Final Report
San Diego County Eye Gnat Research and Education Project 2010

Biology and Control of the Eye Gnat
Liohippelates collusor

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RESEARCH PROJECT GOALS 2010

JACUMBA

- Continued surveillance of eye gnat populations
- Determine what effect a trap crop and dry period has in reducing the population
- Examine the range and background levels of eye gnats away from the farm
- Search for possible organically acceptable treatments for Bornt Farms
- Education by providing pertinent publications and information

ESCONDIDO

- Continue to test trap designs and new attractants
- Locating the greatest sources of the gnats by adult and emergence trapping
- Education by providing pertinent publications and information
- Developing a Collaborative Tools site for greater communication with the Escondido Community

BACKGROUND

Eye gnats are prevalent in the Southern United States, primarily in parts of California and Arizona. In San Diego County, especially in the Jacumba and Escondido areas, they have been a problem for many years and are the source of numerous citizen complaints to Departments of Environmental Health - Vector Control, and Agriculture Weights and Measures. Research has determined that local agriculture is the source of the problem, and the community residents are looking to the County for a solution. Eye gnats are problems in other agricultural areas in Southern California and have been extensively studied for more than a century. These nuisance problems have been successfully addressed by identifying the source, altering land management practices, implementing IPM, and conducting a sound public outreach and education program. Those approaches and more have been implemented in Jacumba, and research lead to noticeable reductions in eye gnats in 2009. Research during 2009 suggested additional measures to take in 2010 that were incorporated in the 2010 Eye Gnat Nuisance Prevention Plan. The results herein demonstrate very significant reductions in eye gnats in Jacumba during 2010.

Benefit to the County

In utilizing our technical and expert resources with UCCE, we can more efficiently offer the County's residents easier access to current and applicable information and educational opportunities to understand and manage the eye gnat problem. Increased awareness of this problem, its causes and possible solutions will assist county departments in dealing with citizen complaints.

Introduction

The eye gnat (*Liohippelates* and *Hippelates* spp.) has been a nuisance pest since the turn of the 20th century. *Liohippelates collusor* (Townsend), formerly known as *Hippelates collusor* in the scientific literature, is the primary species in southern California and was implicated in an epidemic of bacterial conjunctivitis (pinkeye) in the Coachella Valley California and in the southern U.S. (Anonymous 1929, Buehler et al. 1983). Eye gnats later created problems in other cultivated areas, such as the Imperial and San Joaquin valleys of California. In addition, they are present in many desert areas of California, such as the Mojave Desert, and could create problems if and when such areas are intensively cultivated and irrigated.

Problems are heightened when irrigated agriculture is in close proximity to urban areas. Research has shown that irrigated agriculture provides good reproductive potential for eye gnat production (Mulla 1963). However, female gnats need a protein food source (mucus, blood, scabs, etc.) in order to produce their young and that protein source is largely unavailable in agriculture. Therefore, since eye gnats can disperse approximately 4 miles both upwind and downwind, humans and domesticated animals living in close proximity to eye gnat producing areas can become a food source.

The community of Jacumba in southeast San Diego County began experiencing a large influx of eye gnats in 2002-2003, and they petitioned the County of San Diego for help. Consensus in the community suggested that the large organic farm that bordered the town was the source of gnats. County personnel along with various University of California personnel were called upon to investigate the situation and developed an action plan, and in 2007-2008, the County supported a full time UC staff member to investigate the eye gnats in Jacumba under the direction of the University of California Cooperative Extension. During 2008 and 2009, two reports were written, and the results were presented to the County, the community and the farm. They are available at the following web site: http://cesandiego.ucdavis.edu/Floriculture_&_Nursery/San_Diego_County_Eye_Gnat_Research_and_Education_Project.htm.

An initial investigation in 2008 indicated that organic farming by Bornt Family Farm was the key source of the eye gnat infestation in Jacumba. Pest management recommendations were made to the farm in an effort to curb the production of eye gnats. During the 2009 production year, a 76% reduction in eye gnats was observed. Further recommendations to the farm were made for the 2010 production year, and those recommendations were used to construct an 'Eye Gnat Nuisance Reduction Plan' by the County.

Herein are the results of the research study during 2010 following implementation of the 2010 Eye Gnat Nuisance Reduction Plan.

EXECUTIVE SUMMARY

JACUMBA

STUDIES ON THE IMPROVEMENT OF TRAP DESIGN

- Painting the bait container of UCCE collar traps (mason jars) black caused a significant increase in attracting gnats.

SUMMARY OF BACKGROUND LEVELS OF EYE GNATS

- Eye gnats were captured in very low numbers in surrounding environments including the community of Boulevard.

POTENTIAL EFFECTS OF DIFFERENT SOILBORNE FOOD SOURCES ON EYE GNAT POPULATION DYNAMICS

- Fresh lettuce and pelletized chicken manure from Bornt Farms that was incorporated into farm soil produced 16% fewer eye gnats (70% survivorship) than the standard rearing method.
- Incorporated dried lettuce produced 47% fewer eye gnats (40% survivorship) than the standard rearing method.

EYE GNAT OVIPOSITION REPELLANCY BY ECOTROL EC

- Ecotrol EC does not repel eye gnats from egg laying in farm soil. Even at high rates sprayed daily, eye gnats deposited an equal amount of eggs per tray compared to an unsprayed control.

EFFICACY OF THREE DIFFERENT ORGANIC INSECTICIDES AGAINST EYE GNAT LARVAE

- A significant decrease in emerging eye gnats was observed in trays treated with Azadirachtin, Neemix 4.5, applied at 8 gallons per acre (4 times the highest recommended rate on the label). No other products applied at higher rates caused any negative effects.

ADULT EYE GNAT POPULATION DENSITY STUDY

- In-town trapping indicates that eye gnat populations have been reduced by >99% from the number of eye gnats captured using the same methods in 2008.
- Full grid sampling that occurred every year in the month of October has also demonstrated a significant reduction in eye gnats has occurred each year from 222.2, to 73.3, to 1.4 eye gnats per trap per day for 2008, 2009 and 2010 respectively.
- Eye gnat trap capture is correlated with the maximum daily temperature, but not with the average daily temperature or the average wind speed.

ESCONDIDO

CONCENTRATION OF EYE GNATS IN SOUTH ESCONDIDO

- Eye gnats were trapped in all areas around the affected area of Lake Hodges including the Pinery, The Vineyard Golf Course, Orfilia Winery, Sunset Hills community, and

Lake Hodges. The highest populations, however, were observed at The Vineyard Golf Course.
- Traps numbers exceeded those observed in trapping studies in Jacumba.
- Emergence traps located on the golf course, Orfilia winery, and Lake Hodges marsh areas did not capture any emerging adult eye gnats.
- Emergence and collar trapping did not occur at a center location in the area, Be Wise Ranch, an organic produce farm. UCCE was not allowed on the property during 2010, although numerous attempts were made.

Extension Activity
- Meetings were attended and data shared to community leaders, the farm, and the county. Information was made available on the Internet.
- A Collaborative Tools site was constructed for greater communication among the county government, the university and the community.

MANAGEMENT PRACTICES RECOMMENDED FOR EYE GNAT POPULATION REDUCTION IN JACUMBA IN 2010 BASED ON RESEARCH CONDUCTED DURING 2008-2009

The key to reducing huge eye gnat populations to background levels is finding the source and implementing all possible mitigations methods. The following recommendations were based on the current knowledge of the situation and the research conducted in Jacumba during 2008, 2009 and partially in 2010. The solutions may only apply specifically to Jacumba due to the uniqueness of the system, the unique separation between the farm and the community and the uniqueness of organic farming so close to a protein source that is largely based on humans and domesticated pets. Other food sources for the flies are minimized at the farm due to the severe impact those animals (rodents, coyotes, deer, etc.) can have on organic vegetable production.

Preliminary Results 2010

- As in 2009, in 2010 it is clear from adult trapping in the community in Jacumba that in every measure, the number of eye gnats in the community has been significantly reduced. Therefore, the measures that were taken in 2010 and recommended from the results of the research conducted in 2009 (barriers, trapping, and trap crop) have had a very significant impact on the population dynamics of the eye gnat. In addition, further improvement in current methods and an earlier start on the methods will enhance the eye gnat population reduction in 2011.

Specific Recommendations August 2010

Barriers

Barriers are still an important part of the nuisance prevention plan. The current black shade cloth barrier that acts like an erosion or dust barrier is approximately 3 feet high. Since our data shows that a majority of the flies stay low to the ground on the farm due to the lack of refuge,

that the barrier will still pose a hindrance to eye gnat movement between the farm and the community.

- The barrier between the farm and the community needs to be maintained for the length of the farm from the Mexican border to the northern border of the farm.

Trapping

The present trap produced and modified (due to the 2009 research) by Bornt is highly effective when maintained.

- Some traps need to have their plastic tops replaced due to cracks and holes in the sides and corners due to wear and tear and degradation due to the sun.
- Traps need to be maintained on a weekly basis, i.e. addition of new solution, replace broken parts, etc.
- The present inundative trapping is effective. The following methods that were in place during the 2010 season need to be maintained: 2000 traps total, 1000 of them are to be 10 feet apart, 10 feet from the black erosion cloth barrier, and a second row that parallels the first but staggered. Both rows should be within the treated buffer zone, and both rows should extend from the Mexican border to the north most end of the farm.
- The farm, at their discretion, can increase the number of traps where possible, and it is encouraged. Additional trapping that would not hinder the farm's production could begin on the eastern edge of the farm.
- To enhance the capture and removal of eye gnats from the population, mass trapping should begin in the community. Research results from 2009 suggest that the eye gnats are concentrated 1,000 feet on either side of a line that separates the farm and the community. Therefore, trapping should be conducted on a grid that extends 1,000 feet into the community beginning in the community at the south most end of farm production to the north most end of the community by the railroad tracks. The density at present is 1 trap per 1,000 linear feet. The number of traps should be increased to a minimum of 4 traps per 1,000 linear feet. In addition, two locations have concentrated eye gnat populations; the spa and the school. Trapping should occur there as well. The Bornt Farm designed trap is highly effective, and should be used for community trapping.
- Trapping should begin on March 1st or prior to any watering or agricultural operations.

