CONTROL OF SNOW POOL MOSQUITOES WITH *BACILLUS THURINGIENSIS* SEROTYPE H-14 IN MOUNTAIN ENVIRONMENTS IN CALIFORNIA AND OREGON

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ABSTRACT. Studies were conducted in mountainous areas of California and Oregon to test the effectiveness of *Bacillus thuringiensis* serotype H-14 in controlling larvae of snow pool *Aedes* mosquitoes, and also the effect of such larval control on the density of adult mosquitoes. California and Oregon studies showed that a wettable powder formulation of *B.t.i.* was effective in controlling mosquito larvae. In Oregon, treatment was effective even at water temperatures as low as 5°C. Sampling of adult mosquitoes at campgrounds where intensive larval control was done failed to demonstrate a lowering of adult mosquito density in comparison with untreated control areas. Flight range studies showed that snow pool *Aedes* species can fly distances of up to 2 km, suggesting that infiltration from outside the treated area was one cause of failure. Inadequate seasonal timing appeared to be an additional factor. Using a simple computer model, we estimated that larval mosquito control with *B.t.i.* could be done for about $5,000 per season for a 500 ha area similar to our test area, a cost of $10 per ha ($4 per acre).

INTRODUCTION

Mosquitoes are often a problem in mountain environments, and have delayed and complicated the development and operation of recreation facilities wherever they are present in large numbers (Newson 1977). Snow pool *Aedes* are particularly troublesome in areas where topographic features result in extensive pools of water formed from melted snow. The studies reported here were spurred by control problems in two such areas. In the South Lake Tahoe area in the Sierra Nevada range of California a large human population has developed in a subalpine area well supplied with suitable breeding sites for snow pool mosquitoes, and public pressure for relief from mosquitoes is high. At Waldo Lake, in the Cascade range of Oregon, expensive campgrounds have been developed by the U.S. Forest Service, but are little used by the public because of high densities of mosquitoes at the height of the camping season in July and August.

Previous attempts to control the snow pool *Aedes* mosquitoes which characterize mountain habitats have not always been effective, or have had environmental problems associated with them. Hoffman and Lindquist (1952) were able to produce satisfactory control of snow pool mosquitoes by the use of residual insecticidal sprays on vegetation and space sprays in campgrounds in the Cascade Range of Oregon. They found, however, that control was inadequate in campgrounds located adjacent to large breeding sources. Satisfactory control was obtained in high mountain campsites in Utah using various chlorinated hydrocarbons as larvicides, if inspection and treatment was thorough (Rees and Nielsen 1952). There have been few recent reports of mosquito control operations in mountain environments, although some research has been conducted on the biology of snow pool mosquitoes in high mountain environments and at lower elevations (see Newson 1977 for a review of the subject). Repeated application of conventional insecticides to control adult mosquitoes in California had been shown to have undesirable side effects, such as the outbreak of pine needle scale [*Phenacaspis pinifoliae* (Fitch)] on coniferous trees because of the elimination of natural insect predators and parasites (Dahlston et al. 1969). In recent years, increased concern over the impact of conventional pesticides on wildlife and other non-target organisms has stimulated a search for alternative methods of insect control.

The discovery of *Bacillus thuringiensis* serotype H-14 (de Barjac 1978) (*B.t.i.*) led to the commercial availability of an insecticide which seemed to offer the possibility of safe and effective larval control of snow pool mosquitoes. *Bacillus thuringiensis* serotype H-14 is toxic to mosquitoes, black flies, and certain chironomids, but has been reported non-toxic to a wide range of non-target organisms (Burges 1982). Since mountain snow pool *Aedes* are univoltine, the lack of persistence of *B.t.i.* should not be undesirable, and in terms of environmental safety it is desirable.

