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Estimating Probability of Blow Fly Colonization in Eastern Washington: a Forensic Entomology Experiment

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By

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Abstract

Accurately estimating the time since a decedent was alive (postmortem interval/PMI) after the first 24 to 72 hours is dependent upon the ability of forensic entomologists to predict the colonization of remains by insects. Estimations of PMI must be modified for local conditions. This study examines the abiotic environmental factors (ambient temperature, relative humidity, light intensity, rainfall, barometric pressure, and wind speed) that influence the appearance of a specific subset of colonizing insects of forensic importance and known to show up first in other North American settings. These insects include blow and bottle flies, from the taxonomic family of *Calliphoridae*. The goal is to clarify the impact of abiotic environmental factors on predicting the probability of colonization by blow flies in Eastern Washington to more accurately estimate the postmortem interval (PMI). The hypothesis is that ambient temperature, light intensity, and relative humidity will be the most significant factors. About 1/3 to 1/2 of a pound of liver was placed in bowls protected by plastic cages at three locations that differ in terms of the type of vegetation. Logistic regression utilizing SPSS 25.0 (2017) generated equations of probability for blow fly colonization based on the significant abiotic environmental variables. Results show that ambient temperature, relative humidity, and light intensity are all significant predictor variables in blow fly colonization. In addition to studies establishing equations for the probability of blow fly colonization in other geographic regions, further studies are needed on the effects of wildfire smoke on blow fly colonization and activity.

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For my mama, Melodi Coulson (1953-2018)

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Chapter 1: Introduction

Forensic Anthropology: Definition and Scope

Forensic anthropology is an applied science in which human remains and osteological materials are analyzed to assist the medical examiners and coroners in the identification of remains by providing demographic profiles. These demographic profiles are then used by law enforcement officials when the remains of deceased individuals require investigation (Byers 2017).

The five main objectives of forensic anthropology are: (Byers 2017)

1. Determine ancestry, sex, age, and living height.
2. Identify the nature of trauma and causative agents.
3. Determine postmortem interval or the amount of time since an individual died.
4. Ensure the collection of all relevant evidence using archaeological methods.
5. Provide information useful in obtaining positive identification of deceased individuals.

Forensic anthropologists are often consulted in the identification of victims of mass disasters including airplane crashes, wars, terrorist attacks, acts of nature, or any other incident in which many people have died and the expertise of a forensic anthropologist is required for identification. Atrocities committed during warfare provide another area of study for forensic anthropologists. In additions to determining the circumstances surrounding the deaths of victims of political violence, the forensic anthropologist is often responsible for organizing and directing local authorities. Forensic anthropologists study persons of historical interest who have no forensic significance as well as participate in modern death investigations (Byers 2017).

Forensic Entomology

Forensic entomology, a sub-specialty of forensic anthropology, is the study of insects as they are related to the forensic investigation of death. Forensic entomologists use life cycle and succession rates (pattern of arrival at remains) of insects known to colonize human remains in order to estimate the postmortem interval (PMI) or time since death. Understanding the distribution, biology, and behavior of insects found on or near human remains provides information about when, where, and how a person died (Amendt et al. 2007).

Insects, particularly blow flies, are used to estimate time since death, the presence of toxic substances, antemortem trauma, and whether the remains have been moved. Identifying insects using precise morphological techniques provides invaluable information for forensic investigation (Bunchu et al. 2012).

Since the rate of development of blow flies is largely governed by temperature, a set process is undertaken to accurately identify insect species on remains, reconstruct the temperature where the remains were found, and model the rate of development of the most immature insects found on the remains (Amendt et al. 2011). These steps are crucial in the accurate estimation of the postmortem interval.

Historical Background

One of the earliest accounts of forensic entomology used in a murder investigation is detailed in Sung Tz'u's *The Washing Away of Wrongs* written in China in 1247 CE. Tz'u is known as the "founding father of forensic science" in China. While interrogating suspects in a murder investigation, he noted that flies were attracted to one farmer's sickle and determined that it was, in fact, the murder weapon (Benecke 2001; Sung 1981). Some of the first Western accounts of forensic entomology in death investigation took place in France. In 1831, Mathieu Joseph Bonaventure Orfila, a medical doctor and one of the founding fathers of toxicology, noted the importance of maggots in the decomposition process while observing mass exhumations in France and Germany (Bertomeu Sanchez 2004; Benecke 2001; Greenberg 1991). In 1855, Bergeret d'Arbois used insect succession to solve the murder of an infant (Benecke 2001; Ubelaker 1996). Forensic entomology and insects as evidence in death investigations are widely accepted in legal proceedings.

Chapter 2: Estimating the Postmortem Interval

Postmortem Interval: Definition

Postmortem interval (PMI) is the amount of time that has elapsed since death and is the main application of forensic entomology. It is used to limit the list of missing persons and to help facilitate positive identification through fingerprints, DNA, or dental records (Cockle and Bell 2015). Therefore, an accurate estimation of PMI is very important.

PMI can be estimated using one of several methods when death is fairly recent. These methods include livor mortis, which is the settling of blood in the body, algor mortis, the cooling body temperature after death, rigor mortis, changes in muscle stiffness, and changes in the fluid or vitreous humor of the eye (Byers 2017, 109). These methods become less accurate after 24-72 hours since death and once tissue begins to decompose the above methods may not be usable at all (Amendt et al. 2011). After 72 hours, the most accurate and usually the only method to estimate PMI is through forensic entomology (Anderson and VanLaerhovern 1996).

Postmortem interval is reported as a range that includes minimum and maximum postmortem interval. Minimum postmortem interval (PMI_{min}) is estimated by calculating the age of the oldest immature insect on the remains. Maximum postmortem interval (PMI_{max}) is calculated using the time the missing person was last seen alive until the discovery of the remains (Villet, Richards, and Midgley 2011). The accuracy of a postmortem interval estimate is dependent on how close the range of minimum and maximum postmortem interval reflect actual events, keeping in mind that those events (insect succession, colonization, life cycle stages, and when the decedent was last seen alive) may be simultaneous. The arrows (Figure 1) depict the possible range of the estimation of postmortem interval. The longer the postmortem interval, the less accurate the estimation of PMI becomes (Amendt et al. 2007).

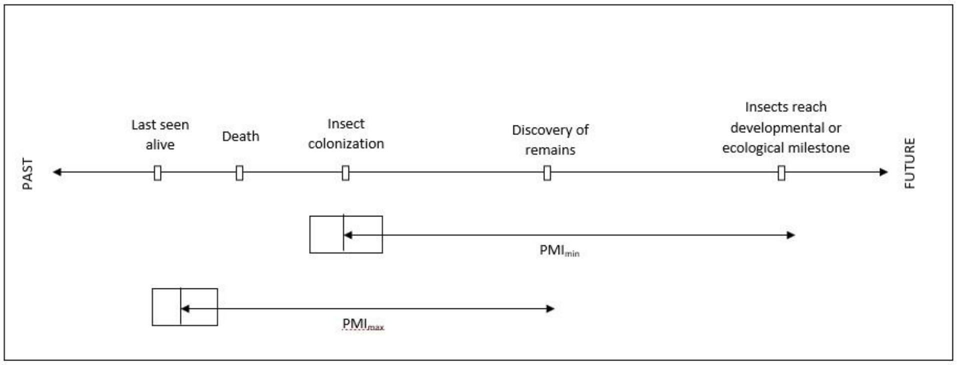

Figure 1. Timeline of events in a death investigation and indicating postmortem maximum and minimum intervals. Boxes are windows of prediction. Event placement is arbitrary and may be simultaneous. The accuracy of the estimate of PMI is reflected in how close the windows are to the actual events they estimate and the precision of the estimate is reflected by the width of the window (Villet, Richards, and Midgley 2011).

Geographic Variation

Estimates of postmortem interval must be modified for variability in local conditions and studies in various geographic regions help increase the accuracy of the estimate of postmortem interval. It cannot be assumed that data collected in one geographic region can be successfully applied to cases outside that region because the variables that contribute to the rate of decomposition may differ from one geographic region to another (Cockle and Bell 2015). Developmental data for local population-specific species is required for estimating larval age to determine the postmortem interval (Bunchu et al. 2012; Amendt et al. 2011). This allows investigators to put better limits around the time from death to colonization activities instead of assuming colonization is simultaneous to death.

Errors in Estimating the Postmortem Interval

A major source of error in the estimation of the postmortem interval is that there is little information about how long it takes for insects to initially colonize the decedent. This can make it very difficult to estimate PMI accurately since PMI must be adjusted for the time it takes for insects to find the remains. Adjusting for the time it takes insects to find the remains allows investigators to put better limits around the time of colonization instead of assuming it happens simultaneously to death, improving the accuracy of the estimation of minimum postmortem interval.

Another error is the failure to search extensively enough on and around the remains to locate the most immature insects. Post-feeding larvae leave the remains before entering the pupal stage. Thus, the area surrounding the remains must be carefully searched. Dispersal patterns may vary by location, ecology, and insect species (Anderson 2011). Pupae can also be mistaken for mouse droppings and disregarded.

Accumulated Degree Days (ADD)

Another way scientists use forensic entomology to estimate the postmortem interval is to measure the accumulated degree days (ADD) needed to reach the stage of development of the insects found on the remains. ADDs are the heat energy units available for biological processes like larval growth (Megyesi, Nawrocki, and Haskell 2005). Weather data is collected on-site or from the closest National Weather Service (NWS) station. Minimum and maximum daily temperatures are averaged to calculate the ADD. A prediction of insect development is made based on known relationships between a constant temperature (minimum development temperature) and insect development which is called the development threshold temperature (DTT) (Ames and Turner 2003). Direct threshold temperatures are established through studies and vary by fly species as well as geographic region.

Estimations of postmortem interval (PMI) using this method can be misleading when there are prolonged periods of cold weather or mechanical application of cold such as placing the remains in a freezer or in an air-conditioned building. In addition, maggot masses create heat (thermogenesis) and this increase in temperature on the remains accelerates development (Johnson, Wallman, and Archer 2012; Anderson and Warren 2011).

Errors in Estimating Accumulated Degree Days

The greatest source of error when using ADD to estimate the postmortem interval is an error in temperature from inaccurate data collection. This can occur when the local environment is strongly dissimilar from the location where the National Weather Service collects its data or when a local collection of data is done incorrectly (Scala and Wallace 2010; Shean, Messinger, and Papworth 1993). Johnson, Wallman, and Archer (2012) suggest that geographical separation of the weather station from which data is collected and the body discovery site necessitates ambient temperature correction and that more frequent measurements of temperature may provide greater accuracy in correlation and the description of 24-hour variations in ambient temperature. Vass (2011) recommends that approximately 4-5 days of weather data taken at the body discovery site and compared to the nearest National Weather Service data is enough to arrive at a correction factor that can be applied to temperature and humidity data. Dabbs (2015) on the other hand, disagrees and says that there should be no attempt to correct retrospectively collected National Weather Service data and instead standard error should be reported to accommodate generally small degrees of imprecision.

Chapter 3: Early Postmortem Events

Autolysis and Putrefaction (Decomposition)

The death of a human or non-human animal is the beginning of a cycle in which organisms and natural forces begin to break down or destroy the organic tissue that makes up the living body (Byers 2017). The first of these processes is autolysis and putrefaction. Autolysis is the degeneration of body tissues by the digestive fluids of the intestinal tract. No longer under the control of the once live organism, the digestive fluids begin to digest the body in the same way in which they would food, therefore destroying the internal organs (Byers 2017).

Putrefaction happens when microorganisms within the body tissues begin to reproduce, proliferating, and breaking down biological components within the body. As in the case of digestive fluids, they are no longer regulated by the body and the bacteria eat muscle, internal organs, and tissue. This bacterial action causes gas buildup and bloats the body cavity (Byers 2017). Bloating opens the remains allowing insect activity to begin internally. Although these stages are well defined (Table 1), which stage of decomposition the remains are in is relatively subjective and there is no clear demarcation between the stages as they blend together (Archer 2003; Vass 2011).

Stage	Days	Description
Fresh	0 to 1	No odor, algor mortis (cooling/internal temperature drops)
Bloat	2 to 10	Gasses accumulate, abdomen bloats, strong odor, mottling of the skin, the stage ends when body deflates
Active	11 to 16	Wet decomposition, strong smell, reduced to less than 50% of original weight
Advanced	17 to 42	Flesh removed, less odor
Dry/Remains	43+	Bones, cartilage, and skin with little to no flesh

Table 1. Stages of Decomposition (adapted from Anderson and VanLaerhoven 1996).

Variables Affecting Decomposition

Decomposition is affected by many variables. Insects, including flies, begin feeding on the remains within minutes of death (Lopes de Carvalho and Linhares 2001). As they feed, they deposit eggs (oviposition) in and around orifices, which begins the cycle of arthropod activity. Larger animals are also attracted to the remains as they decompose. Carnivores such as dogs and coyotes eat the soft tissues of the body and disarticulate the skeleton which can result in the loss of skeletal elements (Ubelaker 1996). Roots can also separate skeletal elements. Mold may grow on the skin and break down tissues and cells. As autolysis occurs, substances released from the remains often act as fertilizer which can encourage the growth of abiotic material accelerating the decomposition process further (Byers 2017).

Other variables that may affect decomposition are soil acids, climatic factors, and other forces that might destroy the organic remains. Soil acids contained in groundwater accelerate the deterioration of soft and hard tissues. Groundwater may also cause mineralization of hard tissues, especially bone. Fire, sunlight, and wind may also break down bone. The accumulation of sediment on top of remains can destroy bone (Ubelaker 1996).

Climatic conditions and exposure to the elements as well as to insect and animal scavengers are important variables that may accelerate or decelerate the decomposition rate (; Campobasso, Di Vella, and Introna 2001; Lopes de Carvalho and Linhares 2001; Mann, Bass, and Meadows 1990). Temperature greatly affects plant and animal activity, particularly insect activity and succession as they are largely dependent on temperature (Archer 2003). Remains in an outdoor location are subject to increased insect activity which speeds decomposition. Exposure to scavenging, or accessibility to the remains by scavengers, accelerates the decompositional process (Mann, Bass, and Meadows 1990).

Remains left outside typically decompose faster than those in an enclosed location because of accessibility for scavengers and insects (Anderson 2011). Remains closer to the surface and exposed to scavengers and insect activity deteriorated faster than those buried well below the ground. This is due to a decrease or absence of insect activity and the cooler temperatures below ground (Rodriguez and Bass 1985). Early stages of decomposition and blow fly activity occur similarly for remains exposed to the sun and those placed in the shade but shaded remains show slower rates of decay in later stages compared to those in the sun (Castro et al. 2011).

Rainfall has little direct effect on decomposition although fly activity may stop during heavy rainfall. Rainfall and submersion in water may speed decomposition through leaching of fluids and tissue and provide moisture for bacteria and insects (Archer 2004). Neither size nor the weight of the remains has much effect on the decomposition rate since bodies begin to liquefy quickly after death. Therefore, infants and children do not decompose at a faster rate than adults (Mann, Bass, and Meadows 1990).

Archer (2004) found that much of the influence on the decay of neonatal remains was exerted indirectly through the effect of fly larvae feeding on the remains. This feeding drives decomposition and contributes to a loss of mass in the remains since large masses of maggots digest outside of their mouths, secreting enzymes directly onto the flesh. This extraoral digestion along with the mechanical action of the ingestion of flesh can rapidly accelerate the decomposition process.

Chapter 4: Blow Fly Biology & Carrion Ecology

Insects of Forensic Importance

Blow flies (Family: *Calliphoridae*) are often one of the first insects to arrive at remains and consume most of the tissues. At the family level blow flies have similar patterns of succession in different regions (Rochefort et al. 2015; Baque and Amendt 2012; Bunchu et al. 2012; Amendt et al. 2011; Ubelaker 1996; Shean, Messinger, and Papworth 1993). The life cycle and succession pattern of these insects is of great use to forensic entomologists since blow fly larva develops at predictable rates and this time interval can be used to estimate the postmortem interval (Anderson and Warren 2011).

Diptera (flies) are the most common insects found on decomposing remains. There are over 17,000 species from 107 families of Diptera in North America (Ubelaker 1996). Blow flies, also known as bluebottles, clusterflies and greenbottles (Retrieved September 10, 2018, from the Integrated Taxonomic Information System (ITIS) http://www.itis.gov) are the most utilized fly family in death investigations because they are among the first insects to arrive after death. There are over 1,000 species and 150 genera of blow fly worldwide with 5 subfamilies, 17 genera, and 92 species in the Nearctic, the region that is comprised of North America, northern Mexico and Greenland (Whitworth 2017).

Blow Fly Life Cycle

Adult blow flies range from 6 to 14 mm long, depending on species and the availability of food during the larval phase (Byrd and Castner 2010). Eggs are laid in batches or masses of more than 200 eggs. Female flies prefer to deposit their eggs in natural openings (mouth, nose, anus), wounds, and crevices as well as the hairy areas of the body with high moisture and a lower intensity of light (Lopes de Carvalho and Linhares 2001). This protects the eggs from predation by other insects, birds, and mammals and helps retain moisture which is necessary for development.

Blow fly eggs are about 1.5mm long. Eggs hatch approximately 18-21 hours after they are laid depending on temperature. Blow flies are poikilotherms and rely on ambient temperature for metabolic and physiological activity (George, Archer, and Toop 2013b; Ames and Turner 2003; Beck 1983). The optimal temperature for egg laying and hatching is about 70ºF (Mann, Bass, and Meadows 1990). The temperature range for egg laying is between 53.6 ºF and 86 ºF (Erzinclioglu 1996). Temperature ranges vary from species to species and in different geographic regions, which is why it is important to create databases of insect behavior relevant to each species and location.

Female blow flies lay several batches of eggs in a lifetime which lasts 1 to 3 weeks (Ubelaker 1996, 425). Eggs hatch into larva (maggots). A generalized blow fly life cycle is shown in Figure 2. Larvae are white or yellow in color and 10-45 mm long. The larvae take 3-4 days to fully develop through 3 instars or stages. These stages are dependent upon temperature like egg laying and hatching. There is a linear relationship between temperature and development time. An increase in temperature decreases the time needed to develop whereas a decrease in temperature increases the time needed to develop (Cervantes et al. 2018; Gallagher, Sandhu, and Kinsey 2010).

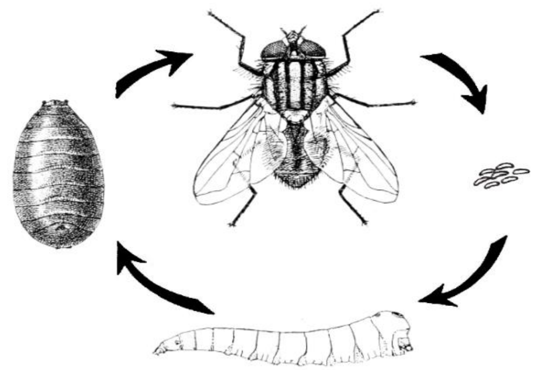

Figure 2. Generalized blow fly life cycle (adult, eggs, larva, and pupa) (https://commons.wikimedia.org/wiki/File:Musca_domestica_-_life_cycle.png)

Larvae feed and then move away from the remains to continue development in the next developmental stage called the pupal stage. This stage is like the cocoon (chrysalis) stage in butterflies and moths. Pupae are light brown, red, or black. They are 9-10 mm long. After several days, dependent on temperature, an adult fly emerges. Within 2-3 days of emerging from the pupal stage, female flies are capable of reproduction. The total life cycle of a blow fly is approximately 17 to 28 days including the larval and pupal stages (Anderson 2000; O'Flynn 1983).

While temperature is very important in the life cycle of calliphorids, there are quite a few other variables that can affect colonization other than climatic ones, but climatic factors and light intensity can so strongly influence fly activity as to prevent it completely. Without the proper temperature, egg laying will not occur. Climate change may exacerbate this effect since fly species adapt to the climatic conditions in their environment and this may alter their development (Gallagher, Sandhu, and Kinsey 2010). Other variables such as location, clothing, the presence of drugs in the body etc. are subtle modifiers of colonization activity whereas temperature is a predictor variable (George et al. 2013b).

Pre-appearance Interval (PAI)

Insect activity on remains can begin within days or even minutes of death. The pre-appearance interval (PAI), the time between death and when insects show up at remains, is strongly dependent on temperature. PAI decreases exponentially with increases in temperature for many blow fly species (Matuszewski and Madra 2015, 2016; Matuszewski, Szaflowicz, and Grzywacz 2014).

Other variables that affect when insect activity include temperature, the location of the remains (i.e. sun, shade, inside or outside and submersion in water), clothing, whether the remains are buried, and possible drugs ingested by the decedent (Merritt and De Jong 2016; Showman and Connelly 2011; Anderson 2010; Ubelaker 1996).

Insect Succession

Succession, the waves or patterns in which insects colonize remains, is essentially the arrival and departure times of insects of forensic importance. The timing of insect succession can be affected by temperature, geographic region, the burning of the remains, burial, variations in habitat, exposure to sun, and the placement of the remains (Archer 2003, 2014; Voss, Spafford, and Dadour 2009; Shalaby et al. 2000; VanLaerhoven and Anderson 1999; Avila and Goff 1998; Shean et al 1993; Payne 1965). Insect succession proceeds at a relatively predictable rate and once this rate has been established it is useful in estimating the minimum postmortem interval (Archer 2014). Even with differences in patterns between season, location, and years insect succession is still predictable since those differences closely mirror patterns in temperature (Matuszewski, Bajerlein, and Szpila 2011).

Successive species of colonizing insects rely on blow flies to make the remains habitable for their colonization (Brundage, Benbow, and Tomberlin 2014; Avila and Goff 1986). For blow flies, arriving first means they can oviposit quickly, and the offspring begin development before other species arrive, ensuring their survival. Secondary colonizers are often predators of early colonizers (Brundage, Benbow, and Tomberlin 2014).

Seasonal Constraints

Changes in seasons (fall, winter, spring, summer) or from wet to dry in tropical regions influences all aspects of insect activity including life cycles, succession, and colonization. Most blow fly activity occurs during the warmer months of fall, spring, and summer with little to none occurring during winter months (Merritt and de Jong 2016).

