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CONTROL OF *AEDES* MOSQUITOES IN TWO RECREATIONAL AREAS IN THE MOUNTAINS OF UTAH[1]

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In certain localities in the mountains of northern Utah mosquitoes of the genus *Aedes* are frequently extremely annoying during early summer. In these localities nine species have been collected: *Aedes cataphylla* Dyar, *Aedes communis* (De Geer), *Aedes excrucians* (Walker), *Aedes fitchii* (Felt and Young), *Aedes impiger* (Walker), *Aedes intrudens* Dyar, *Aedes nearcticus* Dyar, *Aedes pullatus* (Coquillett) and *Aedes punctor* (Kirby). Although any of the nine above mentioned species may be locally annoying, members of the four following species are generally the most abundant and important pests: *Aedes cataphylla, A. communis, A. pullatus* and *A. punctor.*

All of these mosquitoes are produced in a single seasonal brood. The larvae develop in temporary pools formed by melting snow as well as in the water along the protected grassy margins of permanent lakes, ponds and mountain streams.

The larvae hatch from eggs laid the previous summer and usually appear in late April or May at the lower elevations, 6500 to 7500 feet, and throughout June and early July at elevations about 8000 feet. The first adult emergence begins in late May and continues throughout June with peak numbers appearing in early July. By the end of the first week in August the females have disappeared from most areas. Although the average life of the female is only of a few weeks' duration the great annoyance caused by them makes control extremely desirable in mountainous recreational areas which are frequented during the summer by large numbers of people.

Control of these mountain *Aedes* with one effective treatment is possible as these species are produced in a single brood each year. Another factor which favors control is the limited flight of these mosquitoes. Although extended migratory movements of members of some of the above mentioned species have been reported to occur in Arctic regions, observations made by the writers both in Utah and other western states indicate a restricted flight range for these species in timbered mountainous regions. Control has proved effective in Utah if extended one mile beyond the area where control is desired.

A number of workers have attempted control of these single brooded *Aedes* in both Canada and Alaska. Also, Roth *et al.* (1947) have carried on experimental

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control work in Oregon against these species. This account, however, is believed to be the first report in the United States of a successful sustained control program conducted on an area basis.

HISTORY OF CONTROL WORK

In August 1937, an appeal was made by the Girl Scout officials to the Salt Lake City Mosquito Abatement District for assistance in combating pest mosquitoes at Camp Cloud Rim, a summer camp for Girl Scouts near Park City, Utah. The University of Utah was notified and a survey of the area was undertaken under the supervision of the senior author. The region, averaging 9000 feet in elevation, is in the Canadian Life Zone with open forests of spruce, fir and aspen. The forests are interspersed with grassy meadows and small lakes.

The first inspection in June, 1938 revealed larvae and pupae in great abundance. The most typical breeding localities were flooded depressions in meadows, the grassy margins of lakes, the overflow of small streams and in rocky pockets. The source of the water was principally from melting snow. Using a pint dipper as a measure, the larvae and pupae averaged 200 per dip, with extremes varying from 25 to over 1000 per dip. The total area in which control was attempted consisted of approximately two square miles. One hundred and forty gallons of oil were applied over this area, most of it by personnel using 4-gallon knapsack pumps. Although a few adults had emerged before treatment, the results were excellent and the camp officials reported fewer mosquitoes than in any previous season. The effectiveness of the 1938 program was evident at the time of the spring inspection in 1939 when the number of larvae averaged approximately 20 per dip, as compared with 200 in 1938. One hundred and fifty gallons of oil were applied in 1939 with effective results.