This paper reports a 2-year study conducted in the South Lake Tahoe area of California and at Waldo Lake, Oregon. The study addressed several questions. First, is *B.t.i.* suited to these environmental conditions and particularly, would *B.t.i.* be effective as a larvicide at the low temperatures prevailing in snow pools at the time of mosquito hatching? Various studies have indicated that *B.t.i.* is less effective at lower

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temperatures. Jones et al. (1982) found that in field tests conducted in Wyoming, control percentages were approximately twice as high at temperatures of approximately 19°C than at temperatures approximately 6°C. Laboratory studies of Wraight et al. 1981 (mosquitoes) and Lacey et al. 1978 (black flies) concluded that larval insect mortality tended to be reduced at lower temperatures. To evaluate the effects of water temperature on the efficacy of *B.t.i.* we monitored the maximum and minimum water temperatures in California. In 1983, we also monitored the water temperatures of 12 treated pools in Oregon continuously over 48-hr post-treatment periods.

Second, we asked whether thorough larval control in these areas could reduce densities of adult female mosquitoes substantially. We attempted to reduce the adult mosquito population of the Shadow Bay Campground at Waldo Lake, Oregon, by thoroughly larviciding an area within a 1.6 km radius from the campground. Adult mosquito densities in the campground were then compared with densities in two nearby similar campgrounds. The suspicion that adult mosquitoes from a large marshy area about 2 km south of Shadow Bay Campground might infiltrate the treated area led to a third question: would the adult *Aedes* breeding in the marsh migrate to the campground? Although Hoffman and Lindquist (1952) report that migration of snow pool *Aedes* was "high" during evening hours in the Oregon Cascades, they furnish no quantitative data. Little specific information is available on flight ranges of snow pool *Aedes* in general. Nielsen (1957) has estimated the flight range of *Aedes communis* (de Geer) as approximately 1.6 km, but his estimate was not based on modern methods of mark-release-recapture. Jenkins and Hassett (1951) used radioisotopes in mark-release-recapture studies to estimate the maximum flight range of this same species as 1.6 km, but their recapture rate was exceedingly small (0.005%). Carpenter (1961) observed that *Aedes* mosquitoes in the high Sierras of California were seldom encountered in large numbers except in close proximity to their breeding sites. In 1983 we assessed the flight range of the mosquitoes at Waldo Lake using mark-release-recapture techniques developed earlier that year in California.

A fourth objective was to determine if there would be any adverse effects on the non-target macroinvertebrate faunae of snow pools treated with *B.t.i.* These studies will be reported elsewhere.

Finally we wished to estimate costs of mosquito larviciding in mountain environments using primarily light-weight non-powered equipment. This determination was aided by a simple decision-support system program which we wrote for use on a microcomputer.

MATERIALS AND METHODS

STUDY AREAS. California: Studies were conducted at various sites in the El Dorado National Forest in the South Lake Tahoe area in 1983. Most sites were in the Hope Valley area of Alpine County on Highway 88 at an elevation of about 2,400 meters. Observations of the immature stages of aedine mosquitoes were mostly in grassy pools in a large meadow bordered by heavy stands of conifers, mostly *Pinus contorta* (lodgepole pine). Preliminary trials to develop the details of the subsequent mark-release-recapture test in Oregon were also conducted in the Blue Lake area (Abbott Meadows).

Oregon: Studies were conducted in 1982 and 1983 at Waldo Lake (Fig. 1), located in the high Cascades approximately 32 km due east of the town of Oakridge. The lake is 1,650 meters in elevation at water level, and is 2,428 hectares in area. The area is considered a subalpine forest environment, specifically in the *Tsuga mertensiana* (mountain hemlock) zone (Franklin and Dyrness 1973). Three major campgrounds are

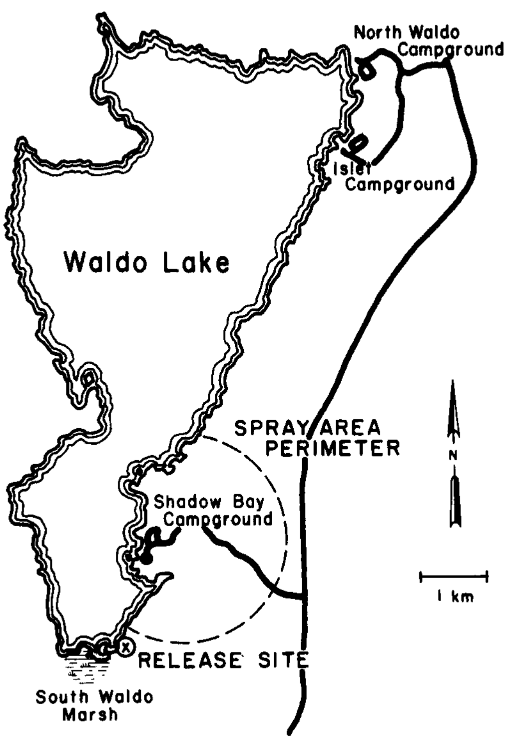

Fig. 1. Map of Waldo Lake, Oregon and surroundings, showing study sites.