Season may have more effect on colonization than time since death. Blow flies have peaks of activity and abundance that vary from season to season and differ by geographic region (Azevedo and Kruger 2013; Archer and Elgar 2003; Archer 2003; Lopes de Carvalho and Linhares 2001; De Souza and Linhares 1997; Tomberlin and Adler 1998; Davies 1999). In addition to variation from season to season and geographic region, inter-year variation due to variation in temperature patterns must be accounted for (Archer 2002). With information on the seasonality of insect, activity, an estimated season of death can be made, even when an accurate time of death cannot be determined (Anderson, 2010; Archer and Elgar 2003).

Changes in global and regional temperature will impact and alter blow fly populations as they are quick to respond to climate change (Azevedo and Kruger 2013). This makes it more difficult to establish succession patterns for any length of time. Anthropomorphic factors, habitat, and human management of insects play an important role in the diversity and abundance of the insect population (Odat et al. 2015). Anthropomorphic factors contribute to changes in insect populations and affect succession, particularly in urban and agricultural settings

Geographic Constraints

The biogeographic distribution of insects must be considered when conducting studies involving insect succession (Castro et al. 2011). Some insect species might be limited to certain regions whereas others might be more widespread. Succession studies conducted in similar climates that are within proximity to each other might find that there are significant differences in the insects present which indicates an aggregation effect. Insect species that feed on remains are invasive species and continually expand their range (Merritt and De Jong 2016). Climate change exacerbates this effect.

Ecological Constraints

The insect species found in a location or space reflect preferences in ecological habitat. Some insect species prefer to colonize remains in the sun rather than shade or on the surface rather than buried, outdoors versus indoors. or even an urban versus rural. The size of the remains influences the species of insects attracted to it with certain species being attracted to larger remains and others to smaller remains (Merritt and De Jong 2016).

Population Parameters

Population parameters of insects that colonize remains are annually variable (Archer 2003). This may affect when insects arrive and leave remains (succession). These parameters cycle due to factors such as disease, predation pressure, competition, and climate variation (Archer 2003).

Oviposition

Insects are attracted to remains almost immediately after death. Blow flies are among the first to colonize and deposit eggs (oviposition) on remains and can come from a great distance in response to the presence of ammonia-rich compounds, moisture, pheromones, and tactile stimuli (Anderson 2010). Blow flies can move up to 12 miles in a day, less in urban environments and more in open rural areas (Greenberg 1990).

Blow flies and other invertebrate scavengers are attracted to carrion by volatile organic compounds (VOCs) which are released from the remains and from the insects that feed on them during decomposition. Some of the chemicals that make up VOCs are hydrocarbons, oxygen-containing compound (esters, ethers, aldehydes, and ketones), nitrogenous compounds (cadaverine and putrescine), and sulfur-containing compounds (dimethyl disulfide) (Cammack et al. 2016). These chemicals aid blow flies in finding remains by olfaction and assist female flies in determining if the remains are a good place to lay eggs.

Blow flies determine the location of remains in a two-step process that involves chemical detection via receptors located on the antenna (olfaction) and a visual search (Byrd and Castner 2010). The olfactory-driven search is used until the fly is near the remains and then a switch is made to a visual search. The remains are visually assessed for size, the location of orifices, and trauma. Flies walk over the surface of the remains to aid in the visual survey of the remains and to taste the remains with receptors located on the fly's body, legs, and feet (Byrd and Castner 2010).

The apparent attractiveness of the remains increases as more eggs are laid in one area in what could be an evolutionary strategy to minimize the predation of eggs as well as to prevent desiccation of the eggs. A large egg mass results in many maggots which increases an individual maggot's chance of survival (Greenberg 1991). Mass egg-laying behavior in response to pheromones was observed in an Australian fly species by Anderson (2010).

As remains decompose, the associated odor changes becoming more (or less attractive) to certain species of colonizing insects and influencing insect succession. Blow flies that arrive while the remains are fresh are not attracted to heavily decomposed, dried, or mummified remains (Anderson 2010). The size of the remains has some effect on its attractiveness and can be species dependent (Merritt and De Jong 2016, 68).

Blow flies are diurnal, that is active during daylight hours and resting at night. Therefore, they do not typically colonize or lay eggs on remains in natural darkness (Soares and Vasconcelos 2016; Barnes Grace, and Bulling 2015; George, Archer, and Toop 2013b; Zurawski et al. 2009; Amendt, Zehner, and Reckel 2008; Baldridge, Wallace, and Kirkpatrick 2006; Grassberger and Frank 2004). In low light levels, some species of flies may walk to the remains if nearby (Smith et al. 2016). Remains placed at night may not attract colonizing insects until daylight, affecting the estimation of the postmortem interval. Blow flies will, however, lay eggs in dark locations such as basements or under tarps during the day indicating that it may not be the lack of light that inhibits colonization but rather the fly's circadian rhythm itself that inhibits it (Amendt, Zehner, and Reckel 2008). Since oviposition is greatly influenced by temperature, nocturnal temperatures may be too low for egg-laying (Anderson 2010). Temperatures at night vary by region and thus may affect the nocturnal oviposition behaviors of local species. For this reason, geographic region-specific research is vital to the most accurate estimation of PMI.

While insects are attracted to remains almost immediately after death, they do not always lay eggs as soon as they find the corpse. Delay in colonization may be caused by factors such as wrapping, concealment, or the burial of the remains which prevent insects from accessing the remains. Remains located inside a building or in a car may also cause a delay in colonization behavior. These factors inhibit decomposition and its odor dispersion that attracts insects to the remains in the first place (Charabidze, Hedouin, and Gosset 2015).

Period of Insect Activity (PIA)

An important strategy for estimating postmortem interval (PMI) beyond the first 24 hours is to recover insects from on or around the decedent. Insect life cycles and the order in which they colonize remains (succession) are used to construct an estimation of how long the remains have been exposed to insect activity. This is often referred to as the period of insect activity (PIA) (Tabor Kreitlow 2010).

Chapter 5: Methods

Research Model and Background

My research experiment is modeled after the study on colonization and abiotic environmental factors by George, Archer, and Toop (2013a). These authors qualified the importance of various meteorological and light-level factors in the initial colonization process of blow flies in Victoria, Australia. Their intent was to determine if the interval between death and insect colonization can be predicted based on climatic conditions to more accurately estimate the postmortem interval for use in forensic death investigations. My experiment studies the same abiotic environmental variables using Eastern Washington as the geographic location with the goal of clarifying the impact of those variables on predicting the probability of colonization by blow flies to more accurately estimate the postmortem interval (PMI).

Using liver as bait to observe evidence of colonization (oviposition), George, Archer, and Toop (2013a) measured the effect of barometric pressure, light intensity, wind speed, ambient temperature, relative humidity, and rainfall for a period of 88 randomly selected days during all seasons, over a three-year period. Analyzing the data using backward stepwise logistical regression, they produced an equation of colonization probability. Results of their study indicated that oviposition or egg laying is most sensitive to ambient temperature and relative humidity (George, Archer, and Toop, 2013a).

Ultimately, George, Archer, and Toop (2013a) determined that due to the abundance of possible variables (clothing, drugs, burial methods, etc.) use of minimum and maximum ranges for the environmental conditions, in addition to accounting for other factors both abiotic and biotic, is a more accurate way to estimate PMI. Relying on statistically generated probability equations alone does not consider abiotic and biotic variables. Minimum and maximum climatic conditions should be a starting point for determining colonization since climatic conditions can entirely prevent colonization whereas variables such as clothing or drugs may delay colonization but not prevent it completely.

Similar studies, compared in Table 2, have been undertaken in England (Barnes, Grace, and Bulling, 2015), Michigan (Zurawski et al. 2009) and Texas (Mohr and Tomberlin 2014) with corresponding results.

Name (Date)	***Location***	***Bait***	***Purpose***	***Results***
Barnes et al. (2015)	*England UK*	*Liver*	*Predict colonization/ rule out nocturnal oviposition*	*No nocturnal oviposition, temperature significant*
Mohr & Tomberlin (2014)	*TX USA*	*Pigs*	*Effect of Abiotic variables on population size*	*No nocturnal oviposition, temperature significant*
Zurawski et al. (2009)	*MI USA*	*Liver*	*Predict colonization/ rule out nocturnal oviposition*	*No nocturnal oviposition, temperature significant*
George et al. (2013)	*Victoria AUS*	*Liver*	*Probability of Colonization*	*Temperature, light, and humidity significant*

Table 2. Relevant studies from the literature on blow fly colonization. Temperature is a significant predictor variable in these studies.

Experiment Location and Vegetation

The data collection portion of my experiment was conducted at an investigation site on approximately 4.3 acres of private wooded land in the unincorporated town of Clayton, Washington in Stevens County, in Eastern Washington (47º 59’ 4” N, 117º 33’ 30” W).

Trees and grasses found at the research site include mountain ash, maple, horse chestnut, quaking aspen, western larch, white and con-color fir, ponderosa pine, river willow, European pea, blue spruce, box elder, honey locust, plum, apple, lilac, Kentucky bluegrass, clover, alfalfa, Canadian thistle, knapweed, and rapeseed. Data collection sites within the larger experiment site were in tall trees, short trees, and grass (no trees) (Figures 3a, 3b, and 3c) as per the modeled experiment (George, Archer, and Toop 2013a). The urban location in the modeled study was eliminated from my study for simplicity. Grassberger and Frank (2004) found that there was no significant delay in colonization in urban habitats. Data collection sites were placed at least 30 feet apart to ensure the independence of insect succession patterns (Perez, Haskell, and Wells 2016).

Figure 3a. Grass data collection site: summer 2017.

(Photo by author)

Figure 3b. Short tree data collection site: summer 2017.

(Photo by author)

Figure 3c. Tall tree data collection site: spring 2017.

(Photo by author)

Colonization Medium

Bait (Figure 4), consisting of whole pieces of beef, deer or elk liver (1/3 to 1/2 of a pound) donated by local hunters or purchased from a butcher, was placed in the three locations at the investigation site to replicate the short trees, tall trees and grass (without trees) of George, Archer, and Toop (2013). Liver is an effective bait as it has been shown to be attractive to a range of blow fly species (Perez, Haskell, and Wells 2016; George, Archer, and Toop 2013a, 2013b; Berg and Benbow 2013; Aak, Knudson, and, Soleng 2010; Anderson 2000).

Davies 1990).

The fresh liver was placed in white plastic bowls (8.25" in diameter, 2.5" deep) with damp paper toweling covering half the colonization medium to inhibit desiccation. Two to three holes were drilled in the bottom of the bowls to facilitate drainage. The bowls were placed on top of a Bundt baking pan (12 cup capacity) which was filled halfway with water to deter ants. The bowls were then covered with plastic cages (laundry baskets) which were weighted down to prevent vertebrate scavengers from compromising the experiment.

Figure 4. Colonization medium (liver) in a plastic bowl with damp paper toweling. (Photo by author)

This experiment was conducted over 41 randomly selected days/weeks beginning in September 2016 and ending in October 2017. Bait was placed between the hours of 09:00 and 16:00. It was left in place for 7-8 hours each experiment day. The bait was checked every 60-90 minutes for evidence of colonization. No experiment days occurred beginning in October 2016 through March 2017 due to freezing temperatures, snow on the ground, and the absence of flies.

Evidence of colonization for this experiment and the modeled experiment is the deposition of eggs (oviposition) by blow flies on the surface of the bait (Figure 5). When colonization was present an attempt was made to identify species based on the flies observed and known for habitation in the region. Bait was replaced with fresh bait when colonized or after 3 hours with no colonization as per the modeled study to observe current colonization. Photos were taken at each bait check to document the conditions of the bait, the presence or absence of colonization and to allow possible identification of species observed.

Figure 5. Evidence of blow fly colonization (egg masses) on colonization medium. (Photo by author)

Environmental Parameters

Parameters measured were ambient temperature (Fahrenheit), relative humidity (%), rainfall (mm), maximum wind speed (mph), light intensity (Lux), and barometric pressure (hPa). Weather data, except for wind speed and barometric pressure, was gathered locally at each data collection site using a Springfield vertical thermometer and hygrometer (Taylor Precision Products Model #TAP90116), a 150 mm rain gauge (ZEAST), and a battery-powered, handheld digital light meter (Dr. Meter Model LX13308).

Wind speed and barometric pressure were retrieved from the Weather Underground app (Weather Underground, version 5.9.4) using an Android smartphone. Weather data for this app is collected at a private weather observation station located at Denison Ridge (48º 0’ 51”, 117º 32’ 32” W) about 1.73 miles north of the experiment site. While the weather observation site is at a slightly higher elevation (167ft.) than the data collection site, it has a similar southwest exposure and the difference in wind speed is most likely minimal. Barnes, Grace and Bulling (2015) used wind speed data collected from a site 10 miles from their experiment site in their study in the United Kingdom.

Chapter 6: Climatic Conditions and Light Intensity

Ambient temperature

Ambient temperatures measured (Table 3) for the experiment ranged between 36ºF and 104ºF (mean=74.73ºF). Temperature ranges for each individual data collection site are as follows: grass 45ºF and 104ºF (mean=77.44ºF), short tree 43ºF and 91ºF (mean=73.82 ºF), and tall tree 24ºF and 99ºF (mean=72.86ºF). Temperature frequencies are shown in Figure 6.

Statistics

		COL	TEMP
N	Valid	600	600
	Missing	0	0
Mean		.34	74.73
Std. Error of Mean		.019	.427
Median		.00	75.00
Minimum		0	36
Maximum		1	104

Table 3. Descriptive stats for colonization and temperature for the experiment site. SPSS 25.0 (IBM Corp. 2017)

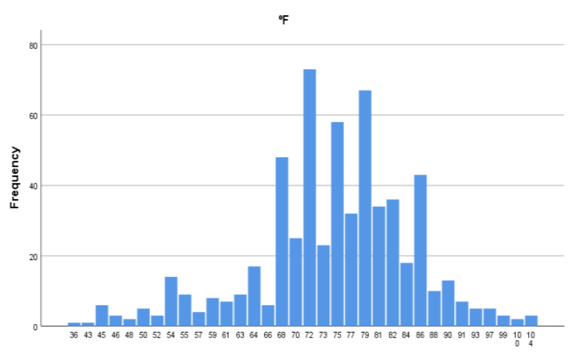

Figure 6. Graph of temperature frequencies for the experiment site. SPSS 25.0 (IBM Corp. 2017)

Moisture Content: Relative Humidity and Rainfall

Relative humidities between 2% and 100% (mean=47.79%) were measured at the data collection site. The range of humidity at each individual data collection site are as follows: grass 45%-90% (mean=46.73%), short tree 8%-100% (mean=47.97%), and tall tree 5%-100% (mean=48.80%). Relative humidity frequencies are shown in Figure 7. Colonization was observed over a wide range of humidities.

Rain fell on 3 of the total 41 experiment days (Figure 8). Colonization occurred on one of those days when rainfall was light (0.508 mm), and rain only fell for part of the day, temperatures reached 70ºF. The temperature did not reach 70ºF on the two other days with rainfall; no colonization occurred on these days. This is consistent with colonization occurring more frequently at temperatures above 70ºF. Rainfall was not recorded for individual data collection sites since it was measured using a remote weather station. The highest level of rainfall was 1.778 mm (Table 4). Minimal colonization occurred during periods of active rainfall and there was a marked decrease in insect activity. Temperatures on rainfall days ranged from 43ºF to 70ºF. Graphs of rainfall and relative humidity frequencies are shown in Figure 7 and Figure 8.

Statistics

		COL	HUM	RAIN
N	Valid	600	600	600
	Missing	0	0	0
Mean		.34	47.79	.0008
Std. Error of Mean		.019	.780	.00024
Median		.00	48.00	.0000
Minimum		0	2	.00
Maximum		1	100	.07

Table 4. Colonization, relative humidity and rainfall descriptive statistics for the experiment site. SPSS 25.0 (IBM Corp. 2017)

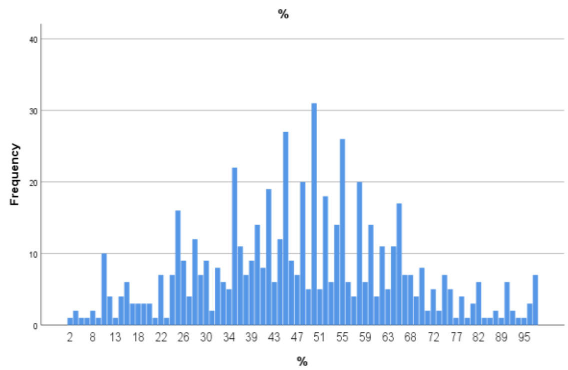

Figure 7. Graph of relative humidity frequencies for the experiment site. SPSS 25.0 (IBM Corp. 2017)

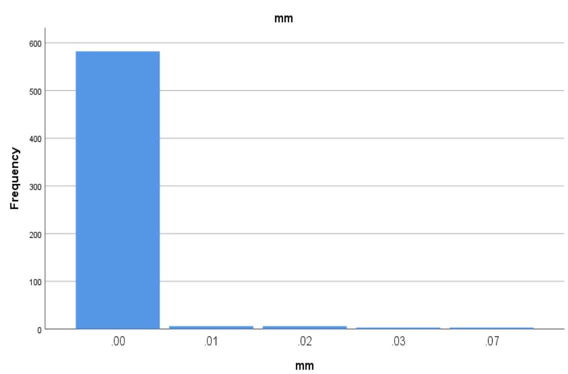

Figure 8. Graph of rainfall frequencies for the experiment site. SPSS 25.0 (IBM Corp. 2017)

Maximum Wind Speed

Wind speed measured (Table 5)remotely for all data collection sites ranged from 0mph to 18mph (mean=3.73mph). Wind speed relative frequencies are shown in Figure 9. Bait was colonized during both minimal and higher recorded wind speeds. Flies most likely could not walk to the bait due to the water moat under the bait bowl, therefore they must be able to fly at these wind speeds since colonization still occurred.

Statistics

		COL	WIND
N	Valid	600	600
	Missing	0	0
Mean		.34	3.73
Std. Error of Mean		.019	.155
Median		.00	3.00
Minimum		0	0
Maximum		1	18

Table 5. Colonization and wind speed descriptive statistics for the experiment site. SPSS 25.0 (IBM Corp. 2017)

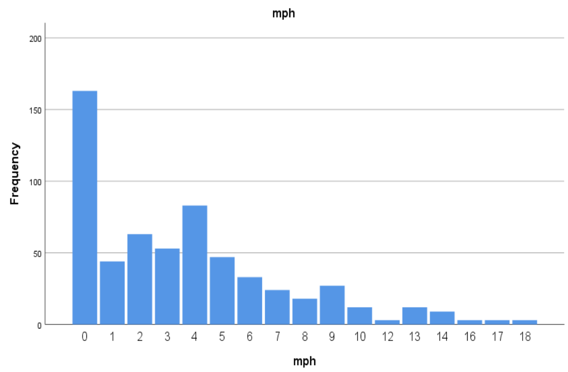

Figure 9. Graph of wind speed frequencies for the experiment site. SPSS 25.0 (IBM Corp. 2017)

Barometric Pressure

Barometric pressure data was taken from a remote weather station. Barometric pressure ranged from 1004.7hPa to 1024hPa (mean=1015.67hPa) (Table 6). Barometric pressure frequencies are shown in Figure 10. Colonization was recorded over a wide range of barometric pressure.

Statistics

		COL	BARO
N	Valid	600	600
	Missing	0	0
Mean		.34	1015.6693
Std. Error of Mean		.019	.13666
Median		.00	1015.6000
Minimum		0	1004.70
Maximum		1	1024.00

Table 6. Colonization and barometric pressure descriptive statistics for the experiment site. SPSS 25.0 (IBM Corp. 2017)

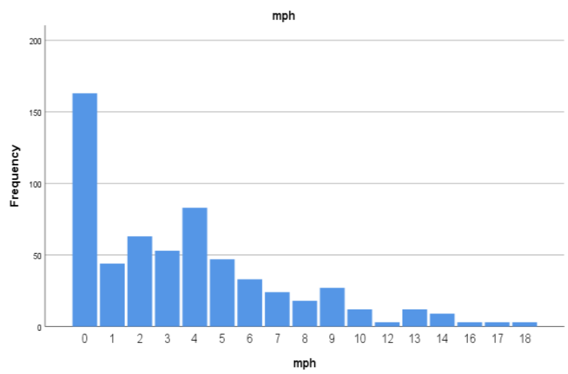

Figure 10. Graph of barometric pressure frequencies for the experiment site. SPSS 25.0 (IBM Corp. 2017)

Light Intensity

Light intensity measured ranged from 100 Lux to 125,100 Lux (mean=24,611.00 Lux) (Table 8). Light intensity ranges measured (frequencies shown in Figure 11) at individual data collection sites were as follows: grass 100 Lux to 125,100 Lux (mean=49.242.36 Lux), short tree 100 Lux to 113,700 Lux (mean=15,698.48 Lux), and tall tree 100 Lux to 115,700 Lux (mean=8352.27 Lux). Reference levels for light intensity are shown in Table 7.

Light Intensity	Lux
Overcast	1000
Full Daylight	10,000
Very Bright	100,000

Table 7. Light intensity levels for reference. (“How to Measure Light” 2016)

Statistics

		COL	LIGHT
N	Valid	600	600
	Missing	0	0
Mean		.34	24611.00
Std. Error of Mean		.019	1435.909
Median		.00	6000.00
Minimum		0	1
Maximum		1	125100

Table 8. Colonization and light intensity descriptive statistics for the experiment site. SPSS 25.0 (IBM Corp. 2017)

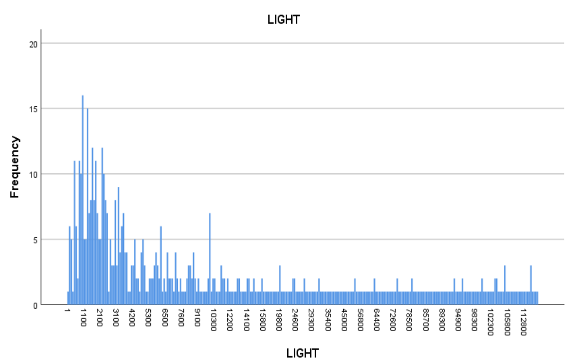

Figure 11. Graph of light intensity frequencies for the experiment site. SPSS 25.0 (IBM Corp. 2017)

Habitat Preference

This research study was conducted in three habitat types: grass, short tree, and tall tree. Colonization comparisons of probability based on site are shown in Table 9. Differences in sample sizes reflect the interruption of data collection due to predation by felids. At the grass data collection site, colonization was observed for 82 of the 203 total observations

(40.4%). At the short tree data collection site, colonization was observed for 69 of the 198 total observations (34.8%). At the tall tree data collection site, colonization events were observed for 55 out of 199 total observations (27.6%). The data shows that blow flies prefer the liver placed in the grass. This is most likely due to higher mean ambient temperatures and light intensities at the grass site since an increase in these variables equals an increase in the probability of colonization. The mean ambient temperature at the tall tree site was 72.86°F and the mean light intensity was 8352.27 Lux. The mean ambient temperature at the short tree site was 73.82°F the mean light intensity was 15,698.48 Lux. The mean ambient temperature at the grass site was 77.44°F and the mean light intensity was 49,242.36 Lux. While habitat type can affect climatic conditions, colonization is more likely dependent on temperature, relative humidity, and light intensity rather than habitat type.