Chemical Control

Laboratory studies conducted in small scale trials during the 2009 season indicated that selected organic pesticides applied to rearing media caused mortality to eye gnat maggots. However, further larger scale studies using soil from the farm have indicated that the organic pesticides had no effect on eye gnat maggots and adult emergence. In addition, the pesticides were tested at 4 times the recommended rate and at applications as often as every other day. Therefore, we must conclude that the organic pesticides recommended in the 2010 eye gnat nuisance prevention plan were ineffective and should not be required in the 2011 Plan.
Further testing of other organic pesticides will continue in the hopes of finding an effective product that can be used against one of the stage of this insect.

Buffer Crop or Buffer Zone

We have been referring to the alfalfa/corn, conventionally, treated crop as a trap crop. Unfortunately, that definition does not provide a proper description of the crop and would cause confusion. Therefore, the crop will be referred to as a buffer crop or buffer zone (see part F - http://www.mosesorganic.org/attachments/productioninfo/fstranscrop.html). The present buffer zone can be treated conventionally and harvested for conventional use by the farm if they so desire. The buffer zone should be treated weekly and products rotated among the following for best results: carbaryl, acephate, and cyfluthrin. They are a carbamate, an organophosphate, and a pyrethroid respectively.

The buffer zone should remain as is with the following exceptions:

1) The present configuration is three rows of alfalfa and one row of corn repeated three times. Corn is not working as an effective barrier. Therefore, the corn can be removed and replaced by alfalfa. That means that there will be 12 rows of alfalfa total.
2) Alfalfa has been used as the buffer crop of choice, but any plant that can be an effective barrier is acceptable. The choice of buffer crop can be modified through the approval of UCCE and San Diego County Vector Control.
3) The buffer crop can be cut in rotation so that there are at least half of the rows at their tallest at any one time.
4) The tallest buffer crop can be as tall as allowed by conventional spray equipment. That means that the tallest buffer crop can be from 2 feet to 4 feet high.
5) The buffer crop can be cut as short as necessary so that the crop does not need constant cutting, mowing, or trimming.

Cultural Control Methods

Change in Fallow Period Terminology. Again, the use of the term 'fallow period' has caused confusion. Therefore, we recommend that since water is key to the development of eye gnat populations, we call the 'fallow period' a 'dry period' instead. Therefore, when we refer to the break in production, we will refer to it as a 'dry period' and it will refer to the length of time that the ground is not irrigated.

Dry Period. Insect development and life cycles are affected by temperature. The warmer it is the faster they develop, and consequently they have more generations in a single year. Therefore, utilizing a dry period during the hotter months of the year (approximately June-Sept) will break the generational cycle and reduce eye gnat populations during the season and over time.

- No water/irrigation should occur on blocks taken out of production during the 6-week continuous dry period. However, other farming operations can be conducted as normal, fertilizing, bed shaping, etc.
- For the crop to be considered in the 'dry period', the crop should be harvested and require no more watering and fresh organic matter should not be tilled under into the soil.
- The farm can successively drop portions of the farm out of production and back into production at their discretion, so long as each plot is out of production in a 'dry period' for at least 6 weeks.

Other Cultural Control Methods.

- Reduce organic matter production by drying the cut crop or burning the crop residue on the bed. Research lacks in the area of how deep tilling effects eye gnat populations. However, it is encouraged until data is available.
- Weed control needs to be by herbicides not tilling. Our research shows that even dry plant matter can cause eye gnat production.
- Our research also shows that the fertilizer used on the farm (pelletized chicken manure) produces similar numbers of eye gnats as dry plant matter. Therefore, fertilizing watering and tilling all enhance eye gnat production in this system.

Changes in practices need to be monitored for effectiveness and future research must accompany the new practices.

STUDIES ON THE IMPROVEMENT OF TRAP DESIGN

It was observed that the farm built collar traps not only included a black collar, but also a black bait container. A trial was designed to test whether painting the glass mason jars used in the UCCE collar trap, would increase the efficiency of the trap. Six stations were chosen (3 in town and 3 at the farm) where the modified traps were placed in close proximity to the regular UCCE traps. Both the jar and duct tape used to hold the trap on the stake were spray painted black.

Table 1. Total numbers and averages of adult eye gnats trapped in collar traps with either a clear of black bait container. Traps were paired and placed at three locations in-town and three locations at the farm.

Date	Bait Container Color	Station #1 in town	Station #3 in town	Station #6 in town	Farm office	S. field	N. field	Ave. # of gnats caught/day
5/13-5/20	Black	96	227	3177	151	313	125	97.36
	Clear	9	8	51	36	225	349	16.14
5/20-5/27	Black	2	3	67	21	3	40	3.23
	Clear	0	0	3	13	5	5	0.62
5/27-6/3	Black	61	35	45	n/a	16	21	5.09
	Clear	2	4	0	39	24	25	2.24
6/3-6/10	Black	11	0	n/a	5	32	12	1.71
	Clear	0	14	1	104	16	2	3.26
6/10-6/17	Black	0	2	2	7	0	0	0.26
	Clear	0	0	2	6	1	1	0.24
6/17-6/24	Black	0	3	7	10	0	0	0.48
	Clear	0	0	52	0	2	1	1.31

Table 2. Mean adult eye gnat trap catch for collar traps with black or clear bait containers.

	Mean no. (±SE) of eye gnats/trap		**Analysis of Variance[1]**			
Date	**Black**	**Clear**	**Source**	**df**	**F value**	**Prob.**
5/13-5/20	681.5 ± 500.0	113.0 ± 57.7	Bait Container color	1	7.23	0.0099
5/20-5/27	22.7 ± 10.8	4.3 ± 2.0	Week	5	20.87	<0.0001
5/27-6/3	35.6 ± 8.2	15.7 ± 6.5	Placement	5	3.81	0.0055
6/3-6/10	12.0 ± 5.4	22.8 ± 16.5	Bait Cont Color*Week	5	1.51	0.2029
6/10-6/17	1.8 ± 1.1	1.7 ± 0.9	Bait Cont Color*Placement	5	1.71	0.1512
6/17-6/24	3.3 ± 1.7	9.2 ± 8.6				
Pooled Over Dates	**132.2 ± 93.0a**	**27.8 ± 11.5b**				

[1] Data were log (x+1) transformed prior to analysis of variance.

Results- Bait container color had a significant effect on the number of eye gnats captured over time (Table 2). There is a clear indication that the black color on trap parts increases trap catch as was observed in our 2009 research. In addition, the placement of the traps (In-town or Farm) and the week of sampling also had an effect on the number of eye gnats captured. This is expected since conditions within the town and the farm are different and the weather conditions vary from day to day. There were no interactions among bait container color and either week or placement, which means that the variance among trap catches could be explained by the main effects (bait container color, week, or placement) individually. In other words, you would not have to know both the placement of the traps and the color of the bait containers before explaining why there is a difference in trap catch.

SUMMARY OF BACKGROUND LEVELS OF EYE GNATS

Objective- Determine how prevalent eye gnats are in the natural environment away from the influence of agriculture. Eye gnats have been documented to travel up to 4.3 miles away from origination (Mulla, March 1959).

Collar traps were placed in areas away from Jacumba to pick up any eye gnats that may be present (Photo 1) in the surrounding environment. Two collar traps were placed in the community of Boulevard (Blvd FS and Blvd Elem), about 7 miles northwest from Jacumba. Boulevard is approximately 1000 feet higher in elevation than Jacumba. The environment consists of oak trees and grasses as compared to the desert like climate in Jacumba. Temperature is usually between 5-10 degrees cooler than in Jacumba. Because the school in Jacumba seems to be a hot spot for gnats, we placed one trap near the elementary school in Boulevard (Blvd Elem). A total of eleven gnats were caught during the period from April-September 2010. There was no particular time when they were more numerous. Five gnats were caught during the season at the second sight near the Boulevard Fire Station (Blvd FS).

The next site was approximately 2-miles west of the border of the farm (Photo 1, West). It was located near a horse stable. This site caught 68 gnats during the season.

A set of six collar traps was established approximately 2.5 miles east of eastern border of the farm (Photo 1, NW, S, SW, N, NE, SE). This was the largest area nearest to the farm that matched the native habitat. The area averaged 500 feet higher in elevation than the farm. The area sampled was approximately 420 acres (3300 ft X 5500 ft). Even though the area was within the flight range of the eye gnat, it was separated by a large hill from the farm and considered isolated from the influence of the farm. Six eye gnats were caught during the 2010 season. They were caught mostly in northern traps during the month of July.

The last traps were placed along Carrizo Gorge Road. This road runs through a valley following the old train tracks. The first trap was directly north of the farm approximately one half mile from the north edge (Carrizo South). The second trap was approximately 1.25 miles from the northern edge of the farm (Carrizo North). The southern trap collected 272 eye gnats during the 2010 season. The northern trap collected nearly 1/3 less at 92 gnats.

Conclusions from the data suggests that eye gnats are present in the natural environment but at very low numbers. Even at a considerable distance from the farm, eye gnats were found, especially if a food source was near (i.e. people, horses, and children). The traps on Carrizo Gorge Road suggest that the gnats are coming from the farm with higher densities caught closer to the farm and lower densities caught further away.

POTENTIAL EFFECTS OF DIFFERENT SOILBORNE FOOD SOURCES ON EYE GNAT POPULATION DYNAMICS

Objective- To determine what effect, if any, different types of soil-borne plant matter and manure sources have on the survivorship of eye gnat larvae. It was determined from previous trials that eye gnats are not attracted to the odor emitted by the composted chicken manure used as fertilizer. However, it was not known whether the fertilizer was a food source for the gnat larvae in the soil. In addition, it is not known whether drying the refuse on the soil surface has an impact on eye gnat production, if it is tilled under for the next crop.