In 1940 control work was started at Brighton, a popular summer resort near Salt Lake City at the head of Big Cottonwood Canyon. Brighton, at an elevation of 8720 feet, lies in a large glacial cirque. This area, also in the Canadian Life Zone, is characterized by spruce, fir, aspen, thick willow growths and extensive marshy meadows. A small lake with grassy margins occupies a portion of the area. Several thousand people are present at Brighton during the summer months living in lodges, private homes and public camp grounds. Control operations were instigated as a result of an appeal to the Salt Lake City Mosquito Abatement District by a committee of private citizens, representing the summer residents at Brighton, who stated that the mosquitoes during June and July were unbearable. An inspection of the area on June 10, 1940 revealed great numbers of larvae developing in practically all standing water throughout the area including the grassy margins of the small lake. The total area requiring control comprised approximately three square miles. The larvae were very abundant, averaging 150 to 200 per pint dipper sample. Seventy-five gallons of oil were dispensed by knapsack sprayers. Dense willow growths in the marshy areas made much of the spraying extremely difficult as it was impossible for a man carrying a spray pump on his back to penetrate and thoroughly treat these areas. The results, however, were encouraging as the adult mosquito population was only a fraction of that of the previous years. Control was continued the following year and again the inspection revealed the effectiveness of this program. Areas that had been treated in 1940 contained only 20–50 larvae per dip with an average reduction of 80% as compared with the previous year. In pools which had not been treated in 1940 the numbers still averaged 150 to 200 per dip.

The results of control in 1941 at both Brighton and Camp Cloud Rim were disappointing as biting adults were more abundant than they had been the previous year. This was due to the fact that at both localities an attempt was made to simplify control operations by providing

caretakers and camp employees with oil and spray pumps for application. It was the intention to supply trained inspectors who would instruct the resort personnel on the correct methods of control. Though the inspections were properly made, the spraying was not carried out efficiently and a great many adults emerged. After this experience all control work in these two areas has been conducted by employees of the Salt Lake City Mosquito Abatement District. Control work at both Camp Cloud Rim and Brighton has been continued yearly and in recent years has been extended to include all of Big Cottonwood Canyon below Brighton. This canyon is 15 miles long and contains many public camp grounds, lodges and private cabins. Control methods have been the same as those used at Brighton and have been very effective. Control in this canyon was easier than anticipated due to its contours. The canyon is narrow with steep walls throughout most of its length. The gradient is steep and the main stream moves rapidly with only a few situations occurring which are favorable to mosquito production.

CONTROL MEASURES

Inspection: Careful inspection is of primary importance in the control of mountain *Aedes* in Utah. Because of the great diversity of breeding habitats in a mountainous area it is easy to overlook small pools which are prolific producers of mosquitoes.

It has been a standard procedure each year at both Cloud Rim and Brighton to conduct an intensive inspection throughout the entire control area before the application of larvicides. This vigilance has increased the effectiveness of control as new pools have been located and treated yearly.

Drainage: Drainage has been used to a limited extent at both Camp Cloud Rim and Brighton. It has been of value in lowering the water level in some of the large breeding areas, but is of secondary importance in overall control. Drainage in mountainous areas is inadequate due to the fact that the gradual melting of snow, which may last over a period of several weeks, can supply a pond with sufficient water to hatch eggs even though the pond may be continually draining. Drainage in situations like this may be unwise as it may cause distribution of larvae over a wider area. There are situations where drainage may be used to good advantage, but the practicality and location of drains must be carefully studied by experienced personnel before this form of control can be utilized. It has been the experience in Utah to date, that the cost of constructing and maintaining an adequate drainage system in mountainous areas where heavy snowfall occurs, is generally greater than the cost of a single effective larviciding program.

LARVICIDES:

Oil: Petroleum oil was the only larvicide used in control operations from 1938 until the summer of 1949. Though now largely replaced by DDT, oiling has produced excellent results in the past and still may be useful in certain situations where pupae are present or where the use of DDT may be objectionable. The best results against mountain *Aedes* were obtained with light oil of good quality. The spreading quality of the oil is especially important in the mountains where the temperature of the water produced from melting snow is often very low. In Utah an oil larvicide consisting of 97% No. 2 fuel oil and 3% cresol has been used. Cresol, which contains 12% coal tar acids, substantially increases the toxicity of the fuel oil. Oil does not have the residual effect of DDT, but it does cause a reduction in the number of larvae which appear in the same pools the following year. It has been observed at both Camp Cloud Rim and Brighton that pools treated with oil show a 50% to 80% reduction in the number of larvae occurring the following season. Herms and Gray (1944) report similar observations in the mountains of California and believe that oiling is a definite deterrent

to deposition of eggs by mountain *Aedes* mosquitoes. This is probably true, but it should be noted that any larvicide which kills as effectively as oil will greatly reduce the potential number of egg laying females, and should naturally cause a reduction in larvae the following year. This is especially true for mountain *Aedes* which produce only one brood yearly and apparently have a limited flight range.