COL

SITE			Frequency	Percent	Valid Percent	Cumulative Percent
GR	Valid	NO COLONIZATION	121	59.6	59.6	59.6
		COLONIZATION	82	40.4	40.4	100.0
		Total	203	100.0	100.0	
ST	Valid	NO COLONIZATION	129	65.2	65.2	65.2
		COLONIZATION	69	34.8	34.8	100.0
		Total	198	100.0	100.0	
TT	Valid	NO COLONIZATION	144	72.4	72.4	72.4
		COLONIZATION	55	27.6	27.6	100.0
		Total	199	100.0	100.0	

Table 9. The frequency of colonization for each habitat for the experiment site. SPSS 25.0 (IBM Corp. 2017)

Chapter 7: Statistical Analysis of Calliphorid Colonization

Binary Logistic Regression Definition and Uses

Binary logistic regression is an application of a generalized linear model used when the dependent (response) variable is dichotomous (Quinn and Keough 2002). The predictor variables are either continuous or categorical. Logistic regression examines the relationship between the dependent and predictor variables. In the case of this research study, logistic regression looks at the relationship between colonization, climatic conditions and light intensities. The dependent variable (colonization) is a binary variable. Colonization occurred (1) or it did not occur (0). The independent variables (ambient temperature, light intensity, wind speed, rainfall, relative humidity, and barometric pressure) are continuous variables.

Assumptions for Logistic Regression

Data collected in this experiment meets the assumptions for analysis using logistic regression which is: minimal missing values (data has no missing values), a sample size greater than 50 (n=600) and, no strong collinearity between independent variables (see section on collinearity analysis). Data collected were analyzed through backward stepwise logistic regression using the Statistical Package for the Social Sciences or SPSS 25.0 (IBM Corp. 2017) to model the effects of barometric pressure, ambient temperature, light intensity, wind speed, and rainfall on the probability of bait colonization by blow flies and to create an equation of colonization probability.

Collinearity Analysis Results

Collinearity diagnostics (Figure 12) were run in SPSS 25.0 (IBM Corp. 2017) between the independent variables (ambient temperature, relative humidity, rainfall, wind speed, barometric pressure, light intensity). Variance inflation factor (VIF) results (Table 10) were all greater than 1.0 but less than 2.0 indicating a relatively small amount of collinearity, but not enough to assume that any of the independent variables were acting together to account for the variability in the dependent variable (colonization) (Schober, Boer, and Schwarte 2018).

VIF	TEMP	HUMIDITY	LIGHT	RAIN	WIND	BARO
TEMP		1.387	1.856	1.963	1.788	1.951
HUMIDITY	1.214		1.778	1.753	1.706	1.624
LIGHT	1.093	1.197		1.195	1.193	1.158
RAIN	1.092	1.114	1.129		1.130	1.129
WIND	1.016	1.108	1.151	1.154		1.128
BARO	1.104	1.049	1.110	1.146	1.122	

Table 10. Collinearity diagnostics results showing VIF all greater than 1.0 but less than 2.0 indicating a relatively small amount of collinearity. SPSS 25.0 (IBM Corp. 2017)

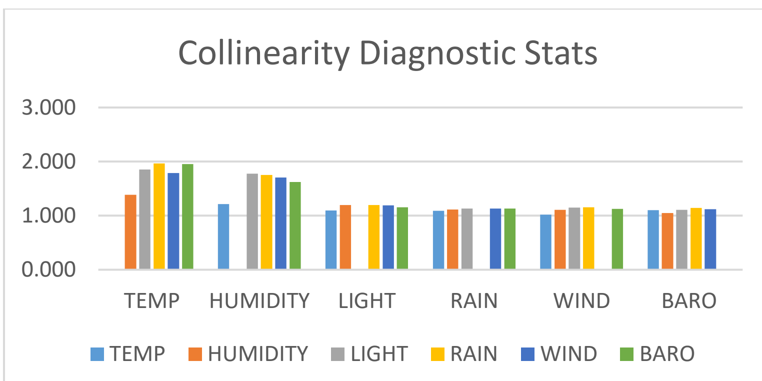

Figure 12. Graph of collinearity diagnostics results showing VIF all greater than 1.0 but less than 2.0 indicating a relatively small amount of collinearity. SPSS 25.0 (IBM Corp. 2017)

Correlation Analysis Results

Analysis of correlation was completed using Pearson's correlation test in SPSS 25.0 (IBM Corp. 2017) to determine if a correlation exists between the independent variables (ambient temperature, relative humidity, rainfall, wind speed, barometric pressure, light intensity) and assess the relationship between ambient temperature and relative humidity.

Four assumptions must be met to use Pearson's correlation test: The variables being tested must be continuous. Variables must have a linear relationship. There must be no significant outliers. The variables must be approximately normally distributed (Quinn and Keough 2002).

All independent variables in this study are continuous. To test their linear relationships, I plotted the variables on scatterplots (Figures 13a-17). Temperature and relative humidity are the only independent variables with a linear relationship. Using SPSS 25.0 (IBM Corp. 2017).

Correlations

		TEMP	HUM
TEMP	Pearson Correlation	1	-.596**
	Sig. (2-tailed)		.000
	N	600	600
HUM	Pearson Correlation	-.596**	1
	Sig. (2-tailed)	.000	
	N	600	600

**. Correlation is significant at the 0.01 level (2-tailed).

Table 11. Correlation Statistics showing a moderate negative correlation between temperature and relative humidity, r=-596, p<0.01 with humidity explaining 35.6% of the variability in temperature. SPSS 25.0 (IBM Corp. 2017)

There was a moderate negative correlation between temperature and humidity, r=-596, p<0.01 with humidity explaining 35.6% of the variability in temperature. Since the absolute value of Pearson's correlation is less than 0.8 and collinearity tests showed no major collinearity (Table 11), I chose to include relative humidity when running my logistic regression statistics, since data collected show colonization throughout a range of humidities.

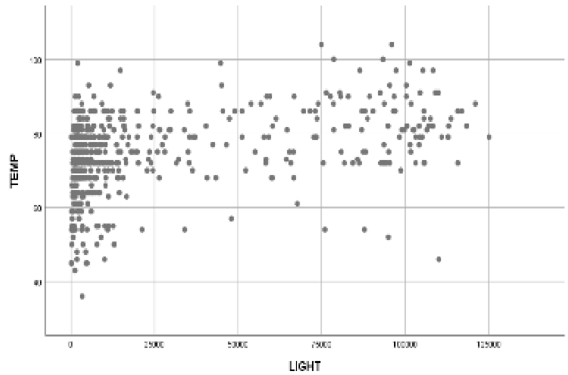

Figure 13a. Collinearity scatterplot showing no linear relationship between temperature and light intensity. SPSS 25.0 (IBM Corp. 2017)

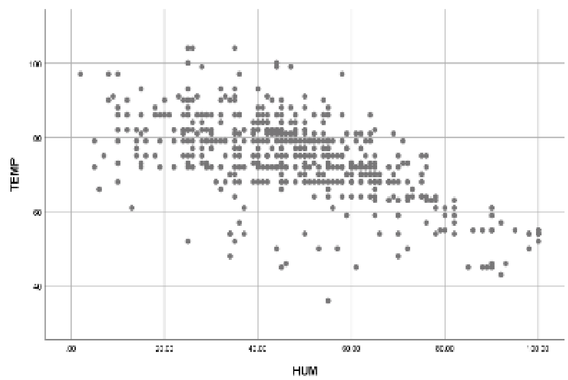

Figure 13b. Collinearity scatterplot showing a linear relationship between temperature and relative humidity. SPSS 25.0 (IBM Corp. 2017)

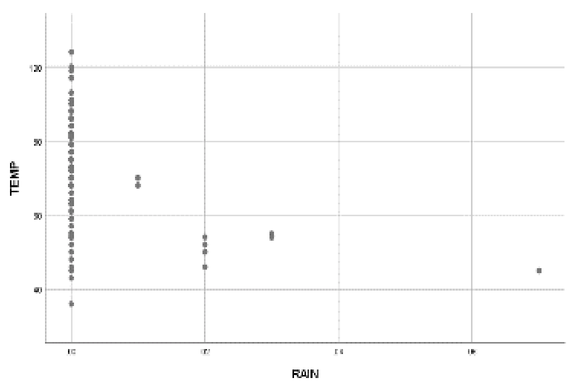

Figure 13c. Collinearity scatterplot showing no linear relationship between temperature and rainfall. SPSS 25.0 (IBM Corp. 2017)

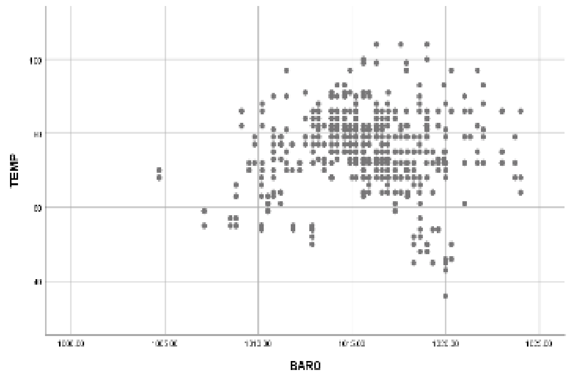

Figure 13d. Collinearity scatterplot showing no linear relationship between temperature and barometric pressure. SPSS 25.0 (IBM Corp. 2017)

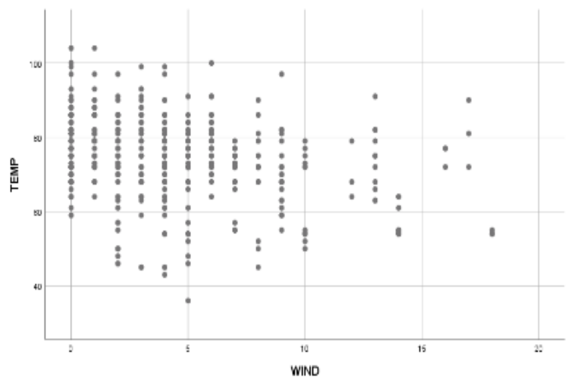

Figure 13e. Collinearity scatterplot showing no linear relationship between temperature and wind speed. SPSS 25.0 (IBM Corp. 2017)

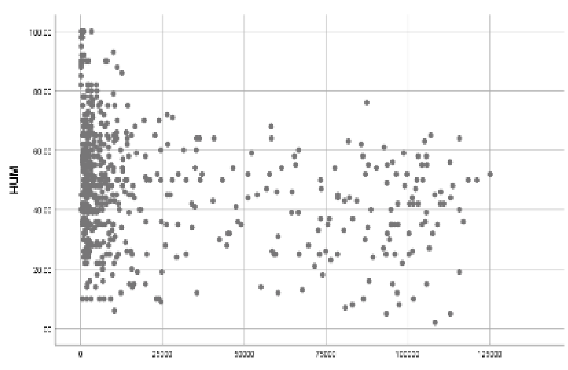

Figure 14a. Collinearity scatterplot showing no linear relationship between relative humidity and light intensity. SPSS 25.0 (IBM Corp. 2017)

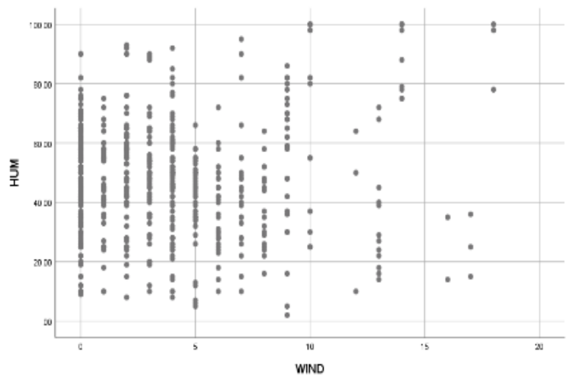

Figure 14b. Collinearity scatterplot showing no linear relationship between relative humidity and wind speed. SPSS 25.0 (IBM Corp. 2017)

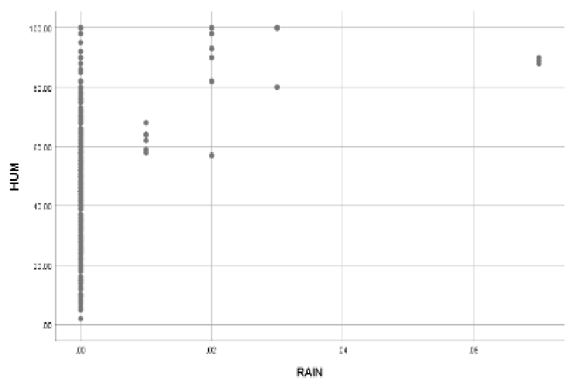

Figure 14c. Collinearity scatterplot showing no linear relationship between relative humidity and rainfall. SPSS 25.0 (IBM Corp. 2017)

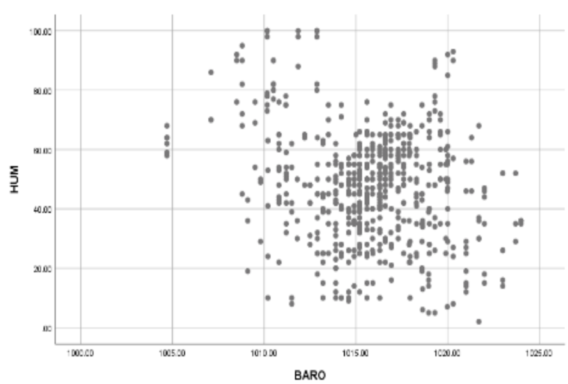

Figure 14d. Collinearity scatterplot showing no linear relationship between relative humidity and barometric pressure. SPSS 25.0 (IBM Corp. 2017)

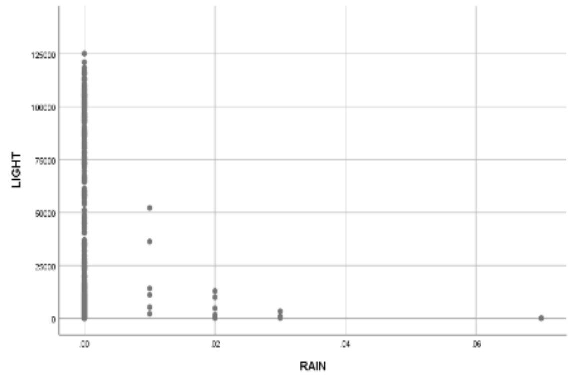

Figure 15a. Collinearity scatterplot showing no linear relationship between light intensity and rainfall. SPSS 25.0 (IBM Corp. 2017)

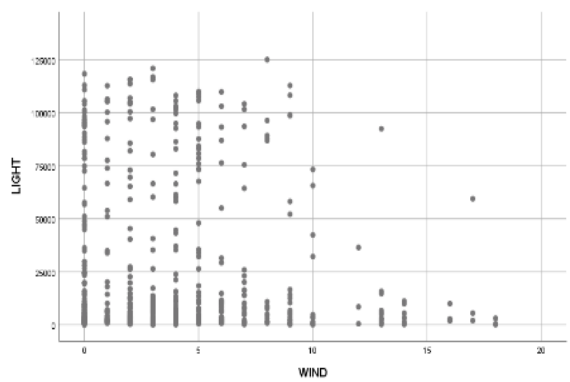

Figure 15b. Collinearity scatterplot showing no linear relationship between light intensity and wind speed. SPSS 25.0 (IBM Corp. 2017)

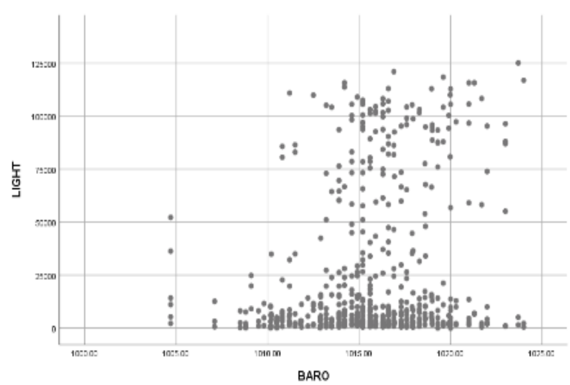

Figure 15c. Collinearity scatterplot showing no linear relationship between light intensity and barometric pressure. SPSS 25.0 (IBM Corp. 2017)

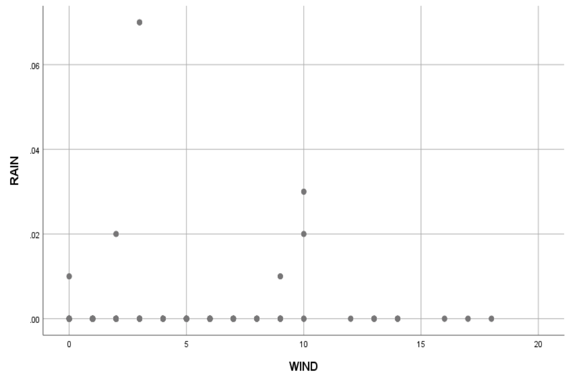

Figure 16a. Collinearity scatterplot showing no linear relationship between rainfall and wind speed. SPSS 25.0 (IBM Corp. 2017)

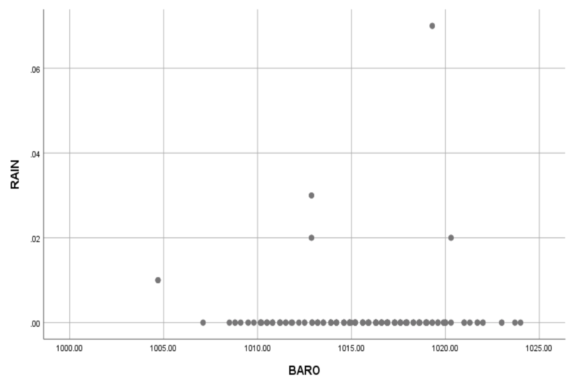

Figure 16b. Collinearity scatterplot showing no linear relationship between rainfall and barometric pressure. SPSS 25.0 (IBM Corp. 2017)

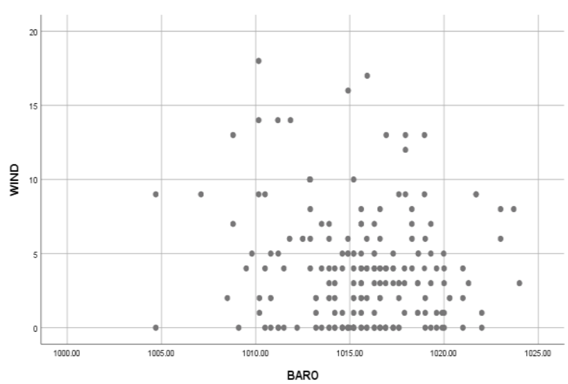

Figure 17: Collinearity scatterplot showing no linear relationship wind speed and barometric pressure. SPSS 25.0 (IBM Corp. 2017)

Binary Logistic Regression Results

For the purposes of this study, the hypotheses being investigated are H_0: Climatic conditions and light intensities have no influence on blow fly colonization and H_1: Climatic conditions and light intensities have a significant influence on blow fly colonization. Logistic regression was completed for each individual data collection site (tall tree, short tree, and grass) as well as the experiment site as a whole.

Tall Tree Data Collection Site

The results of the binary logistic regression model (Figure 18) show that ambient temperature and light intensity are significant predictor variables while barometric pressure, relative humidity, wind speed, and rainfall are not significant predictor variables. All 199 cases were included in this model. The total percentage of correctly predicted colonization by this model for the tall tree site was 73.9% with 97.9% predicted correctly (Figure 20) for no colonization and 10.9% predicted correctly for colonization. The null model (Figure 19) correctly predicted colonization 72.4% of the time.

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	199	100.0
	Missing Cases	0	.0
	Total	199	100.0
Unselected Cases		0	.0
Total		199	100.0

a. If weight is in effect, see classification table for the total number of cases.

Figure 18. Logistic regression case processing summary for the tall tree data collection site. SPSS 25.0 (IBM Corp. 2017)

Classification Table[a,b]

Observed			Predicted COL: NO COLONIZATION	Predicted COL: COLONIZATION	Percentage Correct
Step 0	COL	NO COLONIZATION	144	0	100.0
		COLONIZATION	55	0	.0
	Overall Percentage				72.4

a. Constant is included in the model.

b. The cut value is .500

Figure 19. Null model (no independent variables included) shows an overall 72.4% correct prediction of colonization for the tall tree data collection site. SPSS 25.0 (IBM Corp. 2017)

Classification Table[a]

Observed			Predicted COL: NO COLONIZATION	Predicted COL: COLONIZATION	Percentage Correct
Step 1	COL	NO COLONIZATION	141	3	97.9
		COLONIZATION	49	6	10.9
	Overall Percentage				73.9

a. The cut value is .500

Figure 20. Model 1 (with all independent variables included) showing an overall 73.9% correct prediction of colonization for the tall tree data collection site. SPSS 25.0 (IBM Corp. 2017)

Final probability equations for the tall tree data collection site are as follows:

Temperature: $^{P}\text{Colonization}=\frac{e^{(-0.142)+(0.005)(75°\text{F})}}{1+e^{(-0.142)+(0.005)(75°\text{F})}}$

Light Intensity: $^{P}\text{Colonization}=\frac{e^{(-0.142)+(3.0873E-6)(24000\ Lux)}}{1+e^{(-0.142)+(3.0873E-6)(24000\ Lux)}}$

Short Tree Data Collection Site

The results of the binary logistic regression model (Figure 21) show that ambient temperature and light intensity are significant predictor variables while barometric pressure, relative humidity, wind speed, and rainfall are not significant predictor variables. All 198 cases were included in this model. The total percentage of correctly predicted colonization by this model (Figure 23) for the short tree site was 71.2% with 96.1% predicted correctly for no colonization and 24.6% predicted correctly for colonization. The null model (Figure 22) correctly predicted colonization 65.2% of the time.