Materials & Methods. The trial was conducted using 1-pint glass mason jars as the experimental unit, and there were four replicates per treatment. Each jar was filled with vermiculite and one teaspoon of Baker's Yeast as a base substance for eye gnat larvae development. The standard eye gnat rearing method is to add powdered rabbit food to the vermiculite and yeast (Mulla 1962), and the survivorship of the eye gnats added to the standard rearing method was compared to the treatments.

The products added to the base substance as treatments were as follows: fresh lettuce used by Bornt Farms @ 1 oz/jar, oven dried lettuce @ 1 oz/jar (to simulate drying crop residue on surface before incorporation), and pelletized chicken manure used by the farm @ 1 oz/jar. An untreated control group was added that only contained the vermiculite and not the yeast. The jars were kept in an environmental chamber with constant temperature (25°C ± 1) and humidity (70%).

Table 3. Mean number and percent (±SE) survivorship of eye gnat larvae in Bornt Farm soil treated with selected types of food sources. N = the number of eggs deposited into the soil of each treatment.

Food Source[1]	N	Mean no. of emerged eye gnats	Mean Percent Survivorship[2]
Chicken Manure	650	113.5 ± 13.6	69.7 ± 6.5 b
Dried Lettuce	834	90.0 ± 18.9	39.9 ± 7.1 c
Fresh Lettuce	881	144.0 ± 15.2	70.0 ± 8.3 b
Standard Rearing	770	164.5 ± 17.0	86.0 ± 4.4 a
Yeast	1024	11.5 ± 5.1	4.4 ± 1.8 d
UTC Vermiculite	710	0.2 ± 0.2	0.1 ± 0.1 e

[1] One ounce of each food source was applied to each jar of vermiculite. Yeast was added to all treatments except UTC at a rate of one teaspoon per jar.

[2] Data were transformed arcsine(sqrt(x)) prior to analysis. Means within a column followed by different letters are significantly different, LSD (p=0.05), ANOVA $F=64.30;df=5,15;\ P<0.0001$.

Results

The standard rearing formulation of rabbit food and yeast produced significantly more adult eye gnats than any other treatment, 86% survivorship (Table 3), However, pelletized chicken manure and fresh lettuce used by the farm produced only 16% fewer eye gnats, 70% survivorship. When lettuce is dried and incorporated into the soil, it will produce significantly fewer eye gnat adults than fresh lettuce or pelletized chicken manure, but it still produce good eye gnat numbers because survivorship of eye gnat larvae is still consequential at approximately 40%. The addition of the two control treatments in this study indicated that the rearing of eye gnats was not due to either the vermiculite alone (0.1% survivorship) or the vermiculite with yeast added (4% survivorship), but instead was due to the treatments, the added organic matter.

EYE GNAT OVIPOSITION REPELLANCY BY ECOTROL EC

Objective- It has been documented in scientific literature that herbicidal oils sprayed on weeds discouraged gnats from laying eggs (Mulla et al. 1965). This trial was designed to determine if Ecotrol EC, which is composed of various plant essential oils, would have any effect on eye gnat oviposition.

Materials & Methods- Six trays (20 in. X 10 in., Photo 2) were filled with soil collected from Bornt Farm in Jacumba. Six trays in three cages, two trays/cage (BugDorm, BioQuip, 2321 Gladwick Street, Rancho Dominguez, CA 90220, Photo 3), were used in this study. One tray was treated with Ecotrol EC (now sold as Ecotec EC), and one was left untreated. The eye gnats present in the cage would then have a choice in which to deposit their eggs. In the first cage, one of the trays was sprayed a single time with approximately 25-ml of Ecotrol EC at a concentration of 1-ml Ecotrol EC per 200-mls water (1 gallon Ecotrol/acre). This cage contained 534 adult eye gnats during the seven-day exposure. In cage two, one of the trays was sprayed every other day (4 times) with the same solution and contained 724 eye gnats during the length of the exposure. In the final cage, one of the trays was sprayed every day (7 times) and contained 660 eye gnats during the length of the exposure. At the conclusion of seven days, all adult eye gnats were removed and each tray was placed in its own clean cage and held until all eye gnats had developed into an adult and emerged from the trays. The total number of eye gnats emerging was recorded for each tray and would represent a preference for treated verses untreated soil to deposit their eggs.

Table 4. Adult eye gnat counts on 7/28/2010.

	Number Of Gnats	% Difference From Untreated
Cage 1 Treated	491	
Cage 1 Untreated	508	2%
Cage 2 Treated	413	
Cage 2 Untreated	479	7%
Cage 3 Treated	578	
Cage 3 Untreated	640	5%

RESULTS

This study suggests that even if Ecotrol EC was sprayed every day for a week at 1 gallon per acre, that it would only reduce the number of gnats emerging by a maximum of 7%. Ecotrol EC does not appear to repel eye gnats from ovipositing on sprayed soil. Considering the cost of application of this product, it will not be a feasible solution.

EFFICACY OF THREE DIFFERENT ORGANIC INSECTICIDES AGAINST EYE GNAT LARVAE

Objective- To determine the efficacy of selected organic insecticides to the larval stage of eye gnats in Bornt Farm soil.

Materials &Methods: Soil from Bornt Farms was collected and transported to the greenhouse at the Center for Applied Horticulture Research. The soil was sifted to remove as much organic matter and debris as possible. Trays measuring 10" X 20" X 3" (Photo 2) were filled with the soil, and seventy-five grams of powdered rabbit pellets as a food source was mixed into the soil in each tray. The amount of insecticide (Table 5) needed to treat the square footage of each tray was determined, mixed with 1000-mls of water, and applied to the tray. Eye gnat eggs obtained from a colony raised at the Center of Applied Horticultural Research were counted and applied to the treated trays. The number of eye gnat eggs added to each tray was recorded. The trays were then placed in a cage (BugDorm, BioQuip, 2321 Gladwick Street, Rancho Dominguez, CA 90220, Photo 3) and placed in a greenhouse. The trays were periodically watered and kept moist. The gnats were allowed to develop to an adult in the trays and emerge in the cages. Following the emergence and death of all eye gnats in each cage, they were collected and counted. This number was compared to the number of eggs added to each tray.

Table 5. Organically labeled chemicals tested as larvicides against eye gnat larvae in Bornt Farm soil.

Trade Name	Formulation	Active ingredients		Max. label rate
Ecotrol (Ecotec)	G	Clove Oil Thyme Oil Cinnamon Oil	2% .66% 1.0%	28 lbs/a band treatment
Entrust Naturalyte	powder	Spinosad	80%	3 oz/a foliar (max 9 oz/crop)
Neemix 4.5	liquid	Azadirachtin	4.5%	2 gal/ for subsurface pests

Results

There were no significant differences in the mean number of emerged eye gnats in soil treated with Ecotrol G or Entrust when compared to the results from the untreated control. Neemix 4.5, however, significantly reduced eye gnat emergence when appllied at 8 gallons/acre (four times the maximum labeled rate). These tests are ongoing to determine at what rate and at what stage these chemicals have effect on eye gnat larvae. Our results to date suggest that there can be an effect by these pesticides, but at rates much higher than labelled rates and at a much greater cost than is feasable.

Table 6. Mean number of emerged adult eye gnats and mean percent emergence (±SE) from eggs placed in treated Bornt Farm soil.

Treatment (8/19-9/22)	Rate in Ounces/acre	N	Mean No. of Emerged Eye Gnats	Mean Percent Emergence[1]
UTC	0	704	85	49.7 ± 8.4a
Entrust	3	671	99.5	59.0 ± 1.5a
Entrust	6	998	98	39.3 ± 3.8a
Entrust	12	713	69.7	39.2 ± 3.4a
Treatment (6/22-7/28)	**Rate in Pounds/acre**	**N**	**Mean No. of Emerged Eye Gnats**	**Mean Percent Emergence[1]**
UTC	0	1253	112	44.3 ± 4.9a
Ecotrol G	56	1227	91	38.1 ± 6.5a
Ecotrol G	224	1235	80.2	32.2 ± 4.5a
Treatment (10/1-11/8)	**Rate in Gallons/acre**	**N**	**Mean No. of Emerged Eye Gnats**	**Mean Percent Emergence[1]**
UTC	0	725	62.5	35.0 ± 7.6a
Neemix 4.5	2	710	55.5	31.1 ± 14.2a
Neemix 4.5	4	457	37.8	33.0 ± 6.5a
Neemix 4.5	8	395	9.2	8.7 ± 3.2b

[1]Means followed by different letters are significantly different, LSD (p=0.05).
Entrust; F = 3.11; df = 3,9; P = 0.0815
Ecotrol G; F = 1.43; df = 3,9; P = 0.2953
Neemix; F = 4.27; df = 3,9; P = 0.0392

ADULT EYE GNAT POPULATION DENSITY STUDY

Objective: To determine where eye gnat adults are most concentrated using geo-positioned trapping, and to determine whether the nuisance prevention plan is having a significant effect on eye gnat adult populations.

Materials and Methods

Collar trap design: We used the same UCCE 8-hole collar traps in this study that we used in the 2008 and 2009 study so that we can make comparisons.

Experimental Design and Sampling

Full Grid Sampling. We used the same experimental design that was used in 2008 except that we excluded eastern most traps because they did not capture any eye gnats in 2008. In October 2010 as in October 2008 and 2009, collar traps were placed in the same grid pattern 1000 feet apart extending from the east end of the farm to the west end of the town of Jacumba, and from the north end of the farm to the Mexican border (Photo 4, all three years). The traps were taped to a 3-foot stake, filled with putrefied egg bait, and left for 48 hours. Following the 48-hour period, the traps were collected, capped and brought back to the laboratory so that the number of eye gnats could be counted under a microscope. Numerous other fly species are recovered in the trapping, and eye gnats need to be counted separately.

