

**AN EVALUATION OF AREA AND PERSONAL MOSQUITO REPELLANTS**

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## Abstract

During the summer of 1989, nine different mosquito repellants were tested in the north woods area of northern Wisconsin. Human subjects were used to obtain biting samples in a series of tests. The tests lasted from May to July and gave significant results for all products against the wide range of mosquitos encountered in the field. T-tests were used to attach statistical meaning to the results which gives evidence for and against the products.

## Introduction

During the summer of 1989 mosquito populations across the midwest soared. This provided an excellent opportunity to examine some of the new mosquito repellent products on the market today. The need for repellents is more important than many realize. The general nuisance from mosquitoes is only part of the problem. One must also consider the mosquito as a major disease vector.

Because outdoorsmen have this preoccupation with the mosquito, manufacturers have sought to create ways to alleviate the problem. There are many products on the market today claiming to have the ability to repel mosquitoes. Therefore it is important to the consumer to know which ones work and which ones don't work. This study was done for that purpose. Nine different substances were tested for repelling qualities. The tests were organized to provide information about which work the best in relation to overall repulsion. It was also noted which lasted the longest and which may have adverse effects.

The study was done at the University of Notre Dame Environmental Research Center (UNDERC) on the northern border of Wisconsin in the Land O' Lakes area. It was a part of a summer undergraduate program with the university. This area is great for this type of field research because of the high mosquito population provided by the numerous bogs and marshes.

## Materials and Methods

Human volunteers were used to test each repellent. The experiment was run throughout the summer and test days were determined according to the availability of volunteers. The tests spanned the entire summer which enabled testing of the repellents against many different species emerging at different times. To provide the best possible samples, individual tests were done at different places around the UNDERC property. Each test was organized in order to examine the difference between the control and the experimental groups. On a given night, four subjects were used as replicates in the test. A vacuum aspirator was used to collect biting mosquitos during two five minute periods. The aspirator was a modified flashlight case equipped with an electric motor and a small fan to create a suction in a 1cm diameter tube. Samples were collected in a vial with a screen at the bottom to allow the suction to be created. One five minute period was used as a control count and the other was an experimental count using the repellent. By using each person for the control and experimental counts, person to person variability could be eliminated from the results.

A total of nine different repellents were tested:

“Mosquito Beater ‘Area Mosquito Preventive’”	manufactured by: Bonide
active ingredients: Methalated naphthalenes	16.0%
Napthalene	4.5%
Thiocyanodiethylether	1.0%
Butoxypolypropylene	0.5%
Petroleum Distillate	9.0%

“Mosquito Repellent Coils” Manufactured by: Pic  
active ingredients: not listed

“Skin-So-Soft” manufactured by: Avon  
active ingredients for repellent qualities unknown  
main ingredients: Mineral Oil  
Fragrance

"Baby Oil" manufactured by: Johnson & Johnson  
active ingredients for repellent qualities unknown  
main ingredient: Mineral Oil

"Neverbite" manufactured by: Campmor  
active ingredients: N,N diethyl-meta-toluamide (DEET) 95%  
other isomers

Citronella scented candles

"Moltron Bug Shield" manufactured by: Moltron  
emits a high frequency sound

"Mosquito Hawk" manufactured by: Northwest Merchants Ltd.  
imitates the sound of a dragonfly

"Revenge" manufactured by:  
active ingredients:

All control samples were taken first. This eliminated the possibility of population depletion showing up in the data as a positive effect by the repellent. Excluding the naphthalene trials, all trials were performed within fifteen minutes of each other in the same area. Naphthalene was applied one to two hours prior to the test according to the directions. The control sample was taken far enough away to eliminate any naphthalene effect but close enough to be sure the same density of mosquitoes was being sampled.

After the samples were collected, they were frozen, separated and counted. Mosquitoes were separated into two groups, white striped legs (warm weather species) and black legs (cold weather (vernal pond) species). This record was kept in order to show the changing population structure and to see if there was any relationship in the effectiveness of the repellents.

## Results

The effectiveness of the repellants varied greatly. T-tests were performed on each pair of experimental results. This was done to show differences between experimental and control groups, and it also helps compare the effectiveness of each individual product with the others. The results for each individual test are shown in Table 1 (Data for Substrates on mosquitos.) The control columns and experimental columns do not reflect the results of an individual subject. They are used only for organizational purposes. A total of 15 people volunteered for this experiment and their samples are shown in Table 1.