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	198	100.0
	Missing Cases	0	.0
	Total	198	100.0
Unselected Cases		0	.0
Total		198	100.0

a. If weight is in effect, see classification table for the total number of cases.

Figure 21. Logistic regression case processing summary for the short tree data collection site. (SPSS 25.0 (IBM Corp. 2017)

Classification Table[a,b]

Observed			Predicted: COL: NO COLONIZATION	Predicted: COL: COLONIZATION	Percentage Correct
Step 0	COL	NO COLONIZATION	129	0	100.0
		COLONIZATION	69	0	.0
	Overall Percentage				65.2

a. Constant is included in the model.

b. The cut value is .500

Figure 22. Null model (no independent variables included) showing an overall 65.2% correct prediction of colonization for the short tree data collection site. SPSS 25.0 (IBM Corp. 2017)

Classification Table[a]

Observed			Predicted COL: NO COLONIZATION	Predicted COL: COLONIZATION	Percentage Correct
Step 1	COL	NO COLONIZATION	124	5	96.1
		COLONIZATION	52	17	24.6
	Overall Percentage				71.2

a. The cut value is .500

Figure 23. Model 1 (all independent variables included) showing an overall 71.2% correct prediction of colonization for the short tree data collection site. SPSS 25.0 (IBM Corp. 2017)

Final probability equations for the short tree data collection site are as follows:

Temperature: ^{P}Colonization=$\frac{e^{(-1.241)+(0.017)(75°\mathrm{F})}}{1+e^{(-1.241)+(0.017)(75°\mathrm{F})}}$

Light Intensity: ^{P}Colonization=$\frac{e^{(-1.241)+(2.829E-6)(24000\ Lux)}}{1+e^{(-1.241)+(2.829E-6)(24000\ Lux)}}$

Humidity: ^{P}Colonization=$\frac{e^{(-1.241)+(0.005)(48\%)}}{1+e^{(-1.241)+(0.005)(48\%)}}$

Grass Data Collection Site

The results of the binary logistic regression model (Figure 24) show that ambient temperature and light intensity are significant predictor variables while barometric pressure, relative humidity, wind speed, rainfall are not significant predictor variables. All 203 cases were included in this model. The total percentage of correctly predicted colonization by this model (Figure 26) for the grass site was 65.0% with 76.0% predicted correctly for no colonization and 48.8% predicted correctly for colonization. The null model (Figure 25) correctly predicted colonization 59.6% of the time.

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	203	100.0
	Missing Cases	0	.0
	Total	203	100.0
Unselected Cases		0	.0
Total		203	100.0

a. If weight is in effect, see classification table for the total number of cases.

Figure 24. Logistic regression case processing summary for the grass data collection site. SPSS 25.0 (IBM Corp. 2017)

Classification Table[a,b]

Observed			Predicted COL: NO COLONIZATION	Predicted COL: COLONIZATION	Percentage Correct
Step 0	COL	NO COLONIZATION	121	0	100.0
		COLONIZATION	82	0	.0
	Overall Percentage				59.6

a. Constant is included in the model.

b. The cut value is .500

Figure 25. Null model (no independent variables included) showing an overall 59.6% correct prediction of colonization for the grass data collection site. SPSS 25.0 (IBM Corp. 2017)

Classification Table[a]

Observed			Predicted COL: NO COLONIZATION	Predicted COL: COLONIZATION	Percentage Correct
Step 1	COL	NO COLONIZATION	92	29	76.0
		COLONIZATION	42	40	48.8
	Overall Percentage				65.0

a. The cut value is .500

Figure 26. Model 1 (all independent variables included) showing an overall 65.0% correct prediction of colonization for the grass data collection site. SPSS 25.0 (IBM Corp. 2017)

Final probability equations for the grass data collection site are as follows:

Temperature: $^{P}\text{Colonization}=\frac{e^{(-1.416)+(0.018)(75°F)}}{1+e^{(-1.416)+(0.018)(75°F)}}$

Humidity: $^{P}\text{Colonization}=\frac{e^{(-1.416)+(0.009)(48\%)}}{1+e^{(-1.416)+(0.009)(48\%)}}$

Experiment Site as a Whole

The results of the binary logistic regression model for all data collection sites combined show that ambient temperature and light intensity are significant predictor variables while barometric pressure, relative humidity, wind speed, and rainfall are not significant predictor variables. All 600 cases were included in this model (Figure 27). The total percentage of correctly predicted colonization by this model (Figure 29) for the experiment site was 69.0% with 91.9% predicted correctly for no colonization and 25.2% predicted correctly for colonization. The null model (Figure 28) correctly predicted colonization 65.7% of the time.

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	600	100.0
	Missing Cases	0	.0
	Total	600	100.0
Unselected Cases		0	.0
Total		600	100.0

a. If weight is in effect, see classification table for the total number of cases.

Figure 27. Logistic regression case processing summary for the experiment site. SPSS 25.0 (IBM Corp. 2017)

Classification Table[a,b]

Observed			Predicted: COL: NO COLONIZATION	Predicted: COL: COLONIZATION	Percentage Correct
Step 0	COL	NO COLONIZATION	394	0	100.0
		COLONIZATION	206	0	.0
	Overall Percentage				65.7

a. Constant is included in the model.

b. The cut value is .500

Figure 28. Null model (no independent variables included)showing an overall 65.7% correct prediction of colonization for the experiment site. SPSS 25.0 (IBM Corp. 2017)

Classification Table[a]

Observed			Predicted: COL: NO COLONIZATION	Predicted: COL: COLONIZATION	Percentage Correct
Step 1	COL	NO COLONIZATION	362	32	91.9
		COLONIZATION	154	52	25.2
	Overall Percentage				69.0

a. The cut value is .500

Figure 29. Model 1 (all independent variables included) showing an overall 69.0% correct prediction of colonization for the experiment site. SPSS 25.0 (IBM Corp. 2017)

Final probability equations for the data collection site are as follows:

Temperature: $^{P}\text{Colonization}=\frac{e^{(-0.894)+(0.012)(75°\text{F})}}{1+e^{(-0.894)+(0.012)(75°\text{F})}}$

Light Intensity: $^{P}\text{Colonization}=\frac{e^{(-0.894)+(1.973E-6)(24000\ Lux)}}{1+e^{(-0.894)+(1.973E-6)(24000\ Lux)}}$

Humidity: $^{P}\text{Colonization}=\frac{e^{(-0.894)+(0.005)(48\%)}}{1+e^{(-0.894)+(0.005)(48\%)}}$

Backward Stepwise Logistic Regression Results

Colonization data were also examined using backward stepwise logistic regression. Backward stepwise logistic regression removes any predictor variable that does not contribute to the accuracy of the model (colonization prediction) from the regression equation in the order in which corresponds to their importance in the equation. Data were analyzed separately for each data collection site within the larger experiment site as well as combined to analyze the experiment site as a whole.

Tall Tree Data Collection Site

Descriptive Statistics

	Mean	Std. Deviation	N
COL	.28	.448	199
TEMP	72.86	9.843	199
HUM	48.80	19.106	199
LIGHT	8352.27	20275.415	199
RAIN	.0008	.00580	199
WIND	3.76	3.807	199
BARO	1015.6684	3.35473	199

Table 12. Descriptive statistics for the tall tree data collection site. SPSS 25.0 (IBM Corp. 2017)

As seen in Figure 30, wind speed, rainfall, barometric pressure, and relative humidity were removed from the regression equation in that order which corresponded with their importance in the equation (p=>.100). Wind speed was the least influential variable, so it was removed in the first step, followed by rainfall, barometric pressure, and relative humidity. According to the regression equation (Figure 31), light intensity and ambient temperature are the factors that contribute most significantly to the colonization model for the tall tree data collection site.

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	BARO, RAIN, LIGHT, WIND, TEMP, HUM[b]	.	Enter
2	.	WIND	Backward (criterion: Probability of F-to-remove >= .100).
3	.	RAIN	Backward (criterion: Probability of F-to-remove >= .100).
4	.	BARO	Backward (criterion: Probability of F-to-remove >= .100).
5	.	HUM	Backward (criterion: Probability of F-to-remove >= .100).

a. Dependent Variable: COL

b. All requested variables entered.

Figure 30. Variables entered and removed in successive steps from the logistic regression model for the tall tree data collection site. SPSS 25.0 (IBM Corp. 2017)

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.233[a]	.054	.025	.443	.054	1.840	6	192	.093
2	.233[b]	.054	.030	.442	.000	.000	1	192	.987
3	.233[c]	.054	.035	.441	.000	.054	1	193	.816
4	.223[d]	.050	.035	.440	-.004	.907	1	194	.342
5	.195[e]	.038	.028	.442	-.011	2.357	1	195	.126

a. Predictors: (Constant), BARO, RAIN, LIGHT, WIND, TEMP, HUM

b. Predictors: (Constant), BARO, RAIN, LIGHT, TEMP, HUM

c. Predictors: (Constant), BARO, LIGHT, TEMP, HUM

d. Predictors: (Constant), LIGHT, TEMP, HUM

e. Predictors: (Constant), LIGHT, TEMP

Figure 31. Model summary results for the tall tree data collection site. Light intensity and ambient temperature are significant predictor variables of colonization. SPSS 25.0 (IBM Corp. 2017)

Short Tree Data Collection Site

Descriptive Statistics

	Mean	Std. Deviation	N
COL	.35	.478	198
TEMP	73.82	9.279	198
HUM	47.97	19.155	198
LIGHT	15698.48	27799.050	198
RAIN	.0008	.00582	198
WIND	3.71	3.822	198
BARO	1015.6483	3.36691	198

Table 13. Descriptive statistics for the short tree data collection site. SPSS 25.0 (IBM Corp. 2017).

The short tree data collection site sample size was 198 (Table 13). Wind speed, rainfall, and barometric pressure were removed from the regression equation (Figure 32) in that order which corresponded with their importance in the equation (p=>.100). Wind speed was the least influential variable followed by rainfall and barometric pressure. According to the regression equation, light intensity, ambient temperature, and relative humidity are the factors that contribute most significantly to the colonization model (Figure 3) for the short tree data collection site.

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	BARO, RAIN, WIND, LIGHT, TEMP, HUM[b]	.	Enter
2	.	RAIN	Backward (criterion: Probability of F-to-remove >= .100).
3	.	WIND	Backward (criterion: Probability of F-to-remove >= .100).
4	.	BARO	Backward (criterion: Probability of F-to-remove >= .100).

a. Dependent Variable: COL

b. All requested variables entered.

Figure 32. Variables entered and removed in successive steps from the logistic regression model for the short tree data collection site. SPSS 25.0 (IBM Corp. 2017)

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.285[a]	.081	.052	.465	.081	2.816	6	191	.012
2	.284[b]	.081	.057	.464	-.001	.118	1	191	.732
3	.283[c]	.080	.061	.463	-.001	.174	1	192	.677
4	.279[d]	.078	.064	.462	-.002	.388	1	193	.534

a. Predictors: (Constant), BARO, RAIN, WIND, LIGHT, TEMP, HUM

b. Predictors: (Constant), BARO, WIND, LIGHT, TEMP, HUM

c. Predictors: (Constant), BARO, LIGHT, TEMP, HUM

d. Predictors: (Constant), LIGHT, TEMP, HUM

Figure 33. Model summary results for the short tree data collection site. Light intensity and ambient temperature are significant predictor variables of colonization. SPSS 25.0 (IBM Corp. 2017)

Grass Data Collection Site

The grass date collection sample size was 203 (Table 14). Barometric pressure, wind speed, rainfall, and light intensity were removed from the regression equation (Figure 34) in that order which corresponded with their importance in the equation (p=>.100). Barometric pressure was the least influential variable followed by wind speed, rainfall, and light intensity. According to the regression equation (Figure 35), ambient temperature and relative humidity are the factors that contribute most significantly to the colonization model for the grass data collection site.

Descriptive Statistics

	Mean	Std. Deviation	N
COL	.40	.492	203
TEMP	77.44	11.549	203
HUM	46.73	19.133	203
LIGHT	49242.36	39545.306	203
RAIN	.0008	.00575	203
WIND	3.73	3.789	203
BARO	1015.6907	3.33759	203

Table 14. Descriptive statistics for the grass data collection site. SPSS 25.0 (IBM Corp. 2017)

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	BARO, RAIN, WIND, HUM, LIGHT, TEMP[b]	.	Enter
2	.	BARO	Backward (criterion: Probability of F-to-remove >= .100).
3	.	WIND	Backward (criterion: Probability of F-to-remove >= .100).
4	.	RAIN	Backward (criterion: Probability of F-to-remove >= .100).
5	.	LIGHT	Backward (criterion: Probability of F-to-remove >= .100).

a. Dependent Variable: COL

b. All requested variables entered.

Figure 34. Variables entered and removed in successive steps from the logistic regression model for the grass data collection site. SPSS 25.0 (IBM Corp. 2017)

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.385[a]	.148	.122	.461	.148	5.677	6	196	.000
2	.381[b]	.145	.124	.460	-.003	.602	1	196	.439
3	.377[c]	.142	.125	.460	-.003	.685	1	197	.409
4	.373[d]	.139	.126	.460	-.003	.769	1	198	.382
5	.362[e]	.131	.122	.461	-.008	1.856	1	199	.175

a. Predictors: (Constant), BARO, RAIN, WIND, HUM, LIGHT, TEMP

b. Predictors: (Constant), RAIN, WIND, HUM, LIGHT, TEMP

c. Predictors: (Constant), RAIN, HUM, LIGHT, TEMP

d. Predictors: (Constant), HUM, LIGHT, TEMP

e. Predictors: (Constant), HUM, TEMP

Figure 35. Model summary results for the grass data collection site. Light intensity and ambient temperature are significant predictor variables of colonization. SPSS 25.0 (IBM Corp. 2017)

Experiment Site as a Whole

Descriptive Statistics

	Mean	Std. Deviation	N
COL	.34	.475	600
TEMP	74.73	10.453	600
HUM	47.79	19.106	600
LIGHT	24611.00	35172.432	600
RAIN	.0008	.00578	600
WIND	3.73	3.800	600
BARO	1015.6694	3.34742	600

Table 15. Descriptive statistics for logistic regression testing all variables. (SPSS 25.0 (IBM Corp. 2017)

The sample size for the experiment site as a whole is 600 (Table 15). Results of logistic regression of data for the experiment site show that ambient temperature, relative humidity, and light intensity are positive predictor variables. Temperature is a more significant predictor of colonization than is light intensity and relative humidity. George, Archer, and Toop (2013b) found that relative humidity was a negative predictor value, but this was not the case in my study as colonization occurred throughout a range of relative humidities. Relative humidity even acc accounted for significant variance at short tree data collection site.

Barometric pressure, wind speed, and rainfall were removed from the regression equation (Figure 36) in that order which corresponded with their importance in the equation (p=>.100). Barometric pressure was the least influential variable followed by wind speed and rainfall. According to the regression equation (Figure 37), ambient temperature, light intensity, and relative humidity are the factors that contribute most significantly to the colonization model.

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	BARO, RAIN, WIND, LIGHT, HUM, TEMP[b]	.	Enter
2	.	BARO	Backward (criterion: Probability of F-to-remove >= .100).
3	.	WIND	Backward (criterion: Probability of F-to-remove >= .100).
4	.	RAIN	Backward (criterion: Probability of F-to-remove >= .100).

a. Dependent Variable: COL

b. All requested variables entered.

Figure 36. Variables entered and removed in successive steps from the logistic regression model for all data from the experiment site. SPSS 25.0 (IBM Corp. 2017)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.298[a]	.089	.080	.456	.089	9.633	6	593	.000
2	.297[b]	.088	.081	.456	-.001	.349	1	593	.555
3	.295[c]	.087	.081	.456	-.001	.785	1	594	.376
4	.293[d]	.086	.081	.456	-.002	.987	1	595	.321

a. Predictors: (Constant), BARO, RAIN, WIND, LIGHT, HUM, TEMP

b. Predictors: (Constant), RAIN, WIND, LIGHT, HUM, TEMP

c. Predictors: (Constant), RAIN, LIGHT, HUM, TEMP

d. Predictors: (Constant), LIGHT, HUM, TEMP

Figure 37. Model summary results for all data from the experiment site. Light intensity and ambient temperature are significant predictor variables of colonization. SPSS 25.0 (IBM Corp. 2017)

Predicted Probability of Colonization

Tall Tree Data Collection Site

An increase of 1º Fahrenheit of ambient temperature increases the probability of colonization by 0.005. The predicted probability of colonization within 90 minutes at 75ºF, the average observed temperature, is 0.5580 or 55.8% (Figure 38a). An increase in light intensity by 1 Lux increases the probability of colonization by $3.0870E^{-6}$. The predicted probability of colonization within 90 minutes at 24,000 Lux, the average observed light intensity, is 0.4830 or 48.3% (Figure 38b). Colonization probabilities are calculated using an Excel spreadsheet (Table 16.)

TEMPERATURE				Average		
Variable	Coefficient	60°F	70°F	75°F	85°F	90°F
Constant	-0.142	1	1	1	1	1
Temperature	0.005	60	70	75	85	90
y*=ln(p/(1-p))		0.16	0.21	0.23	0.28	0.31
p=exp(y*)/(exp(y*)+1)		0.5394	0.5518	0.5580	0.5703	0.5764
Probability		54.0%	55.2%	55.8%	57.0%	58.0%
Change			0.01240	0.00617	0.01229	0.00612

LIGHT INTENSITY		overcast	full light	Average		very bright
Variable	Coefficient	1000 Lux	10000 Lux	24000 Lux	50000 Lux	100000 Lux
Constant	-0.142	1	1	1	1	1
Light Intensity	0.0000030870	1000	10000	24000	50000	100000
y*=ln(p/(1-p))		-0.1389	-0.1111	-0.0679	0.0124	0.1667
p=exp(y*)/(exp(y*)+1)		0.4653	0.4722	0.4830	0.5031	0.5416
Probability		46.5%	47.2%	48.3%	50.3%	54.2%
Change			0.00692	0.01078	0.02006	0.03849

Table 16. The predicted probability of colonization within 90 minutes at various ambient temperatures and light intensities for the tall tree data collection site. Values for constant and coefficients are unstandardized coefficients generated during backward stepwise logistic regression.

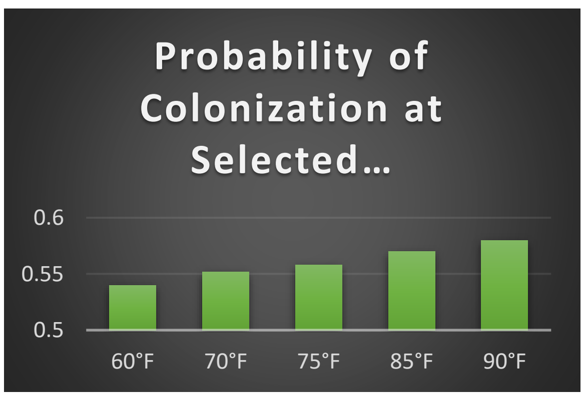

Figure 38a. The probability of colonization at selected ambient temperatures for the tall tree data collection site.

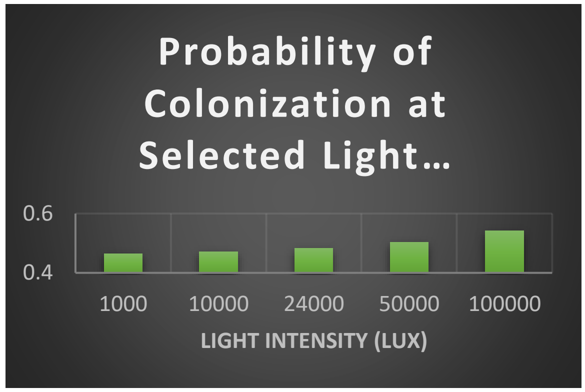

Figure 38b. The probability of colonization at selected light intensities for the tall tree data collection site.

Short Tree Data Collection Site

An increase of 1º Fahrenheit of ambient temperature increases the probability of colonization by 0.017. The predicted probability of colonization within 90 minutes at 75ºF, the average observed temperature, is 0.4873 or 48.7% (Figure 39a). An increase in light intensity by 1 Lux increases the probability of colonization by $2.8290E^{-6}$ (Figure 39b). The predicted probability of colonization within 90 minutes at 24,000 Lux, the average observed light intensity, is 0.2363 or 24.0%. An increase in relative humidity by 1% increases the probability of colonization by 0.005. The predicted probability of colonization within 90 minutes at 48% relative humidity, the average observed relative humidity, is 0.2687 or 27.0% (Figure 39c). Colonization probabilities are calculated using an Excel spreadsheet (Table 17.)

TEMPERATURE				Average		
Variable	Coefficient	60°F	70°F	75°F	85°F	90°F
Constant	-1.241	1	1	1	1	1
Temperature	0.017	60	70	75	85	90
y*=ln(p/(1-p))		-0.22	-0.05	0.03	0.20	0.29
p=exp(y*)/(exp(y*)+1)		0.4450	0.4873	0.5085	0.5508	0.5718
Probability		44.5%	48.7%	51.0%	55.1%	57.2%
Change			0.04228	0.02125	0.04232	0.02093

LIGHT INTENSITY		overcast	full light	Average		very bright
Variable	Coefficient	1000 Lux	10000 Lux	24000 Lux	50000 Lux	100000 Lux
Constant	-1.241	1	1	1	1	1
Light Intensity	0.0000028290	1000	10000	24000	50000	100000
y*=ln(p/(1-p))		-1.2382	-1.2127	-1.1731	-1.0996	-0.9581
p=exp(y*)/(exp(y*)+1)		0.2248	0.2292	0.2363	0.2498	0.2773
Probability		22.5%	23.0%	24.0%	25.0%	28.0%
Change			0.00447	0.00707	0.01353	0.02743

HUMIDITY				Average		
Variable	Coefficient	25.00	35.00	48.00	65.00	85.00
Constant	-1.241	1	1	1	1	1
Humidity	0.005	25	35	48	65	85
y*=ln(p/(1-p))		-1.1160	-1.0660	-1.0010	-0.9160	-0.8160
p=exp(y*)/(exp(y*)+1)		0.2468	0.2562	0.2687	0.2858	0.3066
Probability		25.0%	26.0%	27.0%	29.0%	31.0%
Change			0.00941	0.01258	0.01703	0.02084

Table 17. The predicted probability of colonization within 90 minutes at various ambient temperatures and light intensities for the short tree data collection site. Values for constant and coefficients are unstandardized coefficients generated during backward stepwise logistic regression.