Population Monitoring the In-Town Traps. In the initial 1000-foot grid in 2008, 12 of the traps were west of the farm and considered "In-Town" (Photo 5). Only one trial was conducted in 2008 on October 28-30 to serve as a base line capture of eye gnats. During 2009, these same twelve traps were tested once a month during months of heavy eye gnat infestations, July, August, September, and October (during the Full Grid Sampling). During the 2010 season, nine of the twelve collar traps were monitored throughout the season and we conducted the same 12-trap full grid sampling in October as in 2008 and 2009.

Correlations with Temperature and Wind Speed. Data were collected from the local CIMIS Station located at Otay Lake for comparisons of adult eye gnat trapping and temperature and wind speed.

Statistical Analysis: Data were analyzed using analysis of variance (Proc GLM, Statistical Analysis Systems, SAS version 9.1) and Pearson's Correlation (Proc Corr). Data for grid sampling were transformed log(x+1) prior to analysis to satisfy the assumptions of the analysis. Means were separated using Fisher's Least Significant Difference ($p = 0.05$). Correlations were performed on untransformed weather data.

Results

Full Grid Sampling: Data for the full grid sampling in October 2008, 2009, and 2010 are presented in Table 7. The average number of eye gnats caught per trap per day was 222.2, 73.3, and 1.4 for 2008, 2009, and 2010 respectively. A significant decrease in the number of eye gnats captured per year was observed when comparing the three years with each year being

significantly fewer eye gnats captured than the previous year (Table 7). Trap numbers 10, 11 & 12 collected the most gnats during the 2010 sampling. These traps are located near the southwest corner of the farm.

As in previous years, traps were grouped to ascertain any trends in eye gnat populations in the area (Table 8). Trends were similar to previous years, but the very small numbers captured in 2010 makes it difficult to make any inferences from the data.

Population Monitoring the In-Town Traps. Figure 1 demonstrates the impact of the nuisance prevention plan on the eye gnat population in-town during the month of October for all three years of sampling. There is one data point for 2008, four for 2009, and weekly sampling during 2010. As is represented in the previous results for 2010, the eye gnat numbers in town are significantly lower than in the previous two years. In addition, there were only two minor spikes of about ten eye gnats/trap/day in early June and early July. Less than one eye gnat per trap per day was observed in the majority of the weekly sampling during 2010.

Correlations with Temperature and Wind Speed. Eye gnat populations were weakly correlated with Average Temperature and Average Wind Speed at $p=0.10$, but are not considered significant correlations apriori $p=0.05$ and would not be considered a good predictor of daily eye gnat populations (Table 9). However, there is a significant correlation of adult eye gnat capture in collar traps and daily maximum temperature ($P = 0.0148$, $r = 0.49$).

Table 7. The total number of eye gnat adults captured per trap in 2008-2010 during the month of October. The GPS coordinates and a description of the area where the collar traps were placed are also provided (see Figure 8 for an aerial view and trap position).

Trap #	Description of Collar Trap Locations	(N)	(W)	Oct 28-30,2008 # Gnats	Oct 21-23,2009 # Gnats	Oct 27-29,2010 # Gnats
1	South of Water District building, North riverbed	32 37.224	116 11.575	335	491	1
2	West side of dried pond	32 37.054	116 11.570	207	18	0
3	East side of school	32 36.889	116 11.594	353	463	1
4.5	Behind school near border west side of hill	32 36.715	116 11.614	64	24	1
5	Next to big boulder (shrubs)	32 36.897	116 11.373	100	32	2
6	Behind red house near border	32 36.750	116 11.342	338	48	n/a
7	Corner of Railroad and Hwy 80	32 37.062	116 11.381	442	347	1
8	South of Seely in neighborhood dry	32 37.226	116 11.368	189	165	2
9	Near corner of Carrizo and Brawley	32 37.229	116 11.176	692	75	0
10	Hwy 80 across from Community Park	32 37.065	116 11.175	679	59	6
11	East of ball field on hill	32 36.904	116 11.178	291	122	5
12	Along border road shrubs	32 36.736	116 11.184	112	74	6
13	South western border road mid field	32 36.908	116 10.984	128	n/a	0
14	Mexican border SW farm	32 36.254	116 10.992	309	n/a	0
15	Corner of farm and Hwy 80	32 37.066	116 10.985	354	0	0
16	Side of farm road north field	32 37.237	116 10.980	571	28	2
17	End of road near RR tracks shrubs	32 37.406	116 10.973	45	20	0
19	Mid field south of Hwy 80 western block	32 36.899	116 10.792	207	35	0
20	Along Hwy 80 by irrigation 26	32 37.068	116 10.785	334	0	0
21	Along Hwy 80 north side mid ranch	32 37.066	116 10.592	122	39	0
22	North of trap 21 mid field	32 37.256	116 10.588	194	0	0
23	North of trap 20 mid field	32 37.262	116 10.782	233	1	0
24	North of trap 22 mid field	32 37.440	116 10.583	156	0	0
25	North of trap 23 in weedy uncultivated area	32 37.440	116 10.779	207	3	1
26	North of trap 24 near mid farm vegetative area	32 37.631	116 10.579	83	5	0
28	North of trap 28 north field	32 37.806	116 10.578	38	24	0
29	Along north western border	32 37.636	116 10.763	87	99	0
30	North of trap 29	32 37.813	116 10.745	61	53	0
31	Middle of south field	32 36.877	116 10.596	160	5	0
32	Near farm entrance along Hwy 80	32 37.068	116 10.391	150	n/a	0
33	Along eastern farm border road	32 36.897	116 10.395	29	3	0
37	Mexican border road below trap 19	32 36.768	116 10.793	33	42	2
38	South of trap 31 along border road	32 36.787	116 10.593	0	47	0
39	South east corner of farm field along border	32 36.804	116 10.386	28	1	0
40	Just west of farm office in field	32 37.200	116 10.384	143	12	0
41	In field north of trap 40	32 37.412	116 10.364	215	3	0
42	On hill side north of trap 41	32 37.626	116 10.361	17	31	3
49	Jacumba Spa north east lawn	32 37.111	116 11.303	738	197	18
	Average number of gnats/trap/year[1]			**222.2 ± 31.3 a**	**73.3 ± 20.7 b**	**1.4 ± 0.5 c**

[1] Means followed by different letters are significantly different (F = 105.97; df = 2,107; P <0.0001). Data were transformed log(x+1) prior to analysis of variance.

Table 8. Average number of adult eye gnats captured in traps in specific areas around Jacumba in 2009.

Description of Area Observed	Trap Numbers	Number of Traps	Average No. of Gnats/Trap
South perimeter of farm	37,38,39	3	0.7
North perimeter of farm	42,26,30,29	4	0.7
1000 feet from community edge in farm	37,1,20,23,25	5	0.8
West edge of farm on the community border	15,16,17	3	0.7
Center of town	7,8,9,10	4	2.3
Town's west perimeter	2,3,4.5	3	1.0
Town's south perimeter/Mexican border	4.5,5,12	3	2.3
All Mexican border	4.5,5,12,37,38,39	6	1.8
All farm	20,21,15,16,17,1,25, 26,27,42,31, 33,24,41,22,23,40	17	0.5
Description of Area Observed YEAR???	**Trap Numbers**	**Number of Traps**	**Average No. of Gnats/Trap**
South perimeter of farm	37,38,39	3	29.7
North perimeter of farm	42,26,30,29	4	47
1000 feet from community edge in farm	37,1,20,23,25	5	106.8
West edge of farm on the community border	15,16,17	3	16
Center of town	7,8,9,10	4	161.5
Town's west perimeter	2,3,4.5	3	171.7
Town's south perimeter/Mexican border	4.5,5,12	3	43.3
All Mexican border	4.5,5,12,37,38,39	6	36.7
All farm	20,21,15,16,17,1,25, 26,27,42,31, 33,24,41,22,23,40	17	39

Average number of eye gnats captured in traps in specific areas around Jacumba between Oct 28-30, 2008.

Description of Area Observed	Trap Numbers	Number of Traps	Average No. of Gnats/Trap
East perimeter of farm	34,35,45,46	4	14.8
South perimeter of farm	14,37,38,39	4	92.5
North perimeter of farm	42,43,26,30,29	5	52
1000 feet from community edge in farm	37,1,20,23,25	5	228.4
West edge of farm on the community border	13,15,16,17	4	274.5
Center of town	7,8,9,10	4	500.5
Town's west perimeter	2,3,4.5	4	208
Town's south perimeter/Mexican border	4.5,5,12,14	4	222.2
All Mexican border	4.5,5,12,14,37,38,39	7	107.6
All farm	20,21,13,14,15,16,17 ,32,1,25,26,27, 42,31,33,43,24,41,22 ,23,40	21	182.6