Individual tests show that each person differs in their susceptibility to mosquito attack. The human odor seemed to be the main factor in this variability. It was noticed that by showering with deodorant soap, using deodorants, or using cologne decreased the number of mosquitos attracted in comparison with the other subjects participating during that particular test. Also, if the body temperature was increased on the skin surface by an increase in peripheral blood flow (as in that which occurs after exercise), an increase in the attraction was noticed.

Throughout the summer, each substrate was exposed to different densities of mosquitos. Early in the summer, mosquito populations were high consisting mainly of vernal pond species. For example, in one of the first control samples, 94 mosquitos were collected in a five minute period (a rate of 1128 bites/ hour.) This amount tapered by late June and gradually began increasing again in July with the emergence of the warmer weather species. The lowest number in a control sample was 2 in a five minute period (a rate of 24 bites/ hour.) This change in species composition and density, however, did not have a noticeable effect on any of the products tested.

T-test results give the best evidence for the quality of the products because they show how great of an effect it actually had on the mosquitos by comparing the control samples with the experimental samples. (see Table 2) The T statistic is used to get the probability that the two sample numbers actually come from the same subset of information, and any difference is only due to variance in the collecting. If the probability is low than the difference is significant. The cutoff for significance in this experiment was any probability less than 0.005.

Bonide's "Mosquito Beater," containing the naphthalene flakes, had a probability of 0.393. In many individual samples, there was an increase in the number of mosquitos collected in the experimental group. Almost all the other area repellants were equally ineffective. Citronella candles give off a pleasant aroma, but a probability of 0.241 showed that it also has no affect on mosquitos. "Revenge," another chemical oriented repellant, also proved to be ineffective in the field with a probability of 0.285. However, the results of the "Revenge" tests are not as conclusive as the other tests because of some difficulties in getting it to work. The degrees of freedom for the T-test are less than those used in the other tests. The only chemically oriented area repellant that seemed to work was the "Mosquito Repellant Coils." The probability for these was a very significant 0.001. Some of the more enlightening results come from the sound repellants. The "Bug Shield" and "Mosquito Hawk" produced probabilities of 0.621 and 0.981 respectively. Which provides more evidence against this type of controversial product.

The products which are applied directly to the skin gave much better results. DEET, the active ingredient in most commercial repellants, was very effective, and the 0.023 probability shows its significance. Avon's Skin-So-Soft was also very effective with a probability of less than 0.001, but it does not last

as long as DEET. Baby Oil was tested because of its similarity in composition to Skin-So-Soft and it proved to be almost as effective (probability also less than 0.001.) The repellent qualities were the same, but it does not last as long as Skin-So-Soft.

By running the experiment over the whole summer, the repellents were exposed to a number of different mosquito species. A sample from early July was typed to give an example of the variety of mosquitos being tested against. The types included: Aedes punctor, Aedes provocans, Aedes abseratus, Aedes cinereus, Aedes communicans, Aedes excrucians, Aedes canadensis, and Mansonia perturbans. For the rest of the samples, the mosquitos were lumped into two categories black leg species and white, striped leg species. The black leg species from this sample included: Aedes punctor, Aedes provocans, Aedes abseratus, Aedes cinereus, Aedes communicans. The white, striped leg species from this sample included: Aedes excrucians, Aedes canadensis and Mansonia perturbans. Many other species were present but these were the only ones typed from the samples. Black leg species are primarily early emerging, vernal pond species while the white, striped leg species are late emerging species from more permanent water sources. The progression of these two species throughout the summer has been shown in Graphs 1 and 2. In Graph 2, the mosquito data has been transformed by using natural logarithmic transformation.

## Discussion

The variability noticed in a single person's susceptibility from day to day, seemed to be primarily due to the strength of the human scent. If it was masked in any way with cologne, deodorant or just by taking a shower, there appeared to be a reduction in the susceptibility. This suggests that the most effective means of repelling should center around masking the human odor or preventing the mosquito from detecting it.

In Graph 1, it is important to realize the derivation of the significance line. Significance levels vary between tests because each has its own degrees of freedom. Greater degrees of freedom mean that a lower T statistic will give a significant probability. Taking this into account, the significance line was plotted for the lowest degrees of freedom of an effective substrate. For this substrate (DEET), the T statistic would give a probability of 0.025. This is half of the acceptable probability stated earlier. The height of the individual bars is not important. What is important is that they are above the significance line.