located on the eastern lake shore: Shadow Bay, Islet and North Waldo. Topographical features which are conducive to the breeding of snow pool *Aedes* mosquitoes, i.e., flat or gradually sloped ground with many depressions, are prominent in the vicinity of all three campgrounds. A large marsh exists at the southern edge of the lake, about 2 km from the Shadow Bay Campground.

INSECTICIDAL TREATMENTS. Treatments were with *Bacillus thuringiensis* serotype H-14, wettable powder, furnished by Abbott Laboratories, North Chicago, IL. This formulation contained 2,000 *Aedes aegypti* ITU/mg. All applications were made with handpowered, dual (Oregon) or single (California) nozzle, Solo™ backpack sprayers having a capacity of 15 liters. In all cases, treatment rate was 0.5 kg of active ingredient per hectare of water. The application spray rate was 500 liters/ha.

TEMPERATURE MEASUREMENTS. At Waldo Lake, water temperatures were measured only at the time of treatment in 1982. In 1983, water temperatures were monitored at 30 min intervals from the time of treatment until 48 hr after treatment at two treatment sites per week. This was done with a Datapod™ digital temperature measuring device (Omnidata International, Inc., Logan, UT). The device was placed in a small wooden box which was buried adjacent to the pond being tested, and a probe attached to a 3-meter electrical cable was placed at the bottom of the pond about 1 m from the water's edge, 10–20 cm deep. In California, temperature was measured using maximum-minimum thermometers.

MOSQUITO SAMPLING. To estimate the efficacy of *B.t.i.* treatments, larval mosquitoes were sampled immediately before application, at 24 and 48 hr posttreatment, and in Oregon, 1 week after treatment and periodically thereafter to the end of the study period. Sampling was done with a standard 0.5-liter dipper. Five samples were taken in each of four areas at the treatment site to make a total of 20 samples per site. In Oregon, two sites were selected each week during each season for detailed study. Complete pre- and posttreatment sampling temperature measurement, and non-target organism sampling were done at these sites. Other sites were sprayed if mosquitoes were present, but complete sampling was not done. In California, ponds were selected at random for treatment and to serve as controls.

At Waldo Lake, adult mosquito populations were monitored throughout the summer. Two battery-powered miniature light traps baited with dry ice were operated at each of four locations; campgrounds at Shadow Bay (F-Loop and B-Loop), Islet (Campsite 36), and North Waldo (Campsite 26). Traps were operated weekly from mid-June through the month of August. Human bait collections were made at these same locations at the time light traps were set out. Collections were made by 2-person teams, with one person serving as the bait while the other aspirated all landing mosquitoes. Halfway through the collection period, the individuals exchanged roles. Most collections were 10 min in duration and are expressed as female mosquitoes landing per minute of exposure. All mosquitoes captured in light traps and on human subjects were identified to species.

MARK-RELEASE-RECAPTURE METHODS. Preliminary experiments were conducted in the Hope Valley area of California to develop the methodology which was used in the Waldo Lake area. Based on these experiments, the following methods were used: Mosquitoes were collected as larvae and pupae, and as adults (human bait collections). Larvae and pupae were placed in 1-meter square cages which were placed in shady forest areas for emergence. The number of adults which emerged, even after 1 week, was so low that we used only field-collected adults for the flight range studies. These adult mosquitoes were placed in 3.8 liter ice cream cartons, provided sugar water and raisins, counted, and marked. The interiors of the ice cream cartons were inscribed with two 5% radial quadrants for counting (Dow et al. 1965), which included the sides and the bottom. Mosquitoes resting within the demarkations were counted separately by four individuals and the mean of these counts was multiplied by 10 to obtain an estimate of the total of mosquitoes per cage. Radiant color green fluorescent dust (R-193-G, Radiant Color, Richmond, CA) was used to mark captured mosquitoes. Each cage was placed top down on the ground and the dust was applied through an access port using a Larkin mucous trap (Davol Inc., Providence, RI). About 0.02 g of dust per cage was applied. Although this amount of dust is sufficient to mark mosquitoes in such a way as to be visible under a UV light under a dissecting microscope, the marking is not visible to the naked eye.