DDT: One of the greatest problems in the control of mountain *Aedes* is to reach the mosquito-producing water before the adults are on the wing. Snow-blocked roads often delay work until effective control becomes very difficult. This problem has been experienced at Camp Cloud Rim where the road, because of snow, is usually not open until the larvae are in the late instars or have pupated. The solution to this is the use of a pre-hatch larvicide which can be applied in the fall while the roads are open.

In this program DDT was first used as a pre-hatch larvicide in September, 1949 at Camp Cloud Rim. At this time one of the most prolific mosquito-producing areas was divided into several small plots. These were sprayed with an aqueous solution of DDT at the rates of .2, .3 and .4 lbs. of DDT per acre. All sprayed plots had adjoining untreated control plots. On June 10, 1950 all of these plots were inspected. Those plots treated with .3 and .4 lbs. DDT per acre showed a complete absence of larvae and plots with .2 lb. of DDT per acre contained only an occasional larva. All untreated control plots contained larvae averaging from 10–50 per dip. On June 15, 1950, using the same concentrations of DDT as above, the entire control area at Camp Cloud Rim was treated. A number of pools were left untreated as controls and the pools sprayed in September 1949 received no further treatment. The summer of 1950 was unquestionably the most successful season since the inception of control work at Cloud Rim and very few adults were reported by camp personnel. No pre-hatch

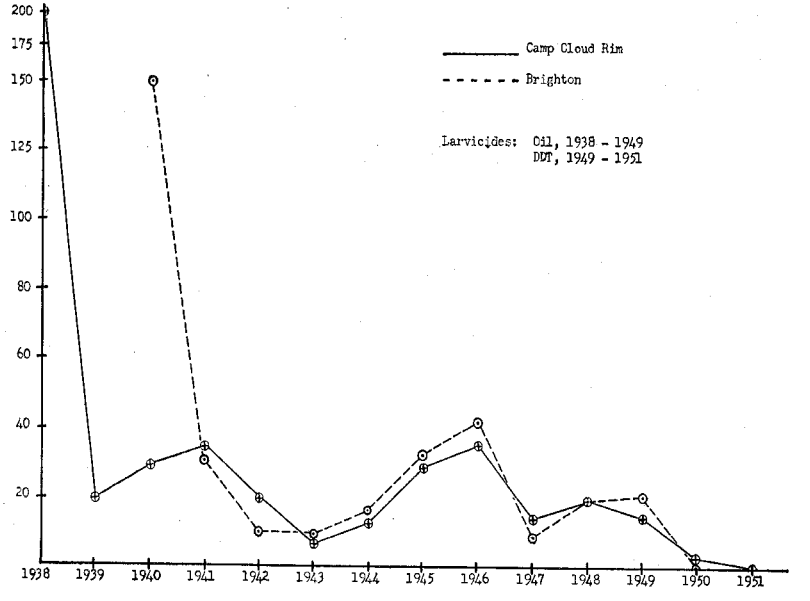

FIG. 1. Reduction in mosquito larvae in water treated with larvicides as determined by the average number of larvae obtained in a pint dipper during all inspections. (Increase in larval production during years of 1944, 1945 and 1946 due to curtailment of control activities during wartime.)

work was attempted during the fall of 1950. In June, 1951 an intensive inspection substantiated the incomplete results of the previous year. Larvae rarely were found in areas treated with .3 and .4 lb. of DDT per acre and relatively few were found in areas treated with .2 lb. per acre. All untreated plots contained numerous larvae except those originally treated in the fall of 1949. These for the second year produced no larvae.