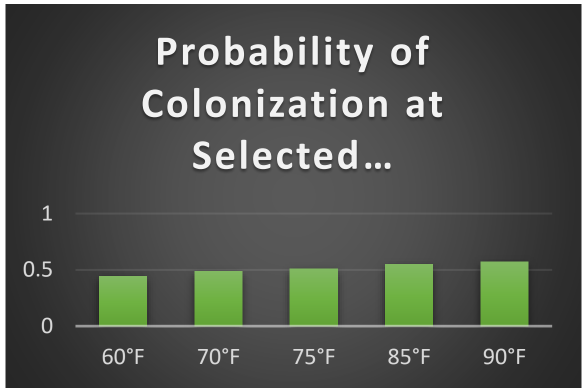

Figure 39a. The probability of colonization at selected ambient temperatures for the short tree data collection site.

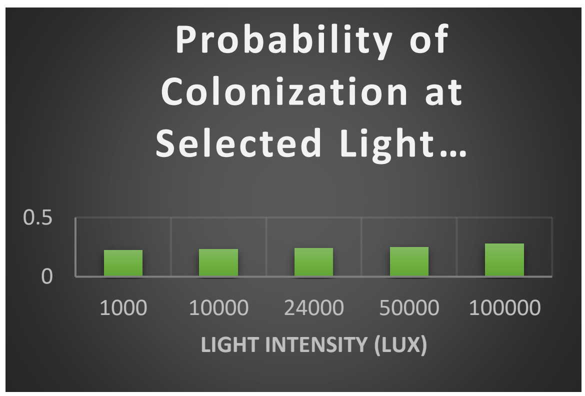

Figure 39b. The probability of colonization at selected light intensities for the short tree data collection site.

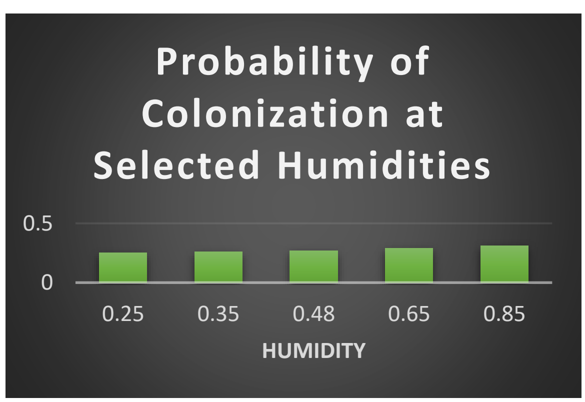

Figure 39c. The probability of colonization at selected relative humidities for the short tree data collection site.

Grass Data Collection Site

An increase of 1º Fahrenheit of ambient temperature increases the probability of colonization by 0.018. The predicted probability of colonization within 90 minutes at 75ºF, the average observed temperature, is 0.4835 or 49.3% (Figure 40a). An increase in relative humidity by 1% increases the probability of colonization by 0.009. The predicted probability of colonization within 90 minutes at 48% relative humidity, the average observed relative humidity, is 0.2721 or 27.2% (Figure 40b). Colonization probabilities are calculated using an Excel spreadsheet (Table 18.)

TEMPERATURE				Average		
Variable	Coefficient	60°F	70°F	75°F	85°F	90°F
Constant	-1.416	1	1	1	1	1
Temperature	0.018	60	70	75	85	90
y*=ln(p/(1-p))		-0.34	-0.16	-0.07	0.11	0.20
p=exp(y*)/(exp(y*)+1)		0.4168	0.4611	0.4835	0.5285	0.5508
Probability		41.7%	46.1%	48.4%	53.0%	55.1%
Change			0.04430	0.02243	0.04496	0.02235

HUMIDITY				Average		
Variable	Coefficient	25.00	35.00	48.00	65.00	85.00
Constant	-1.416	1	1	1	1	1
Humidity	0.009	25	35	48	65	85
y*=ln(p/(1-p))		-1.1910	-1.1010	-0.9840	-0.8310	-0.6510
p=exp(y*)/(exp(y*)+1)		0.2331	0.2496	0.2721	0.3034	0.3428
Probability		23.3%	25.0%	27.2%	30.3%	34.3%
Change			0.01647	0.02255	0.03133	0.03933

Table 18. The predicted probability of colonization within 90 minutes at various ambient temperatures and light intensities for the grass data collection site. Values for constant and coefficients are unstandardized coefficients generated during backward stepwise logistic regression.

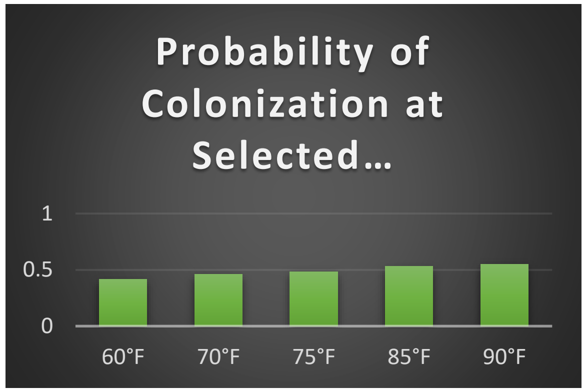

Figure 40a. The probability of colonization at selected ambient temperatures grass data collection site.

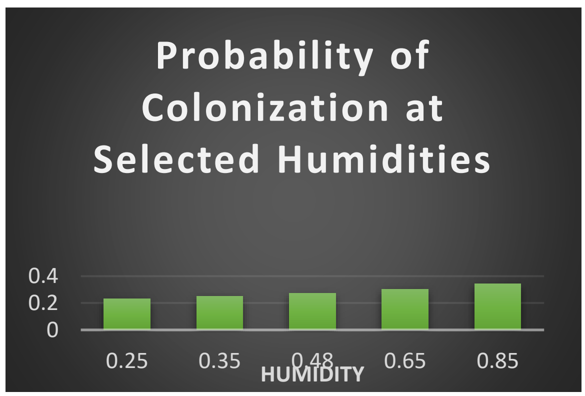

Figure 40b. The probability of colonization at selected relative humidities at the grass data collection site.

Experiment Site as a Whole

An increase of 1º Fahrenheit of ambient temperature increases the probability of colonization by 0.012. The predicted probability of colonization within 90 minutes at 75ºF, the average observed temperature, is 0.5015 or 50.2% (Figure 41a). An increase in light intensity by 1 Lux increases the probability of colonization by 1.9730E^{-6}. The predicted probability of colonization within 90 minutes at 24,000 Lux, the average observed light intensity, is 0.3001 or 30.0% (Figure 41b). An increase in relative humidity by 1% increases the probability of colonization by 0.005. The predicted probability of colonization within 90 minutes at 48% relative humidity, the average observed relative humidity, is 0.3421 or 34.3% (Figure 41c). Colonization probabilities are calculated using an Excel spreadsheet (Table 19.)

TEMPERATURE				Average		
Variable	Coefficient	60°F	70°F	75°F	85°F	90°F
Constant	-0.894	1	1	1	1	1
Temperature	0.012	60	70	75	85	90
y*=ln(p/(1-p))		-0.17	-0.05	0.01	0.13	0.19
p=exp(y*)/(exp(y*)+1)		0.4566	0.4865	0.5015	0.5315	0.5464
Probability		45.7%	48.7%	50.2%	53.2%	54.6%
Change			0.02989	0.01500	0.02996	0.01491

LIGHT INTENSITY		Overcast	Full light	Average		Very bright
Variable	Coefficient	1000 Lux	10000 Lux	24000 Lux	50000 Lux	100000 Lux
Constant	-0.894	1	1	1	1	1
Light Intensity	0.0000019730	1000	10000	24000	50000	100000
y*=ln(p/(1-p))		-0.8920	-0.8743	-0.8466	-0.7954	-0.6967
p=exp(y*)/(exp(y*)+1)		0.2907	0.2944	0.3001	0.3110	0.3325
Probability		29.1%	29.4%	30.0%	31.1%	33.3%
Change			0.00367	0.00577	0.01088	0.02152

HUMIDITY				Average		
Variable	Coefficient	25.00	35.00	48.00	65.00	85.00
Constant	-0.894	1	1	1	1	1
Humidity	0.005	25	35	48	65	85
y*=ln(p/(1-p))		-0.7690	-0.7190	-0.6540	-0.5690	-0.4690
p=exp(y*)/(exp(y*)+1)		0.3167	0.3276	0.3421	0.3615	0.3849
Probability		32.7%	32.8%	34.2%	36.2%	38.5%
Change			0.01092	0.01448	0.01938	0.02339

Table 19. The predicted probability of colonization within 90 minutes at various ambient temperatures, light intensities, and relative humidities for the experiment site. Values for constant and coefficients are unstandardized coefficients generated during backward stepwise logistic regression.

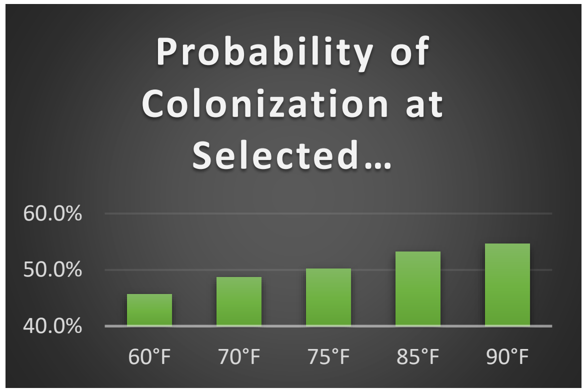

Figure 41a. The probability of colonization at selected ambient temperatures for the experiment site.

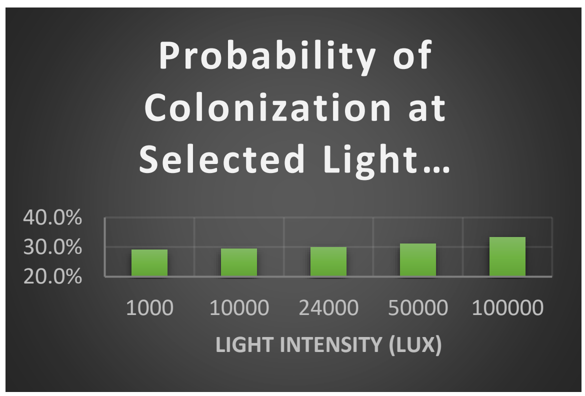

Figure 41b. The probability of colonization at selected light intensities for the experiment site.

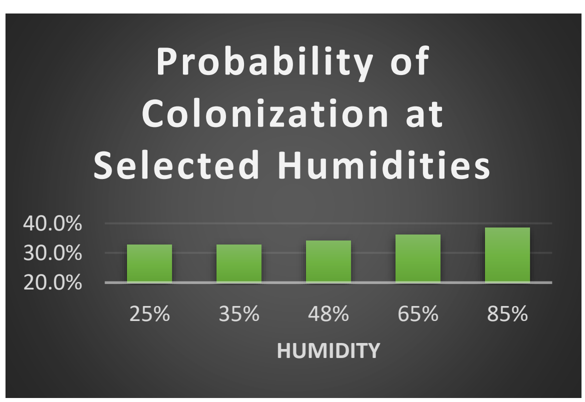

Figure 41c. The probability of colonization at selected relative humidities for the experiment site.

Analysis of Probability

The tall tree data collection site had a slightly higher probability of colonization at the average temperature (75 ºF) at 55.8% compared to the short tree site at 51.0% and 48.49% for the grass data collection site. At the average light intensity (24,000 Lux), the tall tree data collection site also had a higher probability of colonization at 48.3% compared to 24.0% at the short tree data collection site. The grass site was not included in this analysis because light intensity was removed as a significant predictor variable in the logistic regression equation. Comparison of the probability of colonization at the average of 48% relative humidity shows that the short tree data collection site had the highest probability of colonization at 27.0% while it was 27.2% at the grass data collection site. The tall tree site was not included in this comparison because relative humidity was not included as a significant predictor variable in the logistic regression equation.

Accumulated Degree Days (ADD)

Utilizing the method for calculating ADD with a minimum threshold temperature of 70ºF (Mann, Bass, and Meadows 1990), colonization should have occurred on 33 out of the 41 days or 80% of the days. My study had 30 days of the 41 total where colonization occurred or a 73% colonization rate. The ADD method was accurate for 28 of the 41 days or 68%. It incorrectly predicted colonization 13 out of the 41 days or 32% of the time.

Activity Patterns

A total of 600 observations were made at the experiment site with an overall 34% colonization rate. A total of 199 observations were made at the tall tree data collection site with a 28% colonization rate. A total of 198 observations were made at the short tree data collection site with a 35% colonization rate. A total of 203 observations were made at the grass data collection site with a 40% colonization rate. These observations were made under a range of climatic conditions, over the course of several months in successive years (Figure 42), and thus allows the construction of a set of parameters in which colonization did or did not occur.

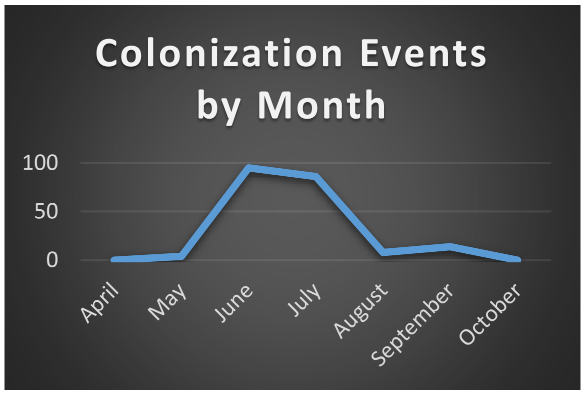

Figure 42. Colonization events by month showing a spike in colonization in summer months. Monthly data is pooled between years.

Similar Applications of Logistic Regression

In France, Cervantes et al. (2018) used linear regression to model the effect of low temperatures on the development and egg-laying habits of the blow fly *Lucilia sericata* and its implications on the estimation of the postmortem interval. Their attempts to create a global linear model showed an overestimation of the effects of some temperatures on development and egg laying.

Zurawski at al. (2009) used both forward and backward stepwise logistic regression to study nocturnal oviposition behavior of blowflies in Michigan. Predictor variables were removed from the logistic regression model based on the significance of influence on egg laying at night. Their final regression model included wind speed, ambient temperature, and relative humidity, but not light intensity. They concluded that ambient temperature and relative humidity, as well as ambient temperature and light intensity, were positively correlated and that the significance of light intensity depends on ambient temperature and relative humidity.

Barnes et al. (2015) used backward stepwise logistic regression to model the behavior of blow flies at night in England. Nocturnal oviposition did not occur during their data collection period. Ambient temperature was found to be the only significant predictor variable in their study and contrary to Zurawski et al., Barnes et al. concluded that temperature and relative humidity were negatively correlated.

George, Archer, and Toop (2013) modeled the influence of abiotic factors on colonization by blow flies using backward stepwise logistic regression in Victoria, Australia. Barometric pressure, light intensity, rainfall, and wind speed were removed from their regression model in with barometric pressure having the lease effect on colonization. Ambient temperature and relative humidity were found to be significant predictor variables. George, Archer, and Toop (2013b) also determined that temperature and relative humidity were negatively correlated.

Chapter 8: Species Observed

Bluebottle fly

Bluebottle flies (*Calliphora vicina*) are found throughout the United States and Canada. Its size ranges from 1/4" to 1/2" long. Bluebottle flies are dark blue to black, very hairy and have a metallic glint (Byrd and Castner 2000). This fly is often found on human remains in urban areas and buzzes loudly. This species was commonly observed during my 41 days of data collection (Figure 43).

Figure 43. Bluebottle flies (*Calliphora vicina*) on the edge of the bait bowl.
(Photo by author)

Shiny Bluebottle Fly

Shiny bluebottle flies (*Cynomyopsis caderverina*) are very common and can be found throughout the United States, particularly in wooded and rural areas. They range in size from 1/3" to 1/2" long. Shiny bluebottle flies are metallic dark blue to blue-black with a shiny blue abdomen (Byrd and Castner 2000). This species was commonly observed during my 41 days of data collection (Figure 44).

Figure 44. Shiny Bluebottle Fly (*Cynomyopsis caderverina*) on colonization medium. (Photo by author)

Greenbottle Fly

Greenbottle flies (*Lucilia sericata*) are common throughout the United States, particularly in rural and wooded areas. They are 1/4" to 3/8” in length. They are metallic green to blue-green. They are often found at fresh remains (Byrd and Castner 2000). This species was the most commonly observed species during my 41 days of data collection (Figure 45).

Figure 45. Greenbottle Fly (*Lucilia sericata*) on colonization medium. (Photo by author)

Cheese Skipper Fly

Cheese skipper flies (*Piophila casei*) are distributed throughout the United States and Canada. They are 1/8” to 1/4” length. Their body is black or to metallic blue (Byrd and Castner 2000). This species shows up late in succession and does not necessarily indicate colonization. A single cheese skipper was observed during the review of photos taken during data collection (Figure 46).

Figure 46. Cheese skipper (*Piophila casei*) on colonization medium.
(Photo by author)

Red-tailed Flesh Fly

Red-tailed flesh flies (*Sarcophaga haemorrhoidalis*) are found worldwide and are associated with human remains in the United States and Canada. Adult flesh flies are up to 3/4” in length. They have gray and black longitudinal stripes on the thorax and a checkerboard pattern on the abdomen. They lack the metallic coloration of blow flies (Byrd and Castner 2010). Some species have bright red compound eyes. Adult females lay live first-instar larva in excrement and on dead animals (Byrd and Castner 2010). This species was seen more often in photos taken during data collection than actually observed on the bait during my 41 days of data collection. Larvae, possibly from the red-tailed flesh fly, were observed twice during data collection (Figure 47).

Figure 47. Red-tailed flesh fly (*Sarcophaga haemorrhoidalis*) on colonization medium. (Photo by author)

Chapter 9: Unanticipated Confounding Factors

Scavenging by Felids

Scavenging of the bait liver by a housecat (Family: *Felidae*) occurred early on in the data collection process. Felid scavenging was observed on two days during the 41 days of my research study, twice in one day which interrupted data collection. This issue was resolved by adding a second plastic basket over the bait, turning the baskets in opposite directions so that the holes overlapped on the sides creating smaller openings and then placing heavier weights on top of the baskets.

Predation of Eggs and Flies by Insects

Predators of fly eggs, larvae and of adult flies include silphids (burying beetles), histerids (hister beetles), and formicids (ants) (Greenberg 1991). Beetles, hornets, and yellowjackets were observed in or around the bait bowl. Ants were observed in the water moat under the bait bowl.

A single multicolored Asian lady beetle larva (*Harmonia axyridis*) (Figure 48) was observed on an egg mass, possibly eating the eggs. Asian lady beetles were introduced into the United States to control aphids (Jacobs 2013). Asian lady beetle larvae are long, flat and covered in tubercles or spines (Jacobs 2013).

Figure 48. Asian Lady Beetle larva (*Harmonia axyridis*) on blow fly egg mass.
(Photo by author)

A single leaf beetle (*Acanthoscelides aureolus*) (Figure 49) was observed on the liver. Leaf beetles are herbivorous thus it was most likely in the bait bowl by coincidence (Acanthoscelides aureolus 2018).

Figure 49. Leaf beetle (*Acanthoscelides aureolus*) on colonization medium.
(Photo by author)

Ants (formicids) were observed occasionally in the bait bowl when they were able to drop from vegetation onto the colonization medium but were mainly inhibited by the “moat” pan under the bait bowl.

Yellowjackets (*Vespula maculifrons)* were observed in great numbers around the bait (Figure 50), but no predation of eggs or adult flies was observed. Yellowjackets nest in the ground and are common in many states. They are approximately 1/2” to 3/4" and are black with yellow stripes. They can be quite aggressive when defending their nest. Data collection sites may have been located near in-ground nests (Jacobs 2015b).

Figure 50. Yellowjackets (*Vespula maculifrons)* eating colonization medium.
(Photo by author)

However, predation by bald-faced hornets (*Dolichovespula maculata*) was observed. There are 7 or 8 species of bald-faced hornets in North America. It is not a “true hornet,” but is a yellowjacket. Bald-faced hornets are found in most of the contiguous United States. The hornets are black with a white face. They range in size from 1/2’ to 3/4”. Nests are made in the brush and shrubs. Bald-faced hornets eat live prey including flies, yellowjackets and other insects (Jacobs 2015a).

Bald-faced hornets (Figure 51) were observed catching adult flies and yellowjackets in mid-air and on the liver itself. Fly wings and legs were observed in the bait bowl (Figure 52).

Figure 51. Bald-faced hornet (*Dolichovespula maculata*) on colonization medium. (Photo by author)

Figure 52. Blow fly wing and leg in bait bowl are evidence of predation by bald-faced hornets. (Photo by author)

Blow fly activity and egg-laying continued to occur in the presence of bald-faced hornets but was often confined to the protected areas under the bait or where bait protruded through the drilled holes in the bottom of the bait bowl. In addition, egg masses were relatively small or single eggs were laid instead of large batches. Data collection was difficult at times due to the number of yellowjackets and hornets on and around the bait.

Predation of Flies by Arachnids

A crab spider (*Misumena vatia*) was observed in the bait bowl eating a blow fly (Figure 53). Crab spiders are found in North America and Europe. The crab spider has a short, wide and flat body with larger front legs compared to the back. They are light colored with white, yellow or red markings. They range in size from 1/4" to 1/3” for females and 1/8” for males (Mahmoud 2002). They do not spin webs or wrap their prey in silk. Crab spiders hold their prey and drink their body fluids. They use venom to immobilize their prey and often eat larger insects like bees, butterflies, and grasshoppers. Their main defense is camouflage. This species was found in the bait bowl near a horse chestnut tree with white blooms.

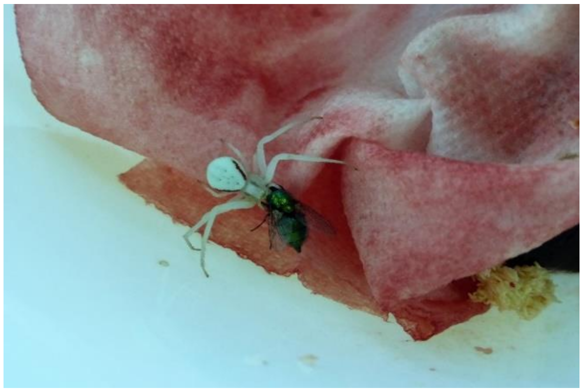

Figure 53. Crab spider (*Misumena vatia*) eating a blow fly.
(Photo by author)

Wildfire Smoke and Fly Activity

The impacts of fire (planned burns, wildfire and agricultural) on insects is widely studied (New 2014; Swengel 2001), but there is little in the literature about the impact of smoke on blow fly oviposition. The direct consequences of fire on insects, in general, is two-fold: the loss of organisms and the loss of resources. The impact of fire may drive populations to extinction through the elimination of individuals, eliminate entire fire susceptible groups, reduce resources so that competition becomes important, and reduce resource variety which may lead to the extinction of feeding specialists and increasing the competition for those resources (New 2014).