Figure 1. 2008-2010 JACUMBA"IN TOWN" COLLAR TRAPS COUNTS

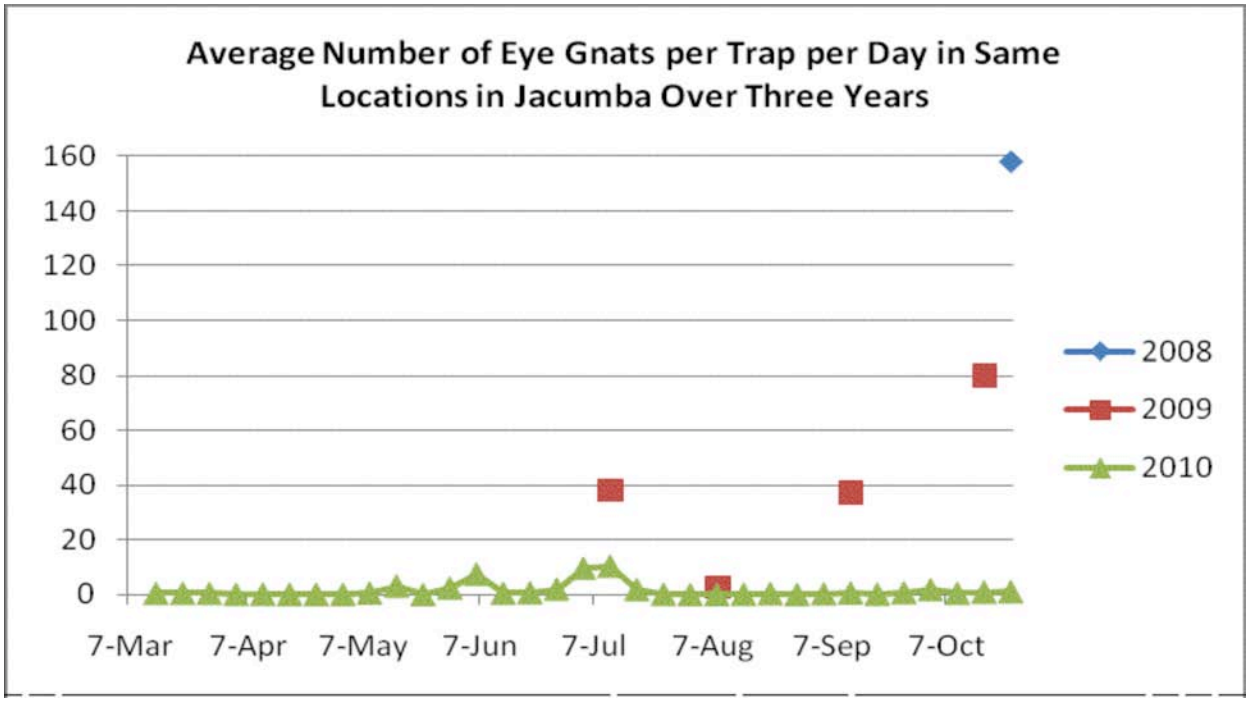


Table 9. Weather data gathered from CIMIS station #147- Otay Lake- South Coast Valley

Date	Max. Temp.(°F)	Ave. Temp.(°F)	Ave. Wind Speed(mph)	Mean Number of gnats in town
10/29/2008	87.9	69.7	2.3	158
7/11/2009	89.3	70.9	2.7	38.4
8/8/2009	75.1	66.3	2.9	2.6
9/12/2009	79.2	69.1	2.8	37.3
10/17/2009	86.8	71.2	2.9	69.3
7/1/2010	78.2	65.8	3.9	2.11
7/7/2010	69.3	62.4	3.5	9.83
7/15/2010	86.8	73.6	3.6	10.55
7/22/2010	71.7	63.6	4.0	1.91
7/29/2010	72.5	65.0	4.4	0.23
8/5/2010	73.1	64.9	4.0	0.12
8/12/2010	76.4	64.3	3.9	0.05
8/20/2010	86.6	72.3	3.5	0.25
8/27/2010	77.0	66.4	3.8	0.46
9/3/2010	88.3	70.3	3.4	0.10
9/9/2010	70.7	63.1	3.6	0.38
9/16/2010	75.0	61.9	3.2	0.71
9/23/2010	74.1	61.7	3.9	0.32
9/30/2010	76.9	69.4	3.2	0.80
10/7/2010	70.6	61.6	4.4	1.92
10/15/2010	65.7	61.7	1.8	0.50
10/21/2010	67.3	61.2	2.3	1.02
10/27/2010	79.1	66.9	7.4	0.02
10/29/2010	81.7	64.6	3.2	2.22

Pearson's Correlation
Eye gnats captured with Maximum Temperature; $P = 0.0148$; $r = 0.49$.
Eye gnats captured with Average Temperature; $P = 0.0545$; $r = 0.40$.
Eye gnats captured with Average Wind Speed; $P = 0.0959$; $r = -0.35$.

ESCONDIDO, CA

CONCENTRATION OF EYE GNATS IN SOUTH ESCONDIDO

Objective. Determine the location of the highest concentration of adult eye gnats in the affected area. Finding a high concentration might lead to the source.

Background. Collar traps were established in four different areas (Sunset Hills, Orfilia Winery, the Vineyard Golf Course, and the Pinery) in order to monitor the population of adult eye gnats. The sites were chosen due to their reported incidence of eye gnats and ease of access. In addition, we investigated the marshy area of Lake Hodges to determine if it was good eye gnat reproductive habitat.

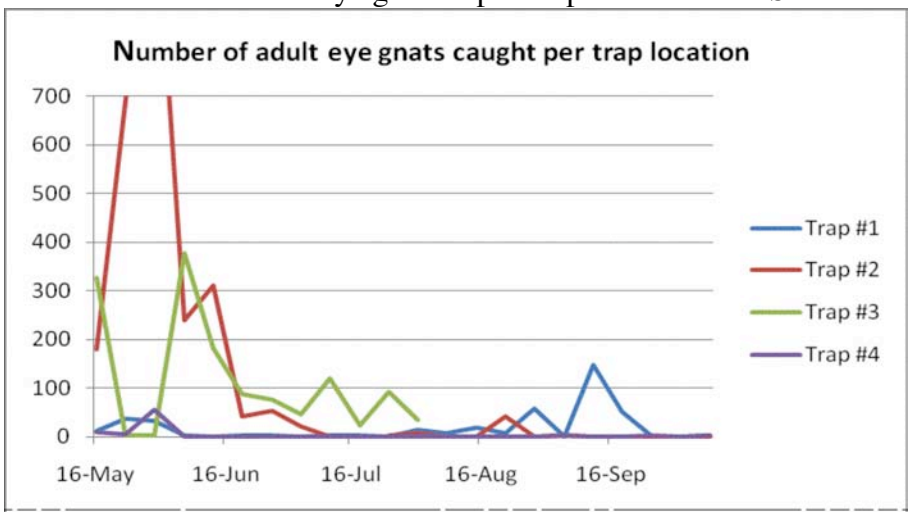
Unfortunately, we were unable to access the Be Wise Ranch, an organic produce farmer that is situated in close proximity to the affected areas (Photo 11, arrows). From our experience in Jacumba, the farm seemed to be a logical choice to investigate. Trapping occurred all around the farm in the North including the community and in the south at the Pinery and Lake Hodges.

Data Handling. The number of eye gnats captured on selected dates was graphed by trap. All graphs have the same scale for comparisons. Very large numbers were excluded from the figures, but inferences can be made from the trend lines.

Site #1 Sunset Hills

This site is located on the north side of San Pasqual Road and Sunset Hills Road. It consists of approximately 15 houses on a hillside. It is directly across from a portion of the Be Wise Ranch. Four collar traps were set at this location (Photo 6). Trap #1 was on the backside of a hill in natural vegetation. Trap #2 was placed under some pine trees with no ground cover. Trap #3 was closest to San Pasqual Road. It was placed on a vacant lot among weeds. Trap #4 was placed next to some shrubs.

Figure 2. The total number of eye gnats captured per week at the Sunset Hills site.

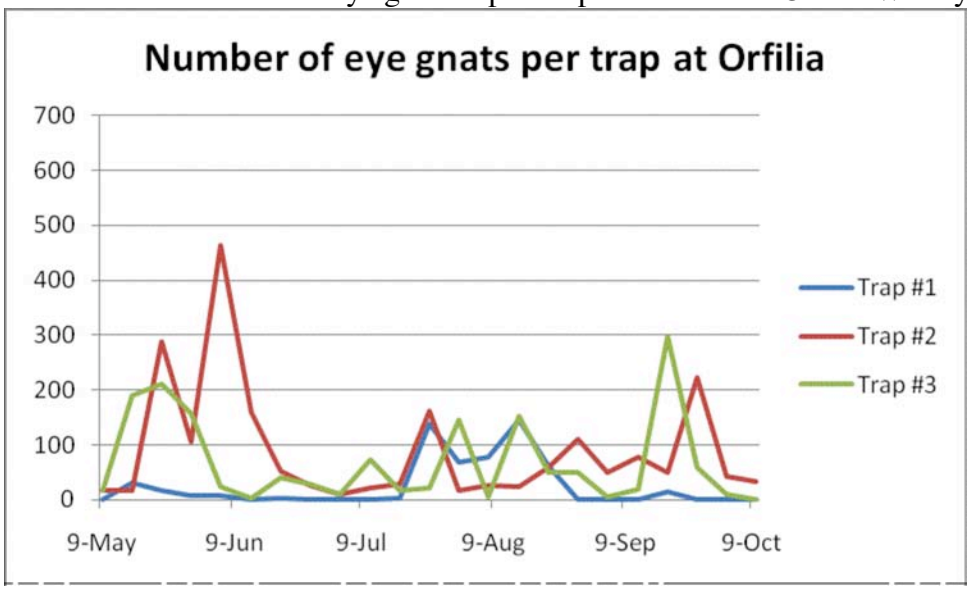


Summary. The adult eye gnat population was highest during early spring (Figure 2). Most of the eye gnats were caught in traps #2 (east) and #3 (south). Trap #3 ends in mid July due to inaccessibility. Eye gnat numbers are high throughout the season for most traps, especially for Traps # 3 prior to its removal, and it is located in close proximity to the farm edge across the street.

Site #2 Orfilia Winery

Three collar traps were established at Orfilia Winery located at 13455 San Pasqual Road (Photo 7). It is comprised of 50 acres of various wine grape varieties. The first trap #1 was located near a large grassy picnic area. Trap #2 was located near the entrance of the winery. The third was placed on the eastern border, just across from the organic farm.

Figure 3. The total number of eye gnats captured per week at the Orfilia Winery site.