Pre-hatch work at Brighton was begun in April, 1950. Brighton is a winter skiing resort and it is possible to gain access to the region at any time during the year. The pre-hatch treatments were conducted here in the same manner as at Camp Cloud Rim using the same concentrations of DDT. At Brighton, however, a 10% dust applied at the rate of 1 lb. per acre also was used and both the spray and dust were applied on the snow over known breeding areas. This method of pre-hatch treatment for snow mosquitoes had been previously reported from Oregon by Roth *et. al.* (1947), although they used a much higher concentration of DDT. This type of treatment was particularly effective at Brighton. In previous years the dense willow growths had made spraying extremely difficult and of limited effectiveness. During the winter as the result of heavy snows the willow thickets were covered and it was a simple matter to spray or dust DDT on the snow over them.

An inspection in June, 1950 revealed almost identical results with those at Camp Cloud Rim. All DDT treated areas showed larval reductions in excess of 98% when compared with untreated areas. All untreated control areas contained larvae ranging from 25 to 50 per dip. These control pools were sprayed with .3 lb. DDT per acre and 100% kill was obtained except in a few pools which contained pupae. In these cases the spraying was only 40–70% effective. In June, 1951 an inspection revealed that all pools treated in the spring and summer of 1950 showed reductions of larvae from 98–100% over previous years. No additional treatment was required at Brighton in 1951 except for a few new localities discovered when control measures were extended over a slightly wider area. Several inspections made during June and July, 1951, revealed almost a total absence of biting adults.

Tossits: One of the extremely valuable aids in the control of snow mosquitoes in Utah has been the use of "Tossits" manufactured by SENTCO Inc., of West Palm Beach, Florida. These are small gelatinous capsules about 20 mm. in diameter, which contain 12% DDT and 4½% BHC. The combination of DDT and BHC makes them very effective on all larval stages and pupae. When immersed in water they soon release the chemicals which spread over the water surface very rapidly. Under normal use each Tossit is reported to have a killing effect in 750 sq. feet of open, unobstructed water surface. In our experience in mountainous areas where the water usually contains vegetation and a considerable amount of organic matter they are most effective when applied at the rate of 1 per 100 sq. feet of water surface.

TABLE 1. Comparison of pools treated at Camp Cloud Rim and Brighton before and after the application of DDT.

Locality	Number of pools treated at first inspection	Maximum number of pools treated with oil, 1949	Number of pools requiring treatment in 1951 after DDT applications
Camp Cloud Rim	46 (1938)	62	9
Brighton	79 (1940)	107	7
Totals	125	169	16

In this program Tossits were used under a wide variety of conditions. Their chief value is attained when used on small pools located during inspections. An inspector can carry a quantity of Tossits very easily through rough heavily vegetated mountainous terrain and can treat an extensive area which would be extremely difficult to treat with knapsack pumps. Their use is by no means limited to small pools. They have been used successfully along lake margins, and in one instance a pond of about 2000 sq. feet of surface was treated successfully with Tossits distributed in the snow over the ice covering the pond.

It appears that Tossits have a good residual effect. In most cases pools treated with Tossits in June, 1950 at both Camp Cloud Rim and Brighton showed a reduction in larvae in 1951 comparable to ponds sprayed or dusted with DDT.

SUMMARY AND CONCLUSIONS

Control of mountain *Aedes* mosquitoes has been carried on successfully in Utah for thirteen years. Although other workers have attempted experimental control against mountain *Aedes* (Roth, *et. al.* 1947) this is believed to be the first report of an effective sustained control program against these mosquitoes on an area-wide basis.

This program was conducted in two recreational areas in the Wasatch Mountains near Salt Lake City. Both of these localities are in the Canadian Life Zone and average 8500–9000 feet in elevation. The principal mosquito species in both regions are *Aedes cataphylla, Aedes communis, Aedes pullatus* and *Aedes punctor.* The following analysis of the results of this control program may be helpful in establishing control in other mountainous localities where pest *Aedes* species occur:

1. The success of mosquito control depends primarily upon the thoroughness with which inspections are made to locate all water producing larvae. This is especially true in controlling *Aedes* in mountainous areas as the larvae occur in diversified situations and the nature of the terrain is conducive to the formation of new mosquito producing sites.

