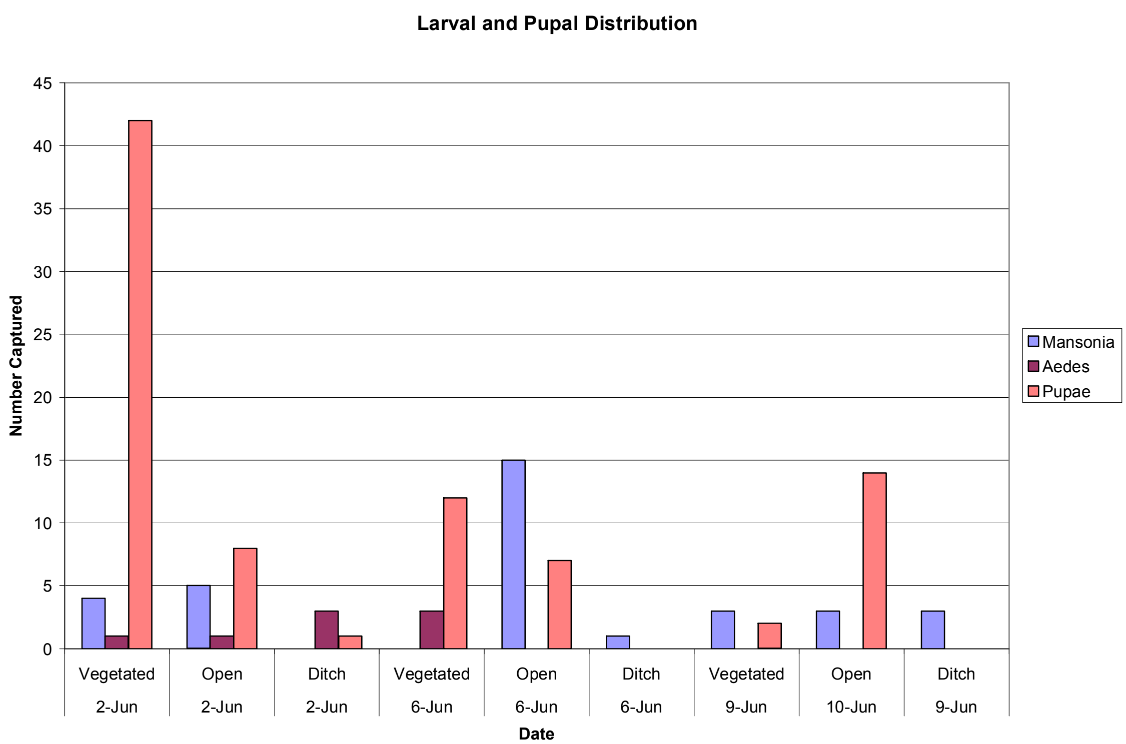


Fig. 6: Water temperature vs habitat and total numbers of pupae and larvae of two genera by site





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MR Ducks, MR Knot, SAR CM Whangs, LIB MR Ducks

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Abstract:

Mosquitoes are important vectors of disease and serve as annoyances throughout the summer months. These are due to their feeding and breeding habits, which are in turn affected by environmental influences. Chief among these factors is temperature, which significantly influences how many adult mosquitoes are actively looking for a blood meal. Temperature also affects the survival and abundance of immature mosquitoes in temporary water habitats. Mosquitoes prefer to breed in water dense with vegetation, and survival of immatures is also increased in a vegetated habitat. Adult mosquitoes, while responding to changes in temperature, are not significantly influenced by factors which control temperature, such as solar radiation, humidity, and wind. There seems to be a 15 day cycle for mosquito development on the UNDERC property, beginning from the day of last known rainfall. While mosquitoes serve as pests and annoyances on the UNDERC property, it may be possible to devise a control strategy for reducing the breeding mosquito population by targeting adults on those nights when they would be most active.