Wildfires contribute to air pollution by adding particulate matter to the air. Particulate matter or particulate pollution is the mix of solid particles and liquid droplets in the air. The Pacific Northwest (Washington and Oregon) had a total of 67 wildfires in 2016 and 118 wildfires in 2017 (Northwest Annual Fire Report 2016; 2017). Air quality was impacted by these wildfires. The United States Environmental Protection Agency (EPA) measures and reports particulate matter as a public health service. This data is reported as AQI or Air quality index (Table 20) on a scale of 0 to 500.

AQI	LEVEL
0-50	Good
51-100	Moderate
101-150	Unhealthy for sensitive groups
151-200	Unhealthy
201-500	Hazardous

Table 20. Air quality index levels for reference. ("Spokane Regional Clean Air Agency" n.d.)

The Spokane Regional Clean Air Agency monitors air quality thought out Spokane County via 6 monitoring station and reports it to the Environmental Protection Agency ("Spokane Regional Clean Air Agency" n.d.).

According to the Spokane Regional Clean Air Agency, there were 16 days in 2017 and 0 days in 2016 when smoke from wildfires exceeded health-based air quality standards. Wildfire smoke was observed at the data collection site 1 day in 2016 and 15 days in 2017. On data collection days with moderate AQI, colonization occurred 8 out of 12 days. When the AQI moved into the unhealthy for sensitive people range, colonization occurred all three days. No colonization occurred on the only very unhealthy AQI day although temperatures reached at least 70ºF.

It is unclear whether wildfire smoke had any effect on the oviposition behavior of the blow flies in my study. There is a slight negative correlation (Table 22) between colonization and AQI (-0.102 Pearson's Correlation test). It is possible that the smoke and the chemicals that comprise it inhibit the blow fly's ability to sense VOCs. Although flies were still observed on the smoky days (Table 21), without a count of how many flies attended the bait each day, I have no way of knowing if there were fewer flies on the smoky days. The effect of smoke on oviposition in blow flies is an area where more study is needed.

Descriptive Statistics

	Mean	Std. Deviation	N
COLONIZATION	.73	.449	41
FLIES	.98	.156	41
ADD	75.207	9.0471	41
AQI	.51	.746	41

Table 21. Descriptive statistics AQI, ADD, and ambient temperatures vs colonization. SPSS 25.0 (IBM Corp. 2017)

Correlations

		COLONIZATION	FLIES	ADD	AQI
Pearson Correlation	COLONIZATION	1.000	.261	.239	-.102
	FLIES	.261	1.000	.402	.110
	ADD	.239	.402	1.000	.319
	AQI	-.102	.110	.319	1.000
Sig. (1-tailed)	COLONIZATION	.	.050	.066	.263
	FLIES	.050	.	.005	.247
	ADD	.066	.005	.	.021
	AQI	.263	.247	.021	.
N	COLONIZATION	41	41	41	41
	FLIES	41	41	41	41
	ADD	41	41	41	41
	AQI	41	41	41	41

Table 22. Correlation results between colonization, observation of flies, ADD, and AQI. SPSS 25.0 (IBM Corp. 2017)

Chapter 10: Discussion and Conclusions

Ambient Temperature, Light Intensity, Relative Humidity, and Colonization

This is the first study in Eastern Washington to attempt to predict the likelihood of bait colonization by blow flies using abiotic variables. Using logistic regression, an attempt was made to identify which environmental factors significantly contribute to the prediction of bait colonization within the first 60-90 minutes of bait placement. The most significant positive predictor variable was ambient temperature. Increasing the ambient temperature increases the probability of bait colonization. Light intensity and relative humidity also contribute to the probability of colonization.

Other Factors Influencing Colonization

Overall colonization rates of 34% suggest that there are other factors besides ambient temperature, light intensity, and relative humidity that influence the colonization rates of blow flies. Although logistic regression shows that temperature is one of the most influential predictor variables for colonization, given the relatively high prediction rate of colonization for temperatures over 75°F (greater than 50%), it is possible that this model overestimates the effect of ambient temperature since it does not account for these unknown variables. All other variables aside, if a minimum threshold temperature is not met, colonization will not occur.

Optimal Temperature Ranges for Blow Fly Colonization

While the optimal ambient temperature for egg laying and hatching is about 70ºF (Mann, Bass, and Meadows 1990) egg laying has been observed at ambient temperatures between 53.6 ºF and 86 ºF (Erzinclioglu 1996). Of the 206 colonization events that took place, in my research study, 170 of those events occurred when temperatures were above 70°F and 36 occurred when temperatures were below 70°F and as low as 55°F (Table 23).

Analysis of temperature and colonization occurrence in this study show that the upper-temperature range may be higher than 86ºF for the geographic region of Eastern Washington. Temperatures over 86ºF were observed 48 times during data collection, with colonization occurring 26 of the 48 times (54.2%) at temperatures as high as 104ºF. The temperature range for colonization for this region of Eastern Washington would then be 55ºF to 104ºF.

Temperatures higher than 104ºF did not occur during the experiment period and therefore further studies may increase this upper range. Colonization was not recorded at temperatures below 55ºF although data was collected in temperatures as low as 36ºF. The difference in the temperature range for colonization may be due to regional behavioral differences in species or due to species present. This is further evidence that ranges for each geographic region must be established.

Temp °F	Col Events	Temp °F	Col Events
55	2	66	1
56	0	67	0
57	2	68	6
58	0	69	0
59	3	88	5
60	0	90	6
61	1	91	4
62	0	93	3
63	1	97	2
64	6	99	2
65	0	100	1
66	1	104	3

Table 23. The number of colonization events occurring at temperatures below 70°F and above 86°F.

Conclusions

The goal of this study was to determine which abiotic environmental conditions contribute to the probability of colonization for blow flies in Eastern Washington. Logistic regression shows that ambient temperature, relative humidity, and light intensity contribute to the probability of colonization. Ambient temperature contributes at a more significant level than does relative humidity or light intensity since the predicted probability of colonization within 90 minutes at 75ºF, the average observed temperature, is 0.5015 (50.2%) while the predicted probability of colonization within 90 minutes at 24,000 Lux, the average observed light intensity, is 0.3001 (30.0%) and the predicted probability of colonization within 90 minutes at 48% relative humidity, the average observed light intensity, is 0.3421 (34.2%).

There are most likely other variables besides abiotic environmental ones that influence the probability of colonization, perhaps some that cannot be accounted for by statistical measurement. Given its importance in the developmental phases of the blow fly life cycle, temperature is a significant predictor variable. Without adequate temperature, colonization does not occur at all. Minimum and maximum points for environmental conditions, particularly for temperature, should form the basis, or at least the beginning point, of predicting colonization for use in estimating the postmortem interval in forensic investigations rather than the logistic regressions used in this study. Using the minimum and maximum points for environmental conditions could be used in any geographic region once these thresholds were established locally and for the species present allowing for greater accuracy in the estimation of postmortem interval.

Limitations and Future Studies

Maggots were not collected and grown out to identify species due to space constraints, therefore, identification was limited to observation and review of photos taken during data collection. This means that I was unable to distinguish eggs to species. A study looking at which blow fly species are present in the area where this study was done as well as a timeline of species seasonality would have been helpful.

While mammalian liver is often used in colonization studies, it might not attract blow flies in the same way as human remains. Most oviposition studies using bait other than human remains experience this limitation (Pritam and Jayaprakash 2009). Human remains could possibly yield more accurate results allowing a more precise estimation of the postmortem interval.

As a case study from a specific geographic region, this research adds to the current knowledge of insect succession, life cycles and the effects of variables on those processes and on decomposition as well. Clarifying the initial insect contact period is important in estimating time since death in forensic cases. Without adequate information concerning the period of insect activity (PIA), the understanding of the entire decomposition process is limited. Research which expands the literature of forensic entomology and contributes to the knowledge of legal investigations and proceedings is vital to the understanding of the initial insect colonization of human remains to accurate estimate the postmortem interval and establish the time of death. Insect evidence is generally accepted in legal proceedings. Therefore, law enforcement and legal professionals in both criminal and civil investigations seek expert opinion of forensic entomologists.

Gaps in the postmortem interval allow suspects in homicide cases to be included or excluded based on evidence and alibis. The exclusion of a suspect could allow a suspect to avoid prosecution and punishment for their crime while the inclusion of an innocent person as a suspect could contribute to the conviction and punishment of an innocent person, impeding the legal process. More research studies, specific to geographic regions and to blow fly species and habitat are needed to construct a database for use in the estimation of the postmortem interval in forensic death investigations.

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Appendix A

Data Collection Form

Sheet #:

mm/dd/yy	oo:oo	TT, ST, GR	*F	%	lux	in	mph	hPa	0 or 1	0 or 1	
Date	Time	Location	Temp	Humidity	Light Intensity	Rainfall	Windspeed	Barometric Pressure	Colonization	Flies	Notes

Appendix B

Data Coding Sheet

Date:

MM/DD/YY

Time:

HH:MM

Site:

TT: Tall tree 1,2,3,4,5

ST: Short tree 1,2,3,4,5

GR: Grass 1,2,3,4,5

Ambient Temperature: ℉

Relative Humidity: %

Light intensity: Lux

Rainfall: mm

Wind speed: mph

Barometric pressure: hPa

Colonization:

0: No colonization occurred

1: colonization occurred

Flies:

0: No flies observed

1: Flies observed

Notes:

yj: yellow jacket

h: bald-faced hornet

rtff: red-tailed flesh fly

Appendix C

DATE	TIME	SITE	TEMP	HUM	LIGHT	RAIN	WIND	BARO	COL	FLIES	NOTES
9/15/16	10:46	ST1	79	0.25	59100	0	2	1021.00	0	1	yj
9/15/16	10:50	GR1	61	0.56	3000	0	2	1021.00	0	0	
9/15/16	10:53	TT1	72	0.19	115700	0	2	1021.00	0	1	yj
9/15/16	12:34	TT2	72	0.15	105700	0	4	1021.00	1	1	yj
9/15/16	12:42	GR2	72	0.46	13500	0	4	1021.00	0	1	yj
9/15/16	12:48	ST2	79	0.14	4600	0	4	1021.00	1	1	yj
9/15/16	14:18	TT3	79	0.05	112900	0	9	1018.96	1	1	yj
9/15/16	14:22	GR3	72	0.48	5200	0	9	1018.96	0	1	yj
9/15/16	14:26	ST3	82	0.16	6800	0	9	1018.96	1	1	yj
9/15/16	15:42	TT4	75	0.18	5000	0	13	1018.96	1	1	yj
9/15/16	15:46	GR4	75	0.39	14800	0	13	1018.96	1	1	yj
9/15/16	15:51	ST4	82	0.14	15800	0	13	1018.96	1	1	yj
9/15/16	16:45	TT5	82	0.29	3000	0	13	1017.95	0	1	yj
9/15/16	16:49	GR5	72	0.22	5700	0	13	1017.95	0	1	yj
9/15/16	16:53	ST5	75	0.24	2400	0	13	1017.95	0	1	yj
9/16/16	11:27	TT1	73	0.28	2200	0	4	1016.93	0	0	
9/16/16	11:32	GR1	86	0.21	71500	0	4	1016.93	0	0	
9/16/16	11:37	ST1	75	0.39	66500	0	4	1018.96	0	0	
9/16/16	13:12	TT2	79	0.16	2800	0	13	1016.93	1	1	
9/16/16	13:20	GR2	68	0.40	6700	0	13	1016.93	1	1	
9/16/16	13:25	ST2	91	0.27	92500	0	13	1016.93	1	1	yj
9/16/16	15:06	TT3	81	0.15	2000	0	17	1015.92	0	1	yj
9/16/16	15:11	GR3	72	0.36	5500	0	17	1015.92	1	1	
9/16/16	15:14	ST3	90	0.25	59500	0	17	1015.92	0	1	yj
9/16/16	16:53	TT4	77	0.14	1900	0	16	1014.90	1	1	yj
9/16/16	16:56	GR4	72	0.35	10000	0	16	1014.90	1	0	
9/16/16	16:59	ST4	77	0.35	2800	0	16	1014.92	1	1	yj
9/17/16	10:44	TT1	50	0.98	200	0.02	10	1012.87	0	0	rain
9/17/16	10:45	ST1	52	1.00	600	0.02	10	1012.87	0	0	rain
9/17/16	10:46	GR1	54	0.82	4800	0.02	10	1012.87	0	0	rain
9/17/16	12:20	TT2	54	1.00	200	0.03	10	1012.87	0	0	rain
9/17/16	12:21	ST2	54	1.00	1000	0.03	10	1012.87	0	0	rain
9/17/16	12:22	GR2	55	0.80	3400	0.03	10	1012.87	0	0	rain
9/17/16	13:45	TT3	54	0.98	500	0	14	1011.85	0	0	
9/17/16	13:47	ST3	54	1.00	3300	0	14	1011.85	0	0	
9/17/16	13:58	GR3	55	0.88	11200	0	14	1011.85	0	0	

9/17/16	15:22	TT4	54	0.98	100	0	18	1010.16	0	0	
9/17/16	15:23	ST4	55	1.00	500	0	18	1010.16	0	0	
9/17/16	15:24	GR4	54	0.78	3100	0	18	1010.16	0	0	
9/17/16	16:49	TT5	54	1.00	200	0	14	1010.16	0	0	
9/17/16	16:52	ST5	55	1.00	900	0	14	1010.16	0	0	
9/17/16	16:54	GR5	55	0.79	10000	0	14	1010.16	0	0	
4/3/17	10:38	TT1	36	0.55	3300	0	5	1019.98	0	0	
4/3/17	10:41	GR1	75	0.07	80800	0	5	1019.98	0	1	
4/3/17	10:46	ST1	46	0.46	110000	0	5	1019.98	0	0	
4/3/17	12:23	TT2	54	0.34	87700	0	5	1019.30	0	1	
4/3/17	12:28	GR2	72	0.05	93400	0	5	1019.30	0	1	
4/3/17	12:33	ST2	54	0.37	76000	0	5	1019.30	0	1	
4/3/17	14:10	TT3	54	0.34	34000	0	5	1018.63	0	1	
4/3/17	14:12	GR3	66	0.06	10300	0	5	1018.63	0	1	
4/3/17	14:15	ST3	52	0.35	94900	0	5	1018.63	0	1	
4/3/17	15:42	TT4	48	0.34	4400	0	5	1018.63	0	1	
4/3/17	15:45	GR4	61	0.13	67700	0	5	1018.63	0	1	
4/3/17	15:48	ST4	57	0.36	48000	0	5	1018.63	0	1	
4/3/17	16:54	TT5	45	0.45	4500	0	8	1018.29	0	0	
4/3/17	16:57	GR5	52	0.25	8900	0	8	1018.29	0	0	
4/3/17	17:00	ST5	50	0.44	7700	0	8	1018.29	0	1	
5/31/17	10:36	TT1	63	0.78	700	0	9	1010.16	0	1	
5/31/17	10:33	ST1	68	0.75	10400	0	9	1010.16	0	1	
5/31/17	10:31	GR1	66	0.73	6100	0	9	1010.16	0	1	
5/31/17	12:17	TT2	61	0.78	1400	0	14	1011.18	0	0	
5/31/17	12:15	ST2	64	0.75	3400	0	14	1011.18	0	1	
5/31/17	12:12	GR2	64	0.75	5500	0	14	1011.18	1	1	
5/31/17	14:04	TT3	61	0.80	5000	0	4	1010.50	0	0	
5/31/17	14:01	ST3	63	0.82	3200	0	4	1010.50	0	1	
5/31/17	13:56	GR3	63	0.77	3700	0	4	1010.50	1	1	
5/31/17	15:50	TT4	59	0.82	100	0	9	1010.50	0	0	
5/31/17	15:48	ST4	61	0.82	2200	0	9	1010.50	0	0	
5/31/17	15:46	GR4	59	0.80	2200	0	9	1010.50	0	0	
5/31/17	16:59	TT5	59	0.90	500	0	0	1010.50	0	0	
5/31/17	16:57	ST5	61	0.90	2400	0	0	1010.50	1	0	
5/31/17	16:53	GR5	59	0.82	2500	0	0	1010.50	1	0	
6/2/17	10:50	TT1	63	0.65	500	0	9	1017.95	0	1	
6/2/17	10:53	ST1	70	0.59	98700	0	9	1017.95	0	1	
6/2/17	10:57	GR1	63	0.68	16600	0	9	1017.95	0	1	

6/2/17	12:23	TT2	66	0.55	900	0	7	1018.29	0	1	
6/2/17	12:25	ST2	75	0.42	101600	0	7	1018.29	1	1	
6/2/17	12:28	GR2	68	0.66	13900	0	7	1018.29	1	1	
6/2/17	14:13	TT3	68	0.10	500	0	12	1017.95	0	1	
6/2/17	14:16	ST3	64	0.64	8500	0	12	1017.95	1	1	
6/2/17	14:20	GR3	79	0.50	36500	0	12	1017.95	1	1	
6/2/17	15:20	TT4	68	0.42	500	0	9	1017.60	0	1	
6/2/17	15:21	ST4	68	0.62	3900	0	9	1017.60	0	1	
6/2/17	15:24	GR4	81	0.48	99000	0	9	1017.60	1	1	
6/2/17	16:34	TT5	68	0.39	2400	0	5	1017.30	1	1	
6/2/17	16:36	ST5	68	0.58	2700	0	5	1017.30	1	1	
6/2/17	16:39	GR5	84	0.47	73500	0	5	1017.30	1	1	
6/6/17	10:52	TT1	64	0.65	8100	0	3	1017.60	0	1	
6/6/17	10:55	ST1	64	0.69	6300	0	3	1017.60	1	1	
6/6/17	10:56	GR1	68	0.72	26400	0	3	1017.60	1	1	
6/6/17	12:34	TT2	68	0.65	4600	0	0	1016.90	1	1	
6/6/17	12:39	ST2	64	0.75	3600	0	0	1016.90	1	1	
6/6/17	12:41	GR2	70	0.60	24500	0	0	1016.90	1	1	
6/6/17	14:19	TT3	68	0.56	2600	0	0	1015.90	1	1	
6/6/17	14:21	ST3	66	0.65	1600	0	0	1015.90	1	1	
6/6/17	14:24	GR3	68	0.60	5700	0	0	1015.90	1	1	
6/6/17	15:27	TT4	68	0.60	3400	0	0	1015.20	1	1	
6/6/17	15:29	ST4	68	0.66	2400	0	0	1015.20	1	1	
6/6/17	15:32	GR4	68	0.65	15500	0	0	1015.00	1	1	
6/8/17	11:06	TT1	68	0.68	2200	0.01	0	1004.70	1	1	rain
6/8/17	11:08	ST1	70	0.64	11100	0.01	0	1004.70	0	1	rain
6/8/17	11:09	GR1	70	0.64	36300	0.01	0	1004.70	0	1	rain
6/8/17	12:45	TT2	68	0.58	5300	0.01	9	1004.70	1	1	rain
6/8/17	12:47	ST2	68	0.62	14200	0.01	9	1004.70	1	1	rain
6/8/17	12:49	GR2	70	0.59	52200	0.01	9	1004.70	1	1	rain
6/8/17	14:21	TT3	59	0.70	600	0	9	1007.10	1	1	spider
6/8/17	14:23	ST3	59	0.70	3200	0	9	1007.10	1	0	
6/8/17	14:24	GR3	55	0.86	12600	0	9	1007.10	1	0	
6/8/17	15:50	TT4	55	0.95	200	0	7	1008.80	0	0	
6/8/17	15:52	ST4	57	0.82	2200	0	7	1008.80	0	0	
6/8/17	15:54	GR4	55	0.90	7600	0	7	1008.80	0	0	
6/8/17	17:08	TT5	57	0.92	300	0	2	1008.50	1	0	
6/8/17	17:10	ST5	57	0.76	2500	0	2	1008.50	1	1	
6/8/17	17:13	GR5	55	0.90	8100	0	2	1008.50	1	1	

6/19/17	10:40	TT1	70	0.65	10000	0	3	1017.90	0	1	
6/19/17	10:49	ST1	70	0.62	2700	0	3	1017.90	1	1	
6/19/17	10:51	GR1	72	0.60	35300	0	3	1017.90	1	1	
6/19/17	12:25	TT2	72	0.60	12200	0	2	1017.60	1	1	
6/19/17	12:29	ST2	75	0.58	65300	0	2	1017.60	1	1	
6/19/17	12:31	GR2	79	0.55	104300	0	2	1017.60	1	1	beetle
6/19/17	13:34	TT3	75	0.50	28000	0	0	1016.90	1	1	larva
6/19/17	13:37	ST3	73	0.55	2400	0	0	1016.90	1	1	
6/19/17	13:39	GR3	77	0.54	46500	0	0	1016.90	1	1	beetle
6/19/17	14:48	TT4	86	0.35	97000	0	0	1015.20	1	1	
6/19/17	14:51	ST4	77	0.48	5800	0	0	1015.20	1	1	
6/19/17	14:55	GR4	79	0.52	51100	0	0	1015.20	1	1	
6/19/17	16:03	TT5	88	0.25	78500	0	0	1015.20	1	1	
6/19/17	16:05	ST5	72	0.42	600	0	0	1015.20	1	1	
6/19/17	16:07	GR5	79	0.52	57700	0	0	1015.20	0	1	
6/20/17	10:43	TT1	70	0.75	600	0	0	1013.50	1	1	
6/20/17	10:45	ST1	70	0.65	4200	0	0	1013.50	1	1	
6/20/17	10:47	GR1	72	0.70	23900	0	0	1013.50	1	1	
6/20/17	11:33	TT2	73	0.62	600	0	2	1013.20	1	1	
6/20/17	11:35	ST2	77	0.45	27300	0	2	1013.20	1	1	
6/20/17	11:37	GR2	79	0.63	105100	0	2	1013.20	1	1	
6/20/17	13:08	TT3	79	0.48	1400	0	6	1012.50	1	1	
6/20/17	13:11	ST3	79	0.31	10500	0	6	1012.50	1	1	
6/20/17	13:13	GR3	84	0.42	11600	0	6	1012.50	1	1	
6/20/17	14:30	TT4	79	0.48	1800	0	6	1012.50	1	1	h
6/20/17	14:32	ST4	77	0.28	8500	0	6	1012.50	1	1	
6/20/17	14:34	GR4	91	0.42	109900	0	6	1012.50	1	1	
6/20/17	15:57	TT5	81	0.39	1000	0	4	1011.50	1	1	h
6/20/17	15:54	ST5	90	0.08	83000	0	4	1011.50	1	1	
6/20/17	15:52	GR5	97	0.10	86400	0	4	1011.50	1	1	
6/23/17	11:03	TT1	64	0.35	500	0	3	1024.00	0	1	
6/23/17	11:05	ST1	68	0.36	2200	0	3	1024.00	1	1	
6/23/17	11:06	GR1	86	0.36	116900	0	3	1024.00	1	1	
6/23/17	12:47	TT2	68	0.35	1500	0	8	1023.70	1	1	
6/23/17	12:50	ST2	72	0.29	5100	0	8	1023.70	1	1	
6/23/17	12:52	GR2	79	0.52	125100	0	8	1023.70	1	1	
6/23/17	14:30	TT3	72	0.26	1100	0	8	1023.00	1	1	h
6/23/17	14:33	ST3	75	0.16	88100	0	8	1023.00	1	1	
6/23/17	14:36	GR3	86	0.52	96400	0	8	1023.00	1	1	h