2. Drainage is generally of limited usefulness in mountainous regions where deep snow accumulates in the winter and gradually melts in the spring and early summer. In the Wasatch Mountains of Utah the cost of constructing and maintaining an adequate drainage system has proved to be considerably greater than that of an effective larviciding program.

3. The use of a light petroleum oil of good spreading quality is effective on all immature stages of mountain *Aedes.* A No. 2 fuel oil with cresol added to increase the toxicity was used with good results in these recreational areas for several years. Though inferior to DDT in its residual effect and in ease of transportation and application, it nevertheless is an effective larvicide.

4. DDT in both spray and dust form has proved to be very effective against mountain mosquitoes in Utah. Concentrations of .3 and .4 lb. per acre for the spray and 1 lb. per acre for the dust have produced excellent results with residual effects lasting at least one year. The use of the spray has proved more desirable than the dust because it can be used effectively in smaller quantities and can be easily transported in a concentrated soluble form and mixed in the desired proportions with water at the site of application. It also can be applied more uniformly than dust. Although DDT may be applied directly to pools containing larvae and pupae, better results have been obtained when used as a pre-hatch larvicide. In this way areas which produce larvae can be treated in late summer or fall, and the danger of snow blocked roads and trails preventing early treatment in the spring is avoided. If the control areas can be reached during the winter months or in early spring it is often desirable to treat the snow over known mosquito producing sites. This method has proved especially useful in the Wasatch Mountains of Utah where many of the most prolific mosquito producing areas occur in dense willow growth, which are extremely

difficult to penetrate and treat. In the winter these willow growths are covered by heavy snowfall and it is possible to effectively pre-hatch the area on the surface of the snow.

5. "Tossits", the small gelatinous capsules containing 12% DDT and 4½% BHC have proved extremely useful in these recreational areas. Each "Tossit" will effectively treat about 100 square feet of water surface. They can be used in almost any type of situation and have a good residual effect. In this program they were especially valuable when carried by inspectors and used in treating pools found in rugged terrain that would be difficult to reach and treat with knapsack pumps.

6. Some of the other hydrocarbons have been used experimentally in these two recreational areas with promising results. To date it has been unnecessary to use other larvicides extensively, as DDT, supplemented with Tossits, has produced complete control in the Brighton area and has produced excellent results at Camp Cloud Rim and vicinity.

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CONTROL OF BITING GNATS IN NORTH SALT LAKE CITY, UTAH (DIPTERA : HELEIDAE)

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A program for the control of the biting gnat—*Leptoconops kerteszi* var. *americanus* was conducted in North Salt Lake City, Utah during the spring of 1949, 1950 and 1951. The results of the work in 1949 have been published (Rees and Smith, 1950). The control program was continued in 1950 with marked improvements and was repeated in 1951 with complete success, as measured by the absence of gnat annoyance in the area. The program consisted of two phases: first, determination of the location and size of the area in which the gnats are produced, and second, the determination of the most effective and economical methods of control.

SURVEY

The first phase, that of determining the location and size of the area in which the gnats are produced, was at first extremely difficult, time-consuming and expensive. The gnat-producing areas involved, as eventually determined are shown in Fig. 1. The larvae of this gnat develop in moist soil and do not appear on the surface until the time of pupation. In the first surveys that were made to locate the larvae, soil samples were taken at measured intervals, then washed, screened and examined in the laboratory under magnification. This was a slow, laborious method and too expensive to be practicable.

In 1950 it was observed that when the larvicide was applied to the surface of the ground, just prior to the time of pupation, the larvae exposed themselves, and squirmed around for several minutes before dying. Under these conditions they were readily visible to the unaided eye.

As a result of these observations several different insecticides such as DDT, lindane, chlordane, toxaphene and rothane were used in water emulsions of 1.0, 2.5, 5.0, and 10.0 percent, to determine the most effective insecticide and concentra-