The area chemical repellants for the most part did not work all that well. Napthalene flakes did not work at all, and in some individual trials, the experimental samples contained more mosquitos than the controls. (see Table 1) Even if they did work, the odor is unacceptable for home use and the chemical may be harmful. Citronella candles did not work in the field trials either. If the sent of the candles has an affect on the mosquitos ability to sense human presence, it is of no use outside because it dissipates too quickly. The data on "Revenge" is inconclusive because it was difficult to get to work in the field. The initial results however seemed to indicate that it would be comparable to the Citronella results.

The coil smokers did work as an area repellent. They did have the same problem of dissipation, but the chemical strength overcame this problem. These smokers are very effective when used in numbers. Even when used in numbers, the odor is not very evident, and the only drawback is perhaps the ashes left after burning.

The worst results of any of the repellants came from the wildly publicized sound repellants. These products are nothing but a gimmick. The results show (see Table 2 and Graph 1) that there are no repelling qualities in the use of the sound produced by either of the products tested. It has even been shown in the lab that a certain frequency attracts males and is ignored by females.

The best results come from the products that mask odor by direct application to the skin or surface of the cloths. DEET, the chemical ingredient in most commercial repellants proved itself to be the longest lasting of all the repellants tested although it may have its drawbacks. Research is currently being done on the suspicion of possible harmful effects of this substance. Some of the military's results were published in *The Medical Letter On Drugs and Therapeutics* an independently published paper out of New Rochelle, N.Y. (Vol. 31; issue 792; 5/19/89.)

Some of the more surprising results came from Avon's Skin-So-Soft. This product is not marketed as a repellent, but has a surprising effect. The only drawbacks are in the length of effectiveness which is considerably shorter than DEET requiring frequent applications and in the perfumed scent one must endure while wearing it. In light of this affect, regular Baby Oil was tested because of the similarity in composition. These tests were done to provide clues to Skin-So-Soft's effectiveness and possibly narrow down the active repelling ingredient. The Baby Oil's effectiveness and the observation of

mosquitos landing but not biting suggests that these two products work in two ways. The mosquitos may be affected by the biting surface as well as the sent.

Graphs 2 and 3 and Table 3 were provided to show the relative numbers of the species in the individual tests and to show the summer species shift that was experienced. The graphs also give a sense of when the tests were done.

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	date	exp substrate	control 1	control 2	control 3	control 4	experimental 1	experimental 2	experimental 3	experimental 4
1	5/30/89	naphthalene	81.000	46.000	94.000	52.000	40.000	11.000	43.000	85.000
2	5/31/89	coil smoker	50.000	63.000	41.000	35.000	26.000	29.000	25.000	10.000
3	6/1/89	skin-so-soft	48.000	66.000	37.000	87.000	1.000	1.000	1.000	5.000
4	6/1/89	deet	58.000	58.000	39.000	39.000	1.000	0.000	1.000	0.000
5	6/3/89	citronella	52.000	69.000	52.000	67.000	44.000	58.000	18.000	60.000
6	6/3/89	ultra sound	62.000	66.000	55.000	49.000	23.000	90.000	44.000	74.000
7	6/12/89	clickers	20.000	20.000	48.000	58.000	32.000	45.000	27.000	61.000
8	6/12/89	coil smokers	18.000	22.000	42.000	24.000	2.000	10.000	13.000	8.000
9	6/12/89	skin-so-soft	18.000	22.000	42.000	24.000	2.000	0.000	2.000	3.000
10	6/13/89	ultra sound	4.000	2.000	15.000	22.000	9.000	8.000	19.000	20.000
11	6/15/89	naphthalene	8.000	11.000	12.000	37.000	12.000	12.000	31.000	53.000
12	6/15/89	deet	8.000	11.000	12.000	37.000	0.000	0.000	0.000	0.000
13	6/19/89	clickers	3.000	23.000	18.000	14.000	2.000	15.000	19.000	22.000
14	6/19/89	citronella	3.000	23.000	18.000	14.000	3.000	15.000	12.000	31.000
15	6/22/89	coil smokers	13.000	17.000	24.000	16.000	0.000	0.000	1.000	1.000
16	6/22/89	baby oil	13.000	17.000	24.000	16.000	0.000	0.000	0.000	1.000
17	7/4/89	naphthalene	8.000	6.000	33.000	33.000	5.000	16.000	26.000	27.000
18	7/4/89	coil smokers	8.000	6.000	33.000	33.000	3.000	11.000	22.000	20.000
19	7/4/89	baby oil	8.000	6.000	33.000	33.000	0.000	2.000	0.000	3.000
20	7/11/89	naphthalene	10.000	19.000	18.000	15.000	7.000	9.000	16.000	13.000
21	7/11/89	clickers	10.000	19.000	18.000	15.000	11.000	6.000	14.000	13.000
22	7/11/89	citronella	10.000	19.000	18.000	15.000	11.000	4.000	28.000	20.000
23	7/11/89	baby oil	10.000	19.000	18.000	15.000	5.000	0.000	4.000	15.000
24	7/14/89	ultra	4.000	2.000	18.000	16.000	13.000	2.000	24.000	18.000
25	7/18/89	revenge	8.000	6.000	9.000	20.000	5.000	16.000	9.000	33.000
26										
27										
28										
29										
30		product		Mean Diff.	SD Diff.	T	Probability	DF		
31		Mosquito Beat	4.813	4.813	21.864	0.880	0.393	15.000		
32		Repellant Coils	16.500	16.500	9.331	7.073	0.001	15.000		
33		Skin-So-Soft	41.125	41.125	23.006	5.056	0.001	7.000		
34		Baby Oil	15.167	15.167	10.223	5.139	0.001	11.000		
35		(DEET)	48.143	48.143	41.946	3.037	0.023	6.000		
36		Citronella	4.667	4.667	13.034	1.240	0.241	11.000		
37		Bug Shield	-2.417	-2.417	16.445	0.059	0.621	11.000		
38		Mosquito Hawk	-0.083	-0.083	11.828	0.024	0.981	11.000		
39		Revenge	-5.000	-5.000	7.703	1.298	0.285	3.000		