6/23/17	16:05	TT4	72	0.26	900	0	6	1023.00	1	1	
6/23/17	16:07	ST4	75	0.14	55100	0	6	1023.00	1	1	
6/23/17	16:10	GR4	86	0.52	87000	0	6	1023.00	1	1	
6/23/17	17:28	TT5	75	0.36	500	0	9	1021.70	1	1	h
6/23/17	17:25	ST5	72	0.30	1000	0	9	1021.70	1	1	
6/23/17	17:22	GR5	72	0.68	58200	0	9	1021.70	1	1	
6/28/17	10:36	TT1	64	0.60	800	0	2	1010.80	0	1	
6/28/17	10:37	ST1	63	0.76	3500	0	2	1010.80	0	1	
6/28/17	10:39	GR1	73	0.62	85700	0	2	1010.80	1	1	
6/28/17	12:13	TT2	68	0.53	800	0	2	1010.80	1	1	larva
6/28/17	12:16	ST2	73	0.65	4800	0	2	1010.80	1	1	
6/28/17	12:17	GR2	70	0.65	22700	0	2	1010.80	1	1	
6/28/17	13:31	TT3	70	0.53	800	0	2	1010.20	1	1	
6/28/17	13:33	ST3	72	0.63	4100	0	2	1010.20	1	1	
6/28/17	13:34	GR3	70	0.63	5900	0	2	1010.20	1	1	
6/28/17	15:10	TT4	70	0.54	1000	0	4	1009.50	1	1	
6/28/17	15:13	ST4	72	0.76	3200	0	4	1009.50	1	1	yj h
6/28/17	15:15	GR4	70	0.69	8100	0	4	1009.50	1	1	
6/28/17	16:55	TT5	66	0.45	200	0	13	1008.80	0	0	
6/28/17	16:53	ST5	63	0.68	900	0	13	1008.80	0	0	
6/28/17	16:51	GR5	63	0.72	1200	0	13	1008.80	0	0	
6/29/17	10:48	TT1	64	0.73	2300	0	0	1019.30	0	1	
6/29/17	10:53	ST1	64	0.78	4900	0	0	1019.30	1	1	
6/29/17	10:51	GR1	75	0.76	87400	0	0	1019.30	1	1	
6/29/17	12:29	TT2	68	0.66	2900	0	1	1020.00	1	1	
6/29/17	12:33	ST2	72	0.58	105600	0	1	1020.00	1	1	
6/29/17	12:31	GR2	79	0.56	112800	0	1	1020.00	1	1	
6/29/17	14:10	TT3	70	0.65	2700	0	0	1019.60	1	1	yj
6/29/17	14:14	ST3	82	0.35	104200	0	0	1019.60	1	1	
6/29/17	14:13	GR3	82	0.50	118400	0	0	1019.60	1	1	
6/29/17	15:49	TT4	68	0.66	2400	0	0	1019.00	1	1	yj
6/29/17	15:54	ST4	84	0.40	88700	0	0	1019.00	1	1	rtff
6/29/17	15:52	GR4	82	0.40	94800	0	0	1019.00	1	1	
6/29/17	16:55	TT5	68	0.68	1500	0	1	1018.60	1	0	
6/29/17	17:00	ST5	88	0.45	53900	0	1	1018.60	1	1	
6/29/17	16:58	GR5	90	0.54	77600	0	1	1018.60	1	1	
7/5/17	10:45	TT1	68	0.69	1300	0	0	1016.60	0	1	
7/5/17	10:47	ST1	72	0.57	1600	0	0	1016.60	0	1	h
7/5/17	10:50	GR1	86	0.54	90400	0	0	1016.60	1	1	

7/5/17	11:56	TT2	72	0.65	1300	0	4	1016.30	1	1	
7/5/17	11:58	ST2	73	0.60	3000	0	4	1016.30	0	1	
7/5/17	11:59	GR2	81	0.52	99700	0	4	1016.30	1	1	
7/5/17	13:35	TT3	72	0.58	1400	0	2	1015.90	1	1	
7/5/17	13:37	ST3	79	0.47	1500	0	2	1015.90	0	1	
7/5/17	13:39	GR3	91	0.50	104500	0	2	1015.90	1	1	
7/5/17	14:47	TT4	75	0.50	1600	0	0	1015.60	1	1	
7/5/17	14:45	ST4	77	0.50	1300	0	0	1015.60	0	0	h
7/5/17	14:52	GR4	99	0.44	101300	0	0	1015.60	1	1	h
7/5/17	16:00	TT5	77	0.50	1700	0	0	1015.60	1	1	
7/5/17	16:02	ST5	79	0.45	1100	0	0	1015.60	0	1	
7/5/17	16:04	GR5	100	0.44	78600	0	0	1015.60	1	1	
7/6/17	10:47	TT1	73	0.72	1900	0	1	1019.60	0	0	
7/6/17	10:48	ST1	72	0.60	1300	0	1	1019.60	0	0	h
7/6/17	10:50	GR1	86	0.55	87900	0	1	1019.60	0	1	h
7/6/17	12:29	TT2	81	0.64	2200	0	1	1019.00	0	1	h
7/6/17	12:31	ST2	79	0.55	2200	0	1	1019.00	0	0	h
7/6/17	12:33	GR2	104	0.35	95900	0	1	1019.00	1	1	h
7/6/17	13:59	TT3	79	0.58	1800	0	1	1017.90	0	0	h
7/6/17	14:02	ST3	79	0.58	900	0	1	1017.90	0	1	
7/6/17	14:04	GR3	97	0.36	105300	0	1	1017.90	1	1	
7/6/17	15:33	TT4	81	0.69	1700	0	0	1017.60	1	1	h
7/6/17	15:34	ST4	82	0.48	800	0	0	1017.60	1	1	h
7/6/17	15:36	GR4	104	0.25	96000	0	0	1017.60	1	1	h
7/6/17	16:49	TT5	81	0.61	1600	0	0	1016.30	1	1	h
7/6/17	16:51	ST5	81	0.59	800	0	0	1016.30	1	1	
7/6/17	16:53	GR5	104	0.26	74900	0	0	1016.30	1	1	
7/7/17	10:22	TT1	75	0.65	800	0	0	1017.30	0	1	
7/7/17	10:24	ST1	79	0.64	2000	0	0	1017.30	0	1	
7/7/17	10:23	GR1	75	0.70	19400	0	0	1017.30	0	1	
7/7/17	11:28	TT2	82	0.48	2000	0	3	1016.90	0	1	
7/7/17	11:30	ST2	84	0.54	2200	0	3	1016.90	1	1	h
7/7/17	11:32	GR2	88	0.50	121000	0	3	1016.90	1	1	
7/7/17	12:35	TT3	82	0.50	1900	0	4	1016.30	1	1	
7/7/17	12:37	ST3	86	0.55	1900	0	4	1016.30	1	1	h
7/7/17	12:38	GR3	84	0.54	61400	0	4	1016.30	0	1	
7/7/17	13:43	TT4	86	0.41	1300	0	1	1016.30	1	1	h
7/7/17	13:45	ST4	86	0.48	900	0	1	1016.30	1	1	h
7/7/17	13:47	GR4	86	0.54	10100	0	1	1016.30	1	1	

7/7/17	14:51	TT5	90	0.34	2200	0	0	1015.20	1	1	
7/7/17	14:53	ST5	90	0.45	1200	0	0	1015.20	1	1	
7/7/17	14:55	GR5	88	0.55	93700	0	0	1015.20	1	1	
7/10/17	10:17	TT1	72	0.48	5600	0	0	1012.20	0	1	h
7/10/17	10:19	ST1	72	0.65	1000	0	0	1012.20	0	0	h
7/10/17	10:20	GR1	70	0.64	14200	0	0	1012.20	0	1	h
7/10/17	11:53	TT2	77	0.45	2400	0	0	1011.20	1	1	h
7/10/17	11:55	ST2	77	0.59	2200	0	0	1011.20	0	1	
7/10/17	11:57	GR2	79	0.42	110900	0	0	1011.20	1	1	
7/10/17	13:28	TT3	75	0.42	7900	0	5	1010.80	1	1	
7/10/17	13:29	ST3	77	0.54	3300	0	5	1010.80	0	1	
7/10/17	13:30	GR3	75	0.48	4500	0	5	1010.80	1	1	
7/10/17	14:42	TT4	77	0.35	6500	0	5	1011.20	1	1	h
7/10/17	14:45	ST4	77	0.54	3100	0	5	1011.20	0	1	
7/10/17	14:46	GR4	73	0.50	32200	0	5	1011.20	1	1	h
7/10/17	15:52	TT5	79	0.29	4900	0	5	1009.80	1	1	h
7/10/17	15:55	ST5	77	0.49	1200	0	5	1009.80	0	1	h
7/10/17	15:57	GR5	72	0.50	11600	0	5	1009.80	1	1	h
7/11/17	10:37	TT1	64	0.55	700	0	3	1015.60	1	1	
7/11/17	10:41	ST1	68	0.65	800	0	3	1015.60	0	1	h
7/11/17	10:39	GR1	63	0.70	11200	0	3	1015.60	0	1	h
7/11/17	12:15	TT2	68	0.54	1000	0	4	1015.60	0	1	h
7/11/17	12:20	ST2	72	0.60	1300	0	4	1015.60	0	1	h
7/11/17	12:17	GR2	79	0.42	103100	0	4	1015.60	0	1	h
7/11/17	13:28	TT3	72	0.53	1000	0	5	1015.20	0	1	h
7/11/17	13:34	ST3	72	0.58	500	0	5	1015.20	0	0	h
7/11/17	13:31	GR3	84	0.32	107500	0	5	1015.20	1	1	h
7/11/17	14:34	TT4	72	0.48	9500	0	3	1015.20	0	1	h
7/11/17	14:37	ST4	75	0.52	2700	0	3	1015.20	0	1	h
7/11/17	14:36	GR4	86	0.42	96900	0	3	1015.20	1	1	h
7/11/17	16:27	TT5	81	0.46	64600	0	0	1013.90	1	1	h
7/11/17	16:23	ST5	75	0.56	500	0	0	1013.90	0	0	h
7/11/17	16:25	GR5	72	0.62	7100	0	0	1013.90	1	1	h
7/12/17	10:30	TT1	70	0.66	900	0	2	1015.60	0	1	h
7/12/17	10:34	ST1	70	0.50	1000	0	2	1015.60	0	1	h
7/12/17	10:32	GR1	64	0.76	6100	0	2	1015.60	0	0	h
7/12/17	12:07	TT2	73	0.55	1000	0	2	1015.20	0	1	h
7/12/17	12:11	ST2	79	0.39	3700	0	2	1015.20	0	1	h
7/12/17	12:09	GR2	82	0.42	100500	0	2	1015.20	0	1	h

7/12/17	13:14	TT3	75	0.58	1300	0	5	1014.90	0	1	h
7/12/17	13:20	ST3	79	0.35	1300	0	5	1014.90	0	1	h
7/12/17	13:16	GR3	91	0.35	109000	0	5	1014.90	0	1	h
7/12/17	14:22	TT4	79	0.52	1500	0	0	1014.60	0	1	h
7/12/17	14:26	ST4	82	0.26	1500	0	0	1014.60	0	1	h
7/12/17	14:24	GR4	84	0.39	105600	0	0	1014.60	1	1	h
7/12/17	15:36	TT5	81	0.52	1700	0	4	1014.20	0	1	h
7/12/17	15:32	ST5	82	0.24	900	0	4	1014.20	0	1	h
7/12/17	15:34	GR5	79	0.10	23900	0	4	1014.20	1	1	h
7/15/17	10:35	TT1	73	0.60	5900	0	4	1016.60	0	1	yj
7/15/17	10:40	ST1	73	0.64	58300	0	4	1016.60	0	1	h
7/15/17	10:38	GR1	79	0.64	35400	0	4	1016.60	0	1	h
7/15/17	11:57	TT2	72	0.58	8600	0	2	1016.60	0	1	yj h
7/15/17	12:01	ST2	77	0.62	6100	0	2	1016.60	1	1	
7/15/17	12:00	GR2	82	0.65	107000	0	2	1016.60	0	1	h
7/15/17	13:12	TT3	79	0.46	6600	0	3	1021.30	1	1	yj h
7/15/17	13:18	ST3	79	0.56	7000	0	3	1021.30	1	1	
7/15/17	13:16	GR3	86	0.64	115700	0	3	1021.30	1	1	h
7/15/17	14:52	TT4	79	0.61	8500	0	0	1015.20	1	1	yj h
7/15/17	14:57	ST4	79	0.58	4100	0	0	1015.20	1	0	h
7/15/17	14:56	GR4	81	0.62	26600	0	0	1015.20	1	1	h
7/15/17	16:16	TT5	75	0.75	8300	0	0	1014.20	1	1	yj h
7/15/17	16:11	ST5	73	0.71	3700	0	0	1014.20	1	1	h
7/15/17	16:14	GR5	79	0.71	28100	0	0	1014.20	1	1	h
7/16/17	10:53	TT1	68	0.45	4200	0	1	1018.60	0	1	
7/16/17	10:55	GR1	64	0.75	14400	0	1	1018.60	0	1	
7/16/17	11:57	TT2	68	0.41	2500	0	6	1018.30	0	1	h
7/16/17	12:00	GR2	72	0.58	103100	0	6	1018.30	0	1	h
7/16/17	13:35	TT3	70	0.35	3200	0	6	1018.30	0	1	h
7/16/17	13:37	GR3	72	0.60	31500	0	6	1018.30	0	1	yj h
7/16/17	14:52	TT4	70	0.34	12500	0	4	1017.30	0	1	yj h
7/16/17	14:55	GR4	68	0.68	7400	0	4	1017.30	0	1	h
7/16/17	16:00	TT5	73	0.29	2000	0	6	1016.60	0	1	yj h
7/16/17	16:04	GR5	64	0.72	7100	0	6	1016.60	0	1	h
7/17/17	9:51	ST1	68	0.60	66600	0	3	1017.30	0	0	h
7/17/17	9:49	GR1	59	0.65	6000	0	3	1017.30	0	1	h
7/17/17	11:25	TT2	64	0.58	1500	0	0	1017.30	0	0	yj h
7/17/17	11:29	ST2	68	0.57	500	0	0	1017.30	0	1	
7/17/17	11:27	GR2	72	0.56	95300	0	0	1017.30	0	1	yj h

7/17/17	13:03	TT3	68	0.50	900	0	4	1016.60	0	1	h
7/17/17	13:08	ST3	72	0.46	1000	0	4	1016.60	0	0	h
7/17/17	13:05	GR3	81	0.50	102700	0	4	1016.60	1	1	yj h
7/17/17	14:41	TT4	72	0.45	1000	0	4	1016.30	0	1	yj h
7/17/17	14:47	ST4	75	0.44	1700	0	4	1016.30	0	1	h
7/17/17	14:44	GR4	79	0.52	37100	0	4	1016.30	1	1	yj h
7/17/17	16:03	TT5	75	0.42	6100	0	4	1015.60	0	0	h
7/17/17	15:59	ST5	73	0.45	1000	0	4	1015.60	0	1	yj h
7/17/17	16:01	GR5	72	0.55	9300	0	4	1015.60	1	1	h
7/18/17	10:20	TT1	68	0.50	1500	0	3	1016.60	0	0	h
7/18/17	10:24	ST1	70	0.53	1300	0	3	1016.60	0	1	yj h
7/18/17	10:22	GR1	68	0.64	40700	0	3	1016.60	0	1	yj
7/18/17	11:34	TT2	72	0.42	1600	0	5	1016.30	0	1	yj
7/18/17	11:38	ST2	72	0.51	2200	0	5	1016.30	0	1	yj
7/18/17	11:36	GR2	72	0.53	84300	0	5	1016.30	0	1	yj
7/18/17	12:50	TT3	75	0.33	3500	0	1	1015.20	0	1	h
7/18/17	12:54	ST3	77	0.45	2700	0	1	1015.20	0	1	h
7/18/17	12:52	GR3	81	0.27	106500	0	1	1015.20	0	1	h
7/18/17	14:26	TT4	81	0.36	4700	0	0	1014.90	0	1	h
7/18/17	14:30	ST4	79	0.41	2500	0	0	1014.90	0	1	yj h
7/18/17	14:28	GR4	72	0.50	14100	0	0	1014.90	1	1	yj h
7/18/17	16:05	TT5	86	0.28	69600	0	2	1013.90	0	1	yj h
7/18/17	16:12	ST5	79	0.42	1000	0	2	1013.90	1	1	h
7/18/17	16:09	GR5	75	0.58	19800	0	2	1013.90	1	1	yj h
7/19/17	10:20	TT1	68	0.65	1400	0	0	1016.90	0	0	h
7/19/17	10:23	ST1	68	0.52	7500	0	0	1016.90	0	0	yj h
7/19/17	10:21	GR1	72	0.58	86200	0	0	1016.90	0	1	yj h
7/19/17	11:57	TT2	75	0.58	1600	0	4	1016.30	0	1	h
7/19/17	12:02	ST2	75	0.48	4400	0	4	1016.30	0	1	yj h
7/19/17	12:00	GR2	82	0.45	108200	0	4	1016.30	0	1	yj h
7/19/17	13:25	TT3	79	0.55	3000	0	1	1015.60	0	1	
7/19/17	13:30	ST3	79	0.45	2100	0	1	1015.60	1	1	yj h
7/19/17	13:27	GR3	81	0.42	33900	0	1	1015.60	0	1	h
7/19/17	14:41	TT4	81	0.45	78600	0	5	1014.60	0	1	yj h
7/19/17	14:45	ST4	82	0.37	83100	0	5	1014.60	1	1	yj h
7/19/17	14:43	GR4	79	0.50	73300	0	5	1014.60	0	1	h
7/19/17	15:48	TT5	86	0.44	51100	0	1	1013.20	1	1	h
7/19/17	15:54	ST5	81	0.39	2100	0	1	1013.20	0	1	h
7/19/17	15:50	GR5	79	0.44	6600	0	1	1013.20	0	1	yj

7/20/17	10:12	TT1	64	0.62	1300	0	4	1015.90	0	1	yj h
7/20/17	10:18	ST1	68	0.50	43300	0	4	1015.90	0	1	yj
7/20/17	10:15	GR1	72	0.61	92700	0	4	1015.90	0	1	yj h
7/20/17	11:26	TT2	68	0.55	2400	0	5	1016.30	0	1	yj h
7/20/17	11:31	ST2	72	0.44	2000	0	5	1016.30	0	1	h
7/20/17	11:28	GR2	72	0.55	105800	0	5	1016.30	0	1	yj h
7/20/17	12:34	TT3	73	0.40	3500	0	4	1015.90	0	0	yj h
7/20/17	12:39	ST3	77	0.26	101400	0	4	1015.90	0	1	h
7/20/17	12:37	GR3	81	0.47	102300	0	4	1015.90	0	1	h
7/20/17	13:43	TT4	72	0.35	75500	0	7	1015.60	0	1	h
7/20/17	13:47	ST4	75	0.28	4800	0	7	1015.60	1	1	yj
7/20/17	13:45	GR4	72	0.50	20100	0	7	1015.60	0	0	yj
7/20/17	14:52	TT5	79	0.37	73300	0	10	1015.20	1	1	h
7/20/17	14:59	ST5	73	0.25	32200	0	10	1015.20	1	0	h
7/20/17	14:56	GR5	72	0.55	65700	0	10	1015.20	0	1	h
7/24/17	10:52	TT1	68	0.33	1400	0	7	1013.90	0	1	yj
7/24/17	10:27	ST1	68	0.45	1100	0	7	1013.90	0	1	yj
7/24/17	10:54	GR1	77	0.49	93600	0	7	1013.90	0	1	yj
7/24/17	12:15	TT2	72	0.35	1300	0	7	1013.50	0	1	yj h
7/24/17	12:19	ST2	73	0.39	64400	0	7	1013.50	0	1	h
7/24/17	12:17	GR2	77	0.55	104200	0	7	1013.50	0	1	yj
7/24/17	13:27	TT3	72	0.32	1400	0	8	1012.90	0	1	h
7/24/17	13:34	ST3	72	0.37	900	0	8	1012.90	0	1	h
7/24/17	13:32	GR3	72	0.64	10900	0	8	1012.90	0	1	yj
7/24/17	14:39	TT4	72	0.25	1400	0	10	1012.90	0	1	h
7/24/17	14:45	ST4	77	0.30	42400	0	10	1012.90	0	1	h
7/24/17	14:42	GR4	75	0.55	3700	0	10	1012.90	0	1	yj
7/24/17	16:19	TT5	77	0.36	1800	0	6	1011.80	0	1	yj h
7/24/17	16:24	ST5	77	0.30	2300	0	6	1011.80	1	1	h
7/24/17	16:21	GR5	70	0.50	3400	0	6	1011.80	0	1	yj h
7/25/17	10:34	ST1	73	0.53	5900	0	0	1019.90	0	1	yj h
7/25/17	10:31	GR1	72	0.30	94300	0	0	1019.90	0	1	
7/25/17	11:53	TT2	75	0.55	2300	0	1	1019.90	0	1	yj
7/25/17	11:59	ST2	73	0.60	1600	0	1	1019.90	0	1	
7/25/17	11:56	GR2	93	0.25	100300	0	1	1019.90	1	1	yj h
7/25/17	13:24	TT3	79	0.47	8300	0	8	1015.60	0	1	yj
7/25/17	13:29	ST3	75	0.58	1600	0	8	1015.60	1	1	h
7/25/17	13:27	GR3	90	0.24	89300	0	8	1015.60	1	1	h
7/25/17	15:09	TT4	81	0.46	1700	0	4	1014.60	0	1	h