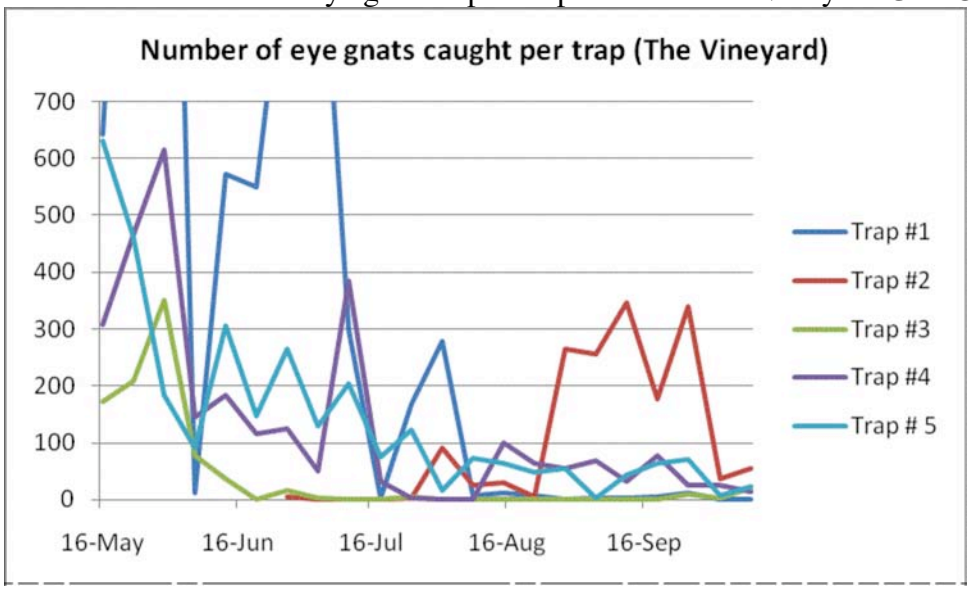


Summary. Again, as for the Sunset Hills site, there is a large population in early spring (Figure 3). However, the population stays more consistant from mid-July through September. Since agricultural sites are a prefered environment for eye gnat breeding, twelve soil samples were taken from various locations and brought back to the lab and monitored for the emergence of gnats. Eye gnat productionis not suspected in a vineyard because of the lack of tilling. A single eye gnat emerged from our samples. The particular sample came from under a dripper on the eastern side of the vineyard. Traps 2 and 3 are located directly adjacent to the farm (Photo 7).

Site #3 The Vineyard Golf Course

The Vineyard Golf Course (500 acres) is located at 925 San Pasqual Road. Golf courses are documented habitats for eye gnats (Mulla 1962). Up to five collar traps were established on site (Photo 8). The first trap was in the northwest corner of the golf course. The second collar trap was located in a heavily vegetative parcel. Trap #3 was also located near a heavily vegetative area. Collar trap #4 was located in some native landscape approximately 40 feet from the irrigated fairway. The last trap was located nearest to the farm at the eastern most point of the golf course in native vegetation.

Figure 4. The total number of eye gnats captured per week at the Vineyard Golf Course.

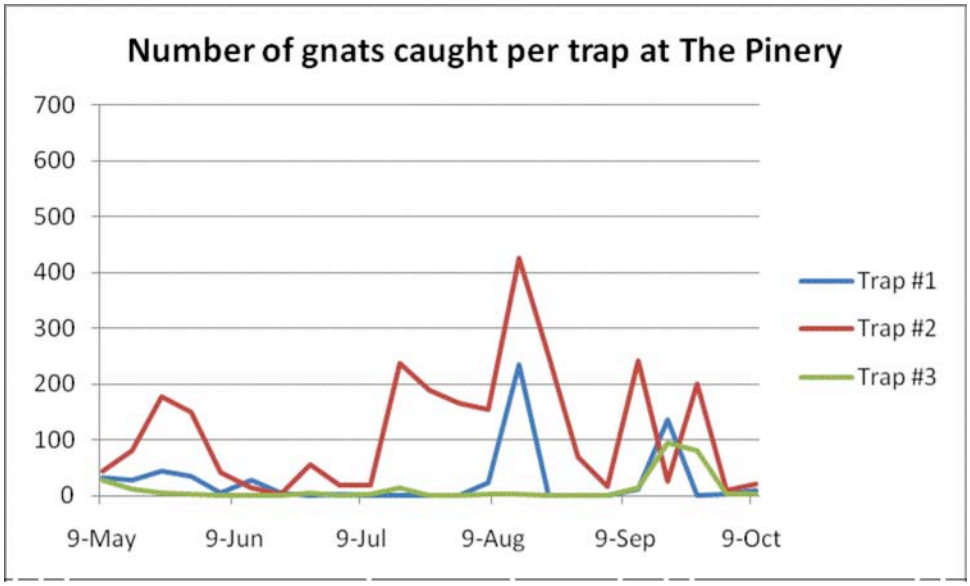


Summary. This site averaged the highest population of eye gnats (Figure 4). Upon this discovery, emergence traps were placed at various locations around the golf course. Traps were left and monitored for approximately one month. No eye gnats were caught in the emergence cages. Sand from 12 sand traps was also collected and brought to the lab to monitor for the emergence of eye gnats. Only one gnat was caught from all twelve samples. Although the golf course provides an ideal habitat for eye gnats to congregate, it does not appear to be the source of eye gnats. Trap #5 is located directly adjacent to the farm.

Site #4 – The Pinery

The Pinery is a potted evergreen plant nursery located on 13701 Highland Valley Road, south of the Lake Hodges area and on the opposite side of the farm from the other four sites. The farm and nursery are separated by approximately 2000 feet of native landscape. Three collar traps were established at this site (Photo 9). The first was on the northeast corner of the property along Highland Valley Road. Trap #2 was also along Highland Valley Road except on the western side near the main entrance of The Pinery. The third trap was placed along an embankment. A creek ran along the other side of the embankment.

Figure 5. The total number of eye gnats captured per week at the Pinery.



Summary. At this site, the population increased later in the summer as opposed to early spring at the other sites (Figure 5). Traps 1 and 2 are located across the road from the farm and trap # 3 is set back a ways.

Lake Hodges

The marshy area around Lake Hodges has been suspected of producing eye gnats. We located several emergence and collar traps where the water had recently receded, but the soil was still moist. They were located just east of the I-15 bridges (Photo 10). Four emergence cages were left in one location for one month and then moved to another damp location for the following month. During these two months, June and July, no eye gnats were caught in any emergence cages.

A collar trap was also established to measure the number of adult gnats present. The following is a table showing the dates and number of eye gnats caught.

Table 10. Total number of eye gnat adults captured in collar traps in the marsh area of Lake Hodges near the bridge.

	6/8-6/14	6/14-6/21	6/21-6/28	6/28-7/6	7/6-7/12	7/12-7/19	7/19-7/26
No. of eye	2	7	17	1	13	9	18

gnats							

The number of gnats caught was very low compared to the other sites. The data suggests that Lake Hodges is not a source for eye gnats but provides an environment for the adults to seek shelter.

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APPENDIX I
Photo Images

Photo 1. Map showing the position of collar traps used to monitor background eye gnat population

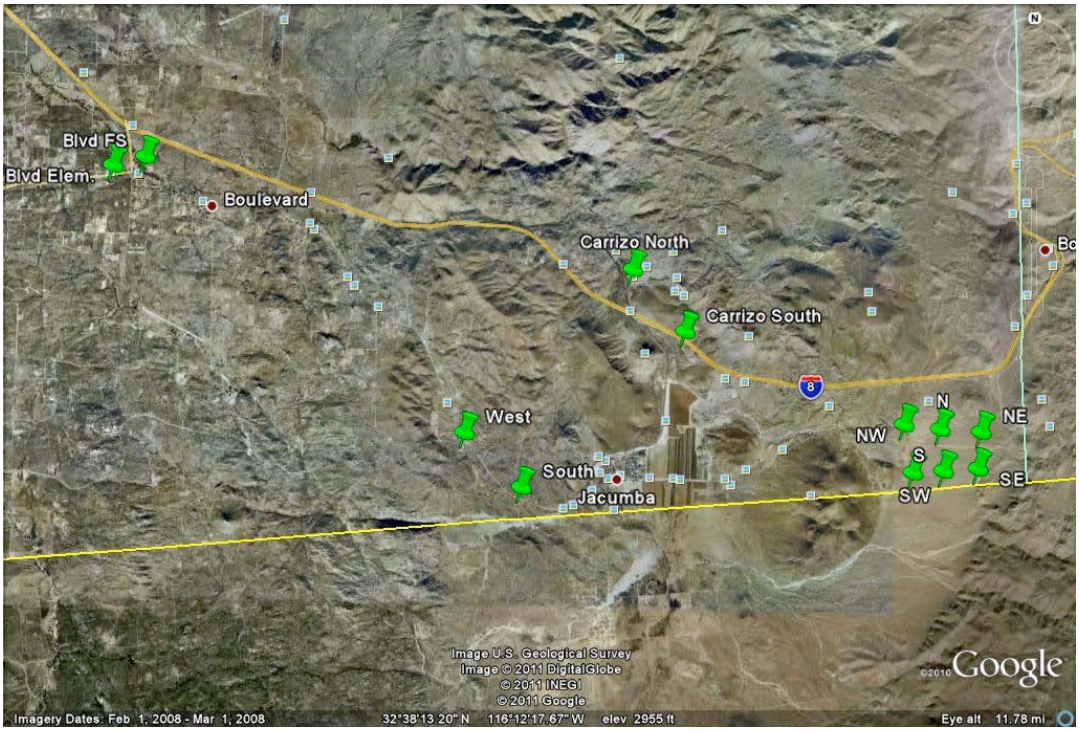
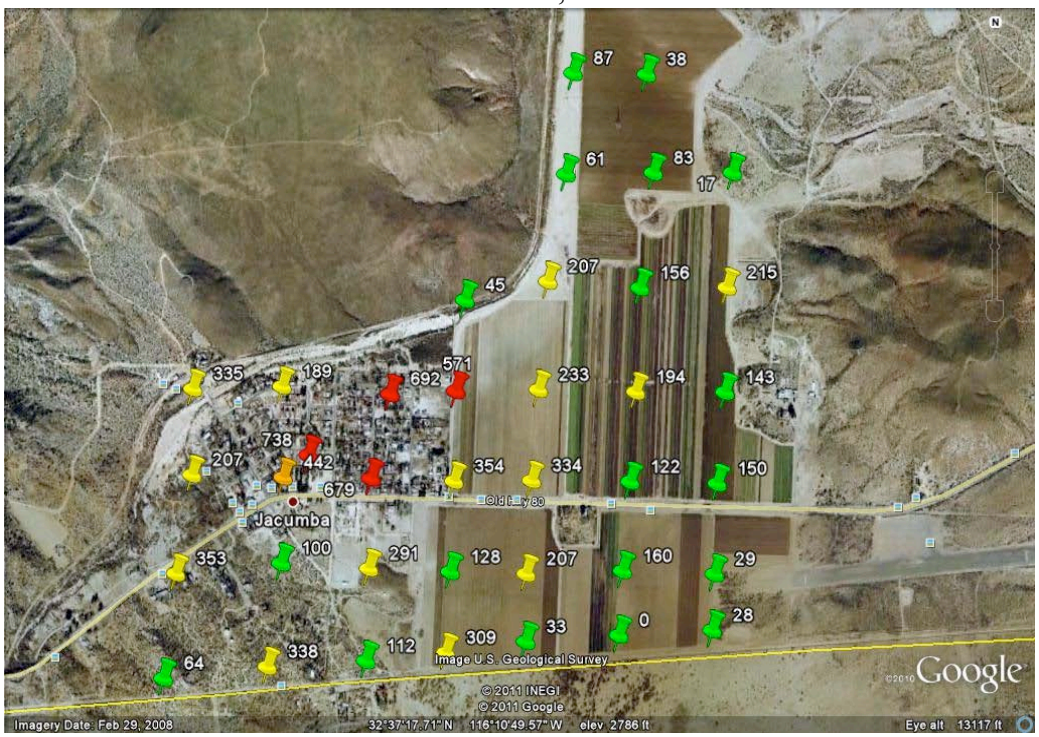