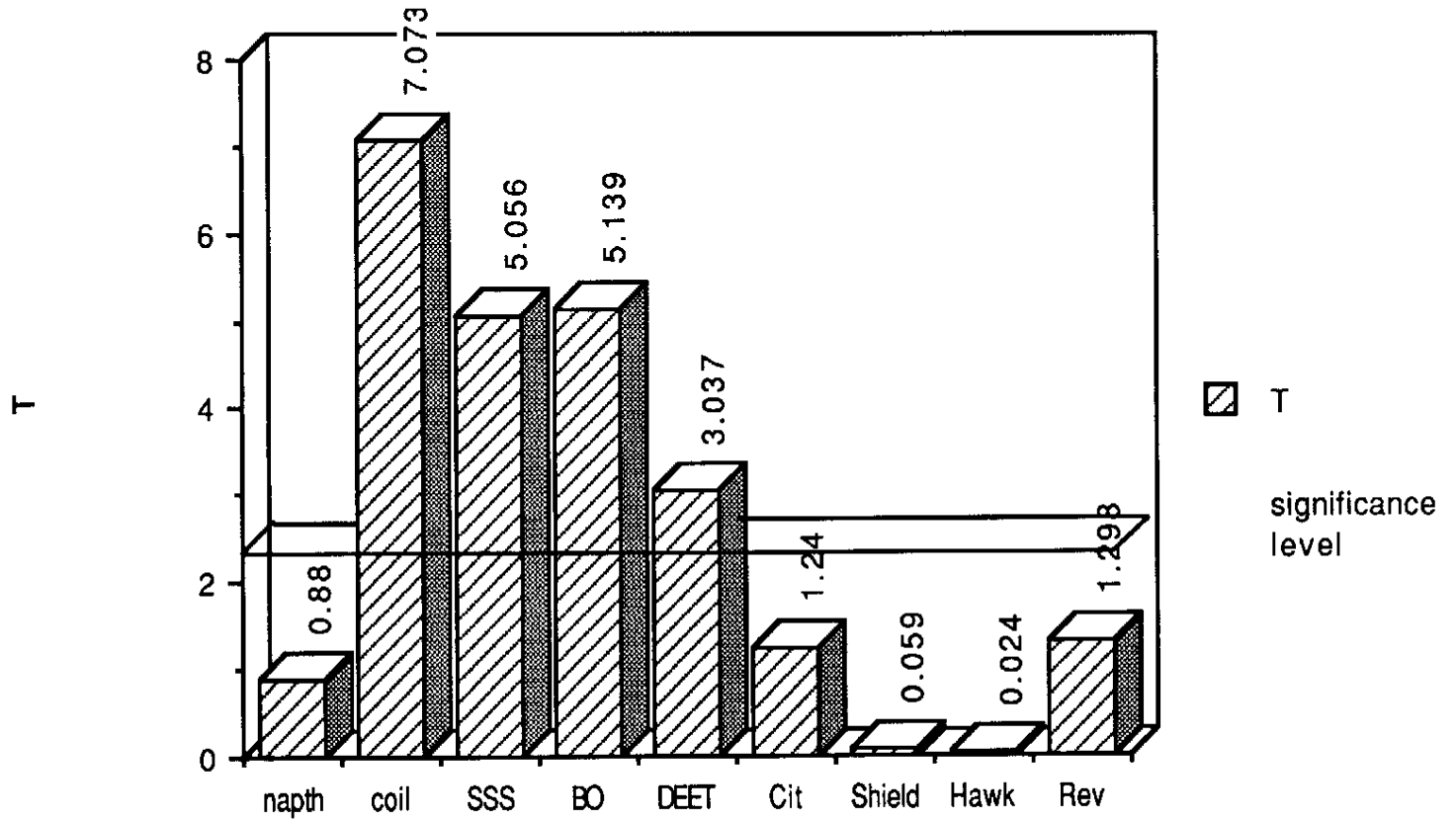
Table 2

T-test

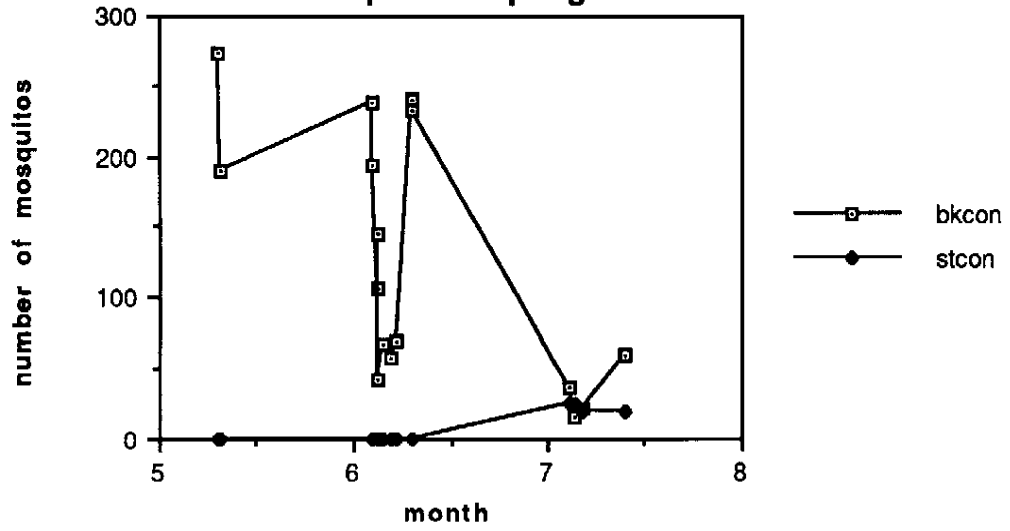
Results

	bkcon	stcon	N	ln bkcon	ln stcon
1	273.000	0.000	5.300	5.609	0.000
2	189.000	0.000	5.310	5.242	0.000
3	238.000	0.000	6.100	5.472	0.000
4	194.000	0.000	6.100	5.268	0.000
5	240.000	0.000	6.300	5.481	0.000
6	232.000	0.000	6.300	5.447	0.000
7	146.000	0.000	6.120	4.984	0.000
8	106.000	0.000	6.120	4.663	0.000
9	106.000	0.000	6.120	4.663	0.000
10	43.000	0.000	6.130	3.761	0.000
11	68.000	0.000	6.150	4.220	0.000
12	68.000	0.000	6.150	4.220	0.000
13	58.000	0.000	6.190	4.060	0.000
14	58.000	0.000	6.190	4.060	0.000
15	70.000	0.000	6.220	4.248	0.000
16	70.000	0.000	6.220	4.248	0.000
17	60.000	20.000	7.400	4.094	2.996
18	60.000	20.000	7.400	4.094	2.996
19	60.000	20.000	7.400	4.094	2.996
20	37.000	25.000	7.110	3.611	3.219
21	37.000	25.000	7.110	3.611	3.219
22	37.000	25.000	7.110	3.611	3.219
23	37.000	25.000	7.110	3.611	3.219
24	15.000	25.000	7.140	2.708	3.219
25	21.000	19.000	7.180	3.045	2.944

**Graph 1**  
**Data from T-test Results**



**Graph 2**  
**Summer species progression**



**Graph 3**  
**Transformed summer progression graph**