7/25/17	15:13	ST4	79	0.49	1700	0	4	1014.60	1	1	yj h
7/25/17	15:11	GR4	90	0.26	58500	0	4	1014.60	1	1	yj h
7/25/17	16:26	ST5	79	0.22	98300	0	0	1014.60	1	1	yj h
7/25/17	16:24	GR5	86	0.35	49000	0	0	1014.60	1	1	h
7/26/17	9:57	TT1	68	0.70	1800	0	0	1016.90	0	1	yj h
7/26/17	9:59	ST1	72	0.68	3300	0	0	1016.90	0	1	h
7/26/17	9:58	GR1	72	0.63	81800	0	0	1016.90	0	1	
7/26/17	11:26	TT2	72	0.58	1800	0	0	1016.60	0	1	yj h
7/26/17	11:30	ST2	72	0.60	3500	0	0	1016.60	1	1	h
7/26/17	11:28	GR2	82	0.44	113000	0	0	1016.60	1	1	h
7/26/17	12:40	TT3	99	0.47	1900	0	3	1016.30	1	1	yj h
7/26/17	12:44	ST3	79	0.45	2900	0	3	1016.30	1	1	yj h
7/26/17	12:43	GR3	88	0.10	101700	0	3	1016.30	1	1	yj
7/26/17	14:07	TT4	88	0.40	3200	0	0	1015.20	0	1	yj h
7/26/17	14:12	ST4	84	0.41	2500	0	0	1015.20	1	1	h
7/26/17	14:10	GR4	86	0.58	105600	0	0	1015.20	1	1	h
7/26/17	15:47	TT5	84	0.41	2500	0	3	1014.20	1	1	yj
7/26/17	15:53	ST5	82	0.28	3000	0	3	1014.20	1	1	yj h
7/26/17	15:57	GR5	93	0.40	11800	0	3	1014.20	1	1	yj h
7/27/17	10:50	TT1	75	0.63	10200	0	2	1016.60	0	1	yj h
7/27/17	10:53	ST1	77	0.59	17000	0	2	1016.60	0	1	yj h
7/27/17	10:52	GR1	82	0.44	82100	0	2	1016.60	0	1	yj h
7/27/17	12:28	TT2	81	0.54	12800	0	3	1015.60	0	1	yj h
7/27/17	12:32	ST2	81	0.45	3200	0	3	1015.60	1	1	yj h
7/27/17	12:30	GR2	91	0.33	80400	0	3	1015.60	0	1	h
7/27/17	14:08	TT3	86	0.48	3400	0	2	1014.20	0	1	yj
7/27/17	14;11	ST3	84	0.48	113700	0	2	1014.20	1	1	h
7/27/17	14:10	GR3	86	0.40	115700	0	2	1014.20	0	1	
7/27/17	15:17	TT4	82	0.42	1800	0	6	1013.90	0	1	yj h
7/27/17	15:21	ST4	82	0.10	1800	0	6	1013.90	0	1	yj
7/27/17	15:19	GR4	91	0.23	76400	0	6	1013.90	1	1	h
7/27/17	16:25	TT5	84	0.40	4400	0	2	1013.20	0	1	yj h
7/27/17	16:32	ST5	82	0.22	1800	0	2	1013.20	0	1	yj h
7/27/17	16:28	GR5	86	0.25	73000	0	2	1013.20	0	1	yj h
7/28/17	10:19	TT1	72	0.41	600	0	0	1016.30	0	1	yj
7/28/17	10:21	ST1	70	0.45	1500	0	0	1016.30	0	1	
7/28/17	10:20	GR1	72	0.32	93700	0	0	1016.30	0	1	yj
7/28/17	11:25	TT2	73	0.40	800	0	0	1016.30	0	1	yj h
7/28/17	11:27	ST2	72	0.37	1000	0	0	1016.30	0	1	yj h

7/28/17	11:26	GR2	79	0.33	72600	0	0	1016.30	0	1	yj h
7/28/17	12:30	TT3	79	0.30	800	0	6	1015.90	0	1	yj h
7/28/17	12:33	ST3	77	0.40	2300	0	6	1015.90	0	1	yj h
7/28/17	12:31	GR3	81	0.45	800	0	6	1015.90	0	1	yj h
7/28/17	13:33	TT4	82	0.28	2300	0	4	1015.20	0	1	yj h
7/28/17	13:36	ST4	75	0.35	95000	0	4	1015.20	0	1	yj h
7/28/17	13:35	GR4	82	0.42	1300	0	4	1015.20	0	1	yj h
7/28/17	14:44	TT5	90	0.20	6800	0	3	1013.90	0	1	yj h
7/28/17	14:47	ST5	84	0.26	2800	0	3	1013.90	0	1	yj h
7/28/17	14:45	GR5	82	0.12	60300	0	3	1013.90	0	1	yj h
7/31/17	10:23	TT1	72	0.46	1900	0	1	1022.00	0	0	yj h
7/31/17	10:26	ST1	72	0.44	4200	0	1	1022.00	0	1	h
7/31/17	10:25	GR1	88	0.18	73900	0	1	1022.00	0	1	yj h
7/31/17	11:29	TT2	79	0.35	10000	0	0	1022.00	0	1	yj h
7/31/17	11:34	ST2	81	0.47	2300	0	0	1022.00	0	1	yj h
7/31/17	11:32	GR2	93	0.15	95300	0	0	1022.00	0	1	yj h
7/31/17	12:40	TT3	82	0.30	2300	0	9	1021.70	0	1	yj
7/31/17	12:43	ST3	82	0.37	1600	0	9	1021.70	0	1	h
7/31/17	12:41	GR3	97	0.02	108300	0	9	1021.70	0	1	h
7/31/17	13:43	TT4	86	0.27	1600	0	0	1021.00	0	1	yj h
7/31/17	13:47	ST4	79	0.29	1900	0	0	1021.00	0	1	h
7/31/17	13:44	GR4	90	0.12	96700	0	0	1021.00	0	1	h
7/31/17	14:40	TT5	86	0.24	1600	0	2	1020.30	0	1	yj h
7/31/17	14:45	ST5	86	0.27	2100	0	2	1020.30	0	1	h
7/31/17	14:43	GR5	97	0.08	97300	0	2	1020.30	0	1	h
8/1/17	11:16	TT1	79	0.40	0.8	0	0	1020.00	0	1	yj h
8/1/17	11:18	ST1	81	0.35	9800	0	0	1020.00	0	1	h
8/1/17	11:17	GR1	88	0.47	56800	0	0	1020.00	0	1	yj h
8/1/17	12:55	TT2	84	0.28	3500	0	6	1019.00	0	1	yj
8/1/17	12:59	ST2	86	0.28	3600	0	6	1019.00	0	1	h
8/1/17	12:57	GR2	100	0.25	93300	0	6	1019.00	0	1	h
8/1/17	14:35	TT3	86	0.29	6900	0	3	1018.60	0	1	yj
8/1/17	14:40	ST3	86	0.20	6600	0	3	1018.60	0	1	yj
8/1/17	14:37	GR3	93	0.35	5300	0	3	1018.60	0	1	
8/1/17	15:46	TT4	86	0.28	2900	0	4	1017.90	0	0	yj
8/1/17	15:48	ST4	82	0.22	4900	0	4	1017.90	0	1	h
8/1/17	15:44	GR4	99	0.28	44700	0	4	1017.90	0	1	h
8/1/17	17:19	TT5	79	0.33	3500	0	0	1017.30	0	0	yj
8/1/17	17:23	ST5	86	0.30	10000	0	0	1017.30	0	1	h

8/1/17	17:22	GR5	86	0.52	29800	0	0	1017.30	0	1	
8/7/17	10:43	TT1	75	0.55	2100	0	0	1015.20	0	0	yj h
8/7/17	10:45	ST1	75	0.46	3000	0	0	1015.20	0	1	yj h
8/7/17	10:44	GR1	81	0.35	29700	0	0	1015.20	0	0	yj
8/7/17	12:04	TT2	79	0.53	10000	0	2	1015.20	0	1	yj h
8/7/17	12:07	ST2	81	0.48	12800	0	2	1015.20	1	1	yj h
8/7/17	12:05	GR2	86	0.32	45400	0	2	1015.20	0	1	yj h
8/7/17	13:28	TT3	81	0.48	6200	0	0	1014.90	0	1	yj h
8/7/17	13:31	ST3	82	0.39	4900	0	0	1014.90	1	1	yj h
8/7/17	13:30	GR3	86	0.36	24700	0	0	1014.90	1	1	yj h
8/7/17	14:38	TT4	86	0.10	7100	0	1	1014.20	0	1	yj h
8/7/17	14:40	ST4	90	0.25	66700	0	1	1014.20	0	1	yj h
8/7/17	14:39	GR4	82	0.25	20200	0	1	1014.20	0	1	yj h
8/7/17	16:13	TT5	88	0.10	9200	0	0	1013.20	0	1	yj h
8/7/17	16:17	ST5	86	0.25	2300	0	0	1013.20	1	1	yj h
8/7/17	16:15	GR5	86	0.15	19800	0	0	1013.20	1	1	yj h
8/8/17	10:30	TT1	75	0.45	3000	0	2	1015.60	0	1	yj
8/8/17	10:32	ST1	75	0.25	7900	0	2	1015.60	0	1	yj
8/8/17	10:33	GR1	82	0.43	40400	0	2	1015.60	0	1	yj
8/8/17	11:56	TT2	75	0.55	3200	0	5	1014.90	0	1	yj
8/8/17	11:58	ST2	79	0.26	15300	0	5	1014.90	0	1	yj
8/8/17	12:00	GR2	81	0.45	26400	0	5	1014.90	0	1	yj
8/8/17	13:33	TT3	79	0.10	3200	0	0	1014.60	0	1	yj
8/8/17	13:34	ST3	86	0.12	12300	0	0	1014.60	0	1	yj
8/8/17	13:35	GR3	93	0.32	45000	0	0	1014.60	1	1	yj
8/8/17	14:49	TT4	84	0.42	5000	0	2	1013.90	0	1	yj
8/8/17	14:50	ST4	86	0.15	14900	0	2	1013.90	0	1	yj h
8/8/17	14:51	GR4	90	0.35	26200	0	2	1013.90	0	1	yj
8/8/17	16:13	TT5	86	0.45	11000	0	6	1012.90	0	1	yj
8/8/17	16:10	ST5	86	0.18	9700	0	6	1012.90	1	1	yj
8/8/17	16:15	GR5	84	0.45	14800	0	6	1012.90	0	1	yj
8/9/17	10:32	TT1	73	0.52	2500	0	6	1014.90	0	0	yj
8/9/17	10:33	ST1	75	0.50	6100	0	6	1014.90	0	0	yj h
8/9/17	10:34	GR1	81	0.24	29300	0	6	1014.90	0	0	yj h
8/9/17	11:39	TT2	75	0.51	7500	0	5	1015.20	0	1	yj h
8/9/17	11:44	ST2	77	0.50	13600	0	5	1015.20	0	0	yj
8/9/17	11:42	GR2	86	0.12	35500	0	5	1015.20	0	1	yj
8/9/17	13:11	TT3	77	0.55	4400	0	0	1014.60	0	1	yj h
8/9/17	13:12	ST3	81	0.48	16000	0	0	1014.60	0	1	h

8/9/17	13:13	GR3	90	0.32	100300	0	0	1014.60	0	1	yj
8/9/17	14:30	TT4	79	0.55	4000	0	0	1014.60	0	1	h
8/9/17	14:31	ST4	81	0.45	9800	0	0	1014.60	0	1	yj
8/9/17	14:32	GR4	91	0.09	24600	0	0	1014.60	0	1	yj
8/9/17	15:51	TT5	81	0.43	4900	0	0	1013.90	0	1	h
8/9/17	15:53	ST5	84	0.50	11100	0	0	1013.90	1	1	
8/9/17	15:52	GR5	86	0.20	15600	0	0	1013.90	0	1	yj h
8/23/17	10:47	ST1	68	0.66	3500	0	5	1015.60	0	1	yj
8/23/17	10:48	GR1	75	0.40	18400	0	5	1015.60	0	1	yj
8/23/17	12:20	TT2	75	0.55	1600	0	1	1014.60	0	1	yj h
8/23/17	12:21	ST2	75	0.57	6100	0	1	1014.60	0	1	yj h
8/23/17	12:23	GR2	75	0.40	18000	0	1	1014.60	0	1	yj
8/23/17	13:27	TT3	79	0.51	4400	0	4	1013.90	0	1	yj
8/23/17	13:29	ST3	75	0.55	6000	0	4	1013.90	0	1	yj
8/23/17	13:31	GR3	68	0.31	60300	0	4	1013.90	0	1	yj
8/23/17	14:36	TT4	82	0.45	3000	0	4	1013.50	0	1	yj h
8/23/17	14:37	ST4	77	0.50	3600	0	4	1013.50	0	1	yj
8/23/17	14:38	GR4	82	0.25	15700	0	4	1013.50	0	1	yj h
8/23/17	15:39	TT5	84	0.45	15700	0	4	1012.90	0	1	yj h
8/23/17	15:41	ST5	79	0.50	5700	0	4	1012.90	0	1	yj
8/23/17	15:42	GR5	82	0.25	11500	0	4	1012.90	0	1	yj h
8/25/17	10:44	TT1	61	0.37	800	0	4	1017.30	0	1	yj
8/25/17	10:45	ST1	59	0.59	1800	0	4	1017.30	0	1	yj
8/25/17	10:46	GR1	68	0.46	59900	0	4	1017.30	0	1	yj h
8/25/17	12:19	TT2	66	0.32	1000	0	4	1016.90	0	1	yj
8/25/17	12:20	ST2	68	0.51	7100	0	4	1016.90	0	1	yj
8/25/17	12:21	GR2	64	0.52	6300	0	4	1016.90	0	1	yj
8/25/17	13:46	TT3	72	0.22	1300	0	8	1016.60	0	1	yj g
8/25/17	13:48	ST3	68	0.48	3100	0	8	1016.60	0	1	yj
8/25/17	13:49	GR3	81	0.30	86900	0	8	1016.60	0	1	yj
8/25/17	14:43	TT4	79	0.22	10200	0	7	1016.30	0	1	yj
8/25/17	14:45	ST4	72	0.40	5800	0	7	1016.30	0	1	yj h
8/25/17	14:47	GR4	75	0.28	25900	0	7	1016.30	0	1	yj h
8/25/17	15:30	TT5	73	0.15	16300	0	7	1015.60	0	1	yj h
8/25/17	15:32	ST5	72	0.44	16400	0	7	1015.60	0	1	yj h
8/25/17	15:34	GR5	73	0.10	23100	0	7	1015.60	0	1	yj
8/28/17	11:36	TT1	68	0.62	1300	0	0	1017.60	0	0	yj
8/28/17	11:37	ST1	72	0.42	7800	0	0	1017.60	0	0	yj
8/28/17	11:38	GR1	75	0.52	23400	0	0	1017.60	0	0	yj

8/28/17	13:08	TT2	75	0.52	3200	0	0	1016.60	0	1	yj h
8/28/17	13:11	ST2	77	0.30	9100	0	0	1016.60	0	1	yj h
8/28/17	13:12	GR2	84	0.41	47400	0	0	1016.60	0	1	yj h
8/28/17	14:13	TT3	77	0.52	3400	0	0	1015.90	0	1	yj h
8/28/17	14:14	ST3	79	0.33	9600	0	0	1015.90	0	1	yj h
8/28/17	14:15	GR3	82	0.50	24500	0	0	1015.90	0	1	yj h
8/28/17	15:23	TT4	75	0.55	1100	0	0	1014.90	0	1	yj h
8/28/17	15:24	ST4	77	0.35	7300	0	0	1014.90	0	1	yj h
8/28/17	15:25	GR4	97	0.58	14700	0	0	1014.90	0	1	yj h
8/28/17	16:37	TT5	77	0.55	1300	0	0	1014.20	0	1	yj
8/28/17	16:38	ST5	79	0.28	5800	0	0	1014.20	0	1	yj
8/28/17	16:39	GR5	79	0.54	8400	0	0	1014.20	0	1	yj
8/30/17	10:44	TT1	70	0.62	2300	0	0	1011.50	0	1	yj h
8/30/17	10:45	ST1	72	0.42	6700	0	0	1011.50	0	1	yj h
8/30/17	10:46	GR1	75	0.54	35000	0	0	1011.50	0	1	yj
8/30/17	12:06	TT2	79	0.52	2300	0	0	1011.20	0	1	yj h
8/30/17	12:07	ST2	79	0.32	8600	0	0	1011.20	0	1	yj h
8/30/17	12:08	GR2	79	0.51	19800	0	0	1011.20	0	1	yj h
8/30/17	13:42	TT3	81	0.44	5600	0	0	1010.80	0	1	yj h
8/30/17	13:43	ST3	79	0.22	6900	0	0	1010.80	0	1	yj h
8/30/17	13:44	GR3	90	0.43	80600	0	0	1010.80	0	1	yj h
8/30/17	14:52	TT4	86	0.10	5800	0	1	1010.20	0	1	yj h
8/30/17	14:53	ST4	82	0.24	6600	0	1	1010.20	0	1	yj h
8/30/17	14:54	GR4	88	0.41	34900	0	1	1010.20	0	1	yj h
8/30/17	16:14	TT5	86	0.36	19900	0	0	1009.10	0	1	yj h
8/30/17	16;15	ST5	86	0.19	24800	0	0	1009.10	0	1	yj h
8/30/17	16:16	GR5	82	0.43	9100	0	0	1009.10	0	1	yj
9/5/17	11:22	TT1	70	0.49	1800	0	3	1020.00	0	0	yj h
9/5/17	11:23	ST1	72	0.50	8400	0	3	1020.00	0	1	
9/5/17	11:24	GR1	72	0.29	13700	0	3	1020.00	0	0	yj
9/5/17	12:37	TT2	72	0.48	1200	0	7	1019.30	0	1	yj
9/5/17	12:38	ST2	75	0.48	8300	0	7	1019.30	0	1	yj
9/5/17	12:39	GR2	75	0.26	14100	0	7	1019.30	0	1	yj
9/5/17	14:13	TT3	75	0.45	1800	0	3	1018.60	0	1	yj
9/5/17	14:15	ST3	77	0.43	10300	0	3	1018.60	0	1	yj
9/5/17	14:16	GR3	79	0.19	17300	0	3	1018.60	0	1	yj
9/5/17	15:12	TT4	75	0.50	2100	0	4	1018.30	0	1	yj
9/5/17	15:13	ST4	75	0.49	7300	0	4	1018.30	0	1	yj
9/5/17	15:14	GR4	79	0.24	11000	0	4	1018.30	0	1	yj

9/5/17	16:48	TT5	75	0.54	1000	0	3	1017.60	0	1	yj
9/5/17	16:49	ST5	75	0.50	4100	0	3	1017.60	0	1	yj
9/5/17	16:50	GR5	75	0.36	8500	0	3	1017.60	0	1	yj
10/2/17	10:49	TT1	48	0.70	1700	0	2	1019.00	0	0	
10/2/17	10:50	ST1	50	0.72	3600	0	2	1019.00	0	0	
10/2/17	10:51	GR1	50	0.53	12900	0	2	1019.00	0	1	
10/2/17	12:13	TT2	54	0.70	1200	0	4	1019.60	0	0	
10/2/17	12:14	ST2	54	0.66	11000	0	4	1019.60	0	0	yj
10/2/17	12:15	GR2	54	0.50	21200	0	4	1019.60	0	1	
10/2/17	14:45	TT3	45	0.88	100	0.07	3	1019.30	0	0	rain
10/2/17	14:46	ST3	45	0.89	100	0.07	3	1019.30	0	0	rain
10/2/17	14:47	GR3	45	0.90	100	0.07	3	1019.30	0	0	rain
10/2/17	15:23	TT4	46	0.90	1700	0.02	2	1020.30	0	0	rain
10/2/17	15:24	ST4	46	0.93	10000	0.02	2	1020.30	0	0	rain
10/2/17	15:25	GR4	50	0.57	12900	0.02	2	1020.30	0	0	rain
10/2/17	16:30	TT5	45	0.85	100	0	4	1020.00	0	0	
10/2/17	16:31	ST5	43	0.92	1100	0	4	1020.00	0	0	
10/2/17	16:32	GR5	45	0.61	4800	0	4	1020.00	0	0	

Appendix D

MEMO

Dean of the Graduate School
Phone: 650-2884 Fax 650-6811

May 18, 2016

Heather Boswell
℅ Joan Stevenson, Faculty Advisor
Anthropology
Mailstop 9083

Dear Heather,

The Graduate Research Review Committee was impressed by the quality of your project entitled "Predicting the Interval Between Death and Insect Colonization Based on Climatic Conditions" and has recommended full funding for your project in the amount of $1,000.00. The funds are to be expended according to the budget contained in the proposal and any stipulations set forth by the Committee. Expenditures deviating from the award budget must be pre-approved by Kathleen L. Kitto, Dean of the Graduate School. Unless otherwise indicated, any equipment purchased with the grant funds becomes property of the University.

Comments of the Committee: The committee members commend you for your potential contributions to establishing a time of death model for this region. The funds are to be applied to the purchase of the items listed in your proposed budget.

Please contact the Anthropology Department office for instructions to access funds which will be transferred from the Graduate School. This Fund for the Enhancement of Graduate Research Award starts Fall Quarter 2016 unless otherwise stipulated. To start your project earlier, please contact Connie Hernandez, Secretary to the Dean at (360) 650-2884.

Sincerely,

Kathleen L. Kitto

Kathleen L. Kitto
Dean of the Graduate School

cc: Joan Stevenson, Faculty Advisor
Chair: Todd Koetje
Dean: LeaAnn Martin
Graduate School