Photo 2. Emergence trial trays inside cages

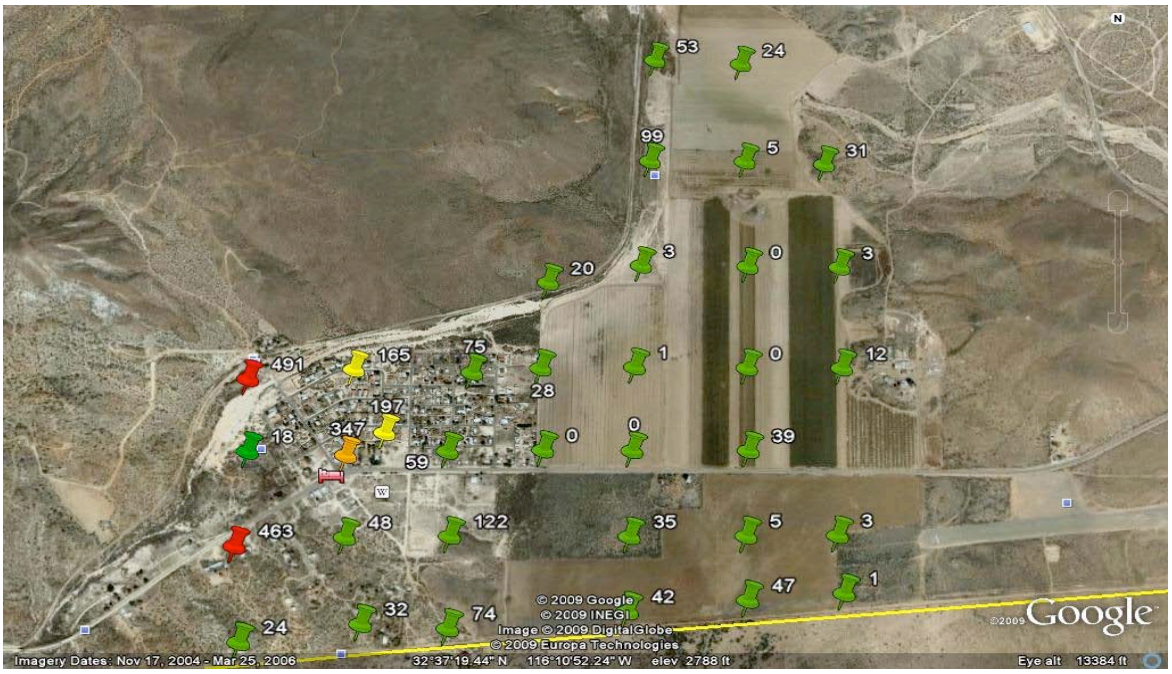
Photo 3. Chemical emergence test conducted at the Center of Applied Hort. Research

Photo 4. Overlay of collar trap positions on aerial view of Jacumba. The numbers on the overlay are the number of gnats collected at that location. Colored pins indicate relative measure of trap catch, red=highest >orange>yellow>green.

October 28-30, 2008



October 16-18, 2009



October 27-29, 2010

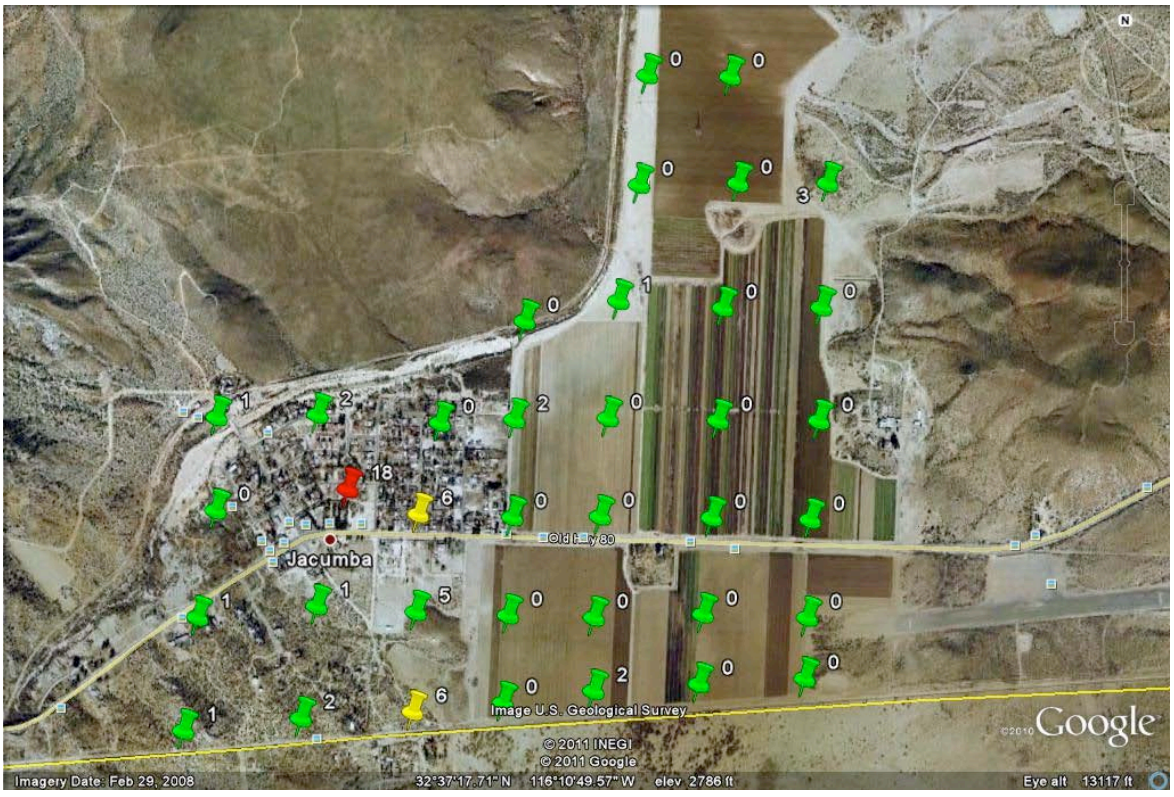


Photo 5. Location of 9 “In Town” traps that were monitored once a week 3/16-10/29, 2010.

Photo 6. Collar trap locations at Sunset Hills, Escondido

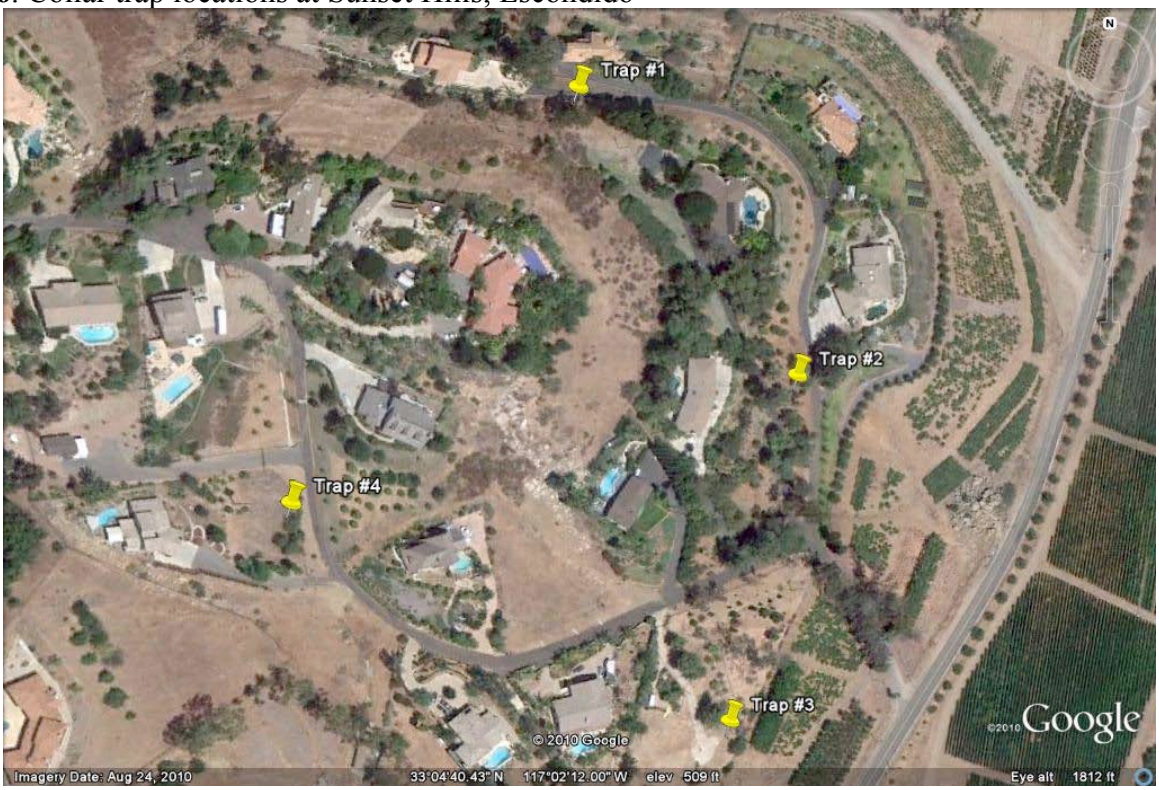


Photo 7. Collar trap locations at Orfilia Winery

Photo 8. Location of collar traps at The Vineyard Golf Course

Photo 9. Collar trap locations at The Pinery Nursery

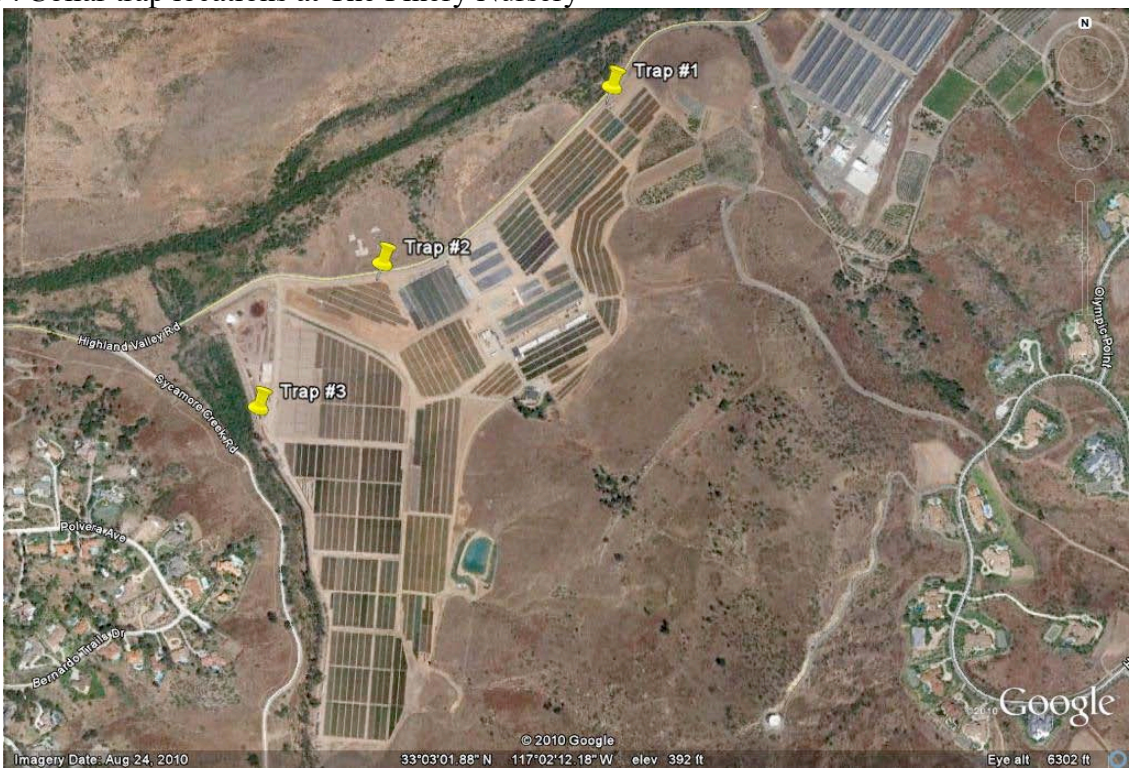
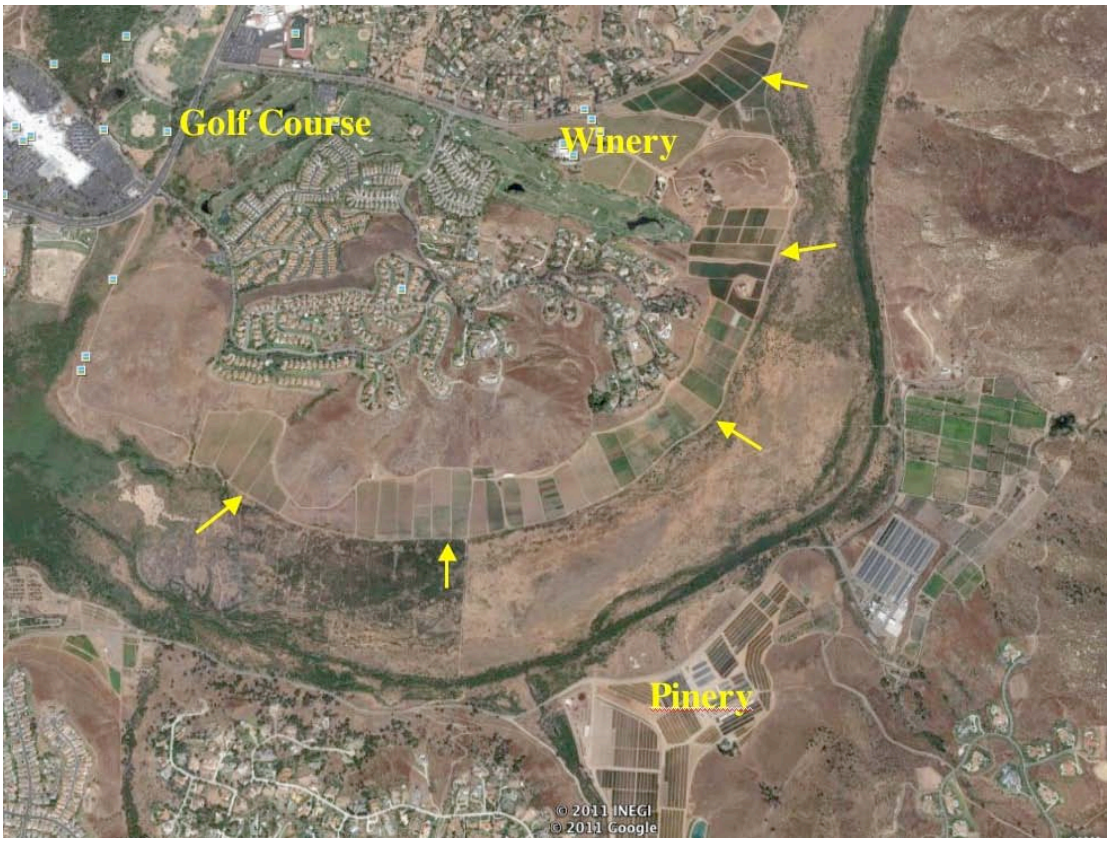


Photo 10. Collar and emergence traps set up at Lake Hodges

Photo 11. To the north lies portions of the community of Escondido and to the South lies the Pinery and Lake Hodges. In the center of the view is Be Wise Ranch, a local organic farm.



APPENDIX II

2010 VISITS TO JACUMBA

Feb 1- Bring traps to farm for upcoming season
Mar 4- Jim B., Bryan V., Marianne W., & Irma D., plan for season
Mar 16- Meeting with Diane J. and set some traps
Mar 30- Check traps and set up new ones
April 7- Irma D. check collar traps
April 15- Meet with Alan Bornt and Mark L. & Jesse from Vector Control
April 23- Meet with Kerry and Mark with Vector Control
May 4- Jim B accompanied Irma D., and Bryan V. to check progress
May 13- Set up emergence traps, take soil samples for lab emergence
May 20- Set up town traps with Cori C.
May 27- Collect collar traps
June 3- Collect collar traps
June 10- Collect collar traps
June 17- Collect collar traps
June 24- Collect collar traps
July 1- Collect collar traps
July 7- Collect collar traps and meeting with Diane J.
July 15- Collect collar traps
July 29- Collect collar traps
Aug 5- Collect collar traps
Aug 12- Collect collar traps
Aug 20- Collect collar traps
Aug 27- Collect collar traps
Sept 3- Collect collar traps
Sept 9- Collect emergence jars and collar test
Sept 16- Collect jars
Sept 23- Collect jars
Sept 30- Collect collar traps
Oct. 7- Pick up jars
Oct 15 – Collect collar traps
Oct 21- Collect collar traps
Oct 27- Set up population test
Oct 29- Pick up emergence traps and population test

2010 VISITS TO ESCONDIDO

April 21- Scout places to place traps
April 27- talks with Be Wise, The Vineyard, and Kit Carson landscape
May 7- Talk with residence and Orfilia Winery
May 10- Set up collar traps at Orfilia
May 12- Set up more collar traps
May 17- Collect collar traps
May 24- Collect collar traps
June 1- Collect collar traps
June 8- Collect collar traps
June 14- Collect collar traps
June 21- Collect collar traps
June 28- Collect collar traps, set up traps at Lake Hodges
July 6- Collect collar traps
July 12- Collect collar traps
July 19- Collect collar traps
July 26- Collect collar traps, talk with residence
Aug 2- Collect collar traps
Aug 9- Collect collar traps
Aug 16- Collect collar traps
Aug 24- Collect collar traps
Aug 30- Collect collar traps
Sept 7- Collect collar traps
Sept 13- Collect jars
Sept 20- Collect jars
Sept 27- Collect collar traps
Oct 5 – Collect collar traps
Oct 11- Collect collar traps
Oct 18- Collect all stakes and collar traps for season