After dusting, mosquitoes were released by placing the holding cages in a shady location and removing the tops. Mosquitoes were recaptured using battery-powered miniature light traps baited with dry ice, and by human bait collections. The release site was a small marsh adjacent to the large South Waldo Marsh. Recapture sites were located on a line extending along the lake shore from the release site and in the opposite direction toward the South Waldo Marsh. The lines extended for distances of up to 2 km. The traps were operated and human bait collections were made from the day of release until 4 days after release. Routine trap and bait collections were examined for marked specimens for several weeks after the release date. To detect marked mosquitoes, each sample was placed under a 15W black light (GE f15/BLB) and examined under a dissecting microscope. Marked mosquitoes were mounted on paper points and later identified to species.

COST ANALYSIS. To perform a cost analysis of *B.t.i.* treatment of snow pools, a simple decision support model was developed in Microsoft BASIC-80™. This program allowed the estimation of costs based on 16 different input variables (Table 1). The data input to the model were gradually refined based on the experiences of the two-year study. A copy of the program may be obtained from the senior author.

RESULTS

CONTROL OF SNOW POOL LARVAE WITH *B.t.i.*, In California, a field trial was conducted in the Hope Valley area in June of 1983. *B.t.i.* was applied to four randomly selected snow pools at a rate of 0.5 kg/ha; a fifth pool served as a control. Pretreatment larval densities ranged from 2.55 (mean larvae per dip, all stages, 20 dips) to 57.05 among the pools tested. Species present were identified as *Aedes ventrovittis* Dyar and *Ae. cataphylla* Dyar. Posttreatment reductions ranged from 98 to 100% after 24 hr and from 92 to 100% after 48 hr. No reduction occurred in the control pool. Temperatures varied from 1 to 30°C during the tests.

Table 1. Variables for a simple decision support system model for microcomputers.

Input variables:	Output variables:
Total area to treat	Total water area to treat
Mean number sites per unit area	Total treatments to make
Number treatments per site	Number days needed to treat
Dosage rate	Teams needed
Days available for treatment	Persons needed
Sites one team can treat per day	Wage costs
Wages per person per day	Total food costs
Cost of food per person per day	Amount of insecticide needed
Cost of insecticide (per unit)	Total insecticide cost
Cost per sprayer	Total supplies cost
Vehicles needed	Total sprayers needed
Per unit distance cost, each vehicle	Total cost for sprayers
Number days vehicle needed	Total equipment cost
Distance driven daily, each vehicle	Total transportation cost
Other supply costs	Miscellaneous costs
Other equipment costs	Total costs

In Oregon, we attempted to treat all mosquito-containing snow pools within a 1.6 km radius of the Shadow Bay Campground. In both 1982 and 1983, the start of the study period was governed by the snow pack melting sufficiently to permit access to the study area. It was not possible to drive to the study areas in conventional vehicles before July 1 either year, and earlier access was by small tracked vehicles or helicopter. In the summer of 1982, 22 snow pools were treated at a rate of 1 kg/ha of *B.t.i.*, A total of 7,384 m² of water was treated. Posttreatment reductions ranged from 59 to 100% after 24 hr, but after 1 week all pools except one were completely mosquito-free. In the exceptional case, the reduction after 1 week was 88%. Water temperatures at the time of treatment varied from 4 to 24°C. During the summer of 1983, 63 snow pools were treated with *B.t.i.* at a rate of 0.5 kg/ha. The total water area treated was 25,960 m². Effective mosquito control was obtained in each of the 12 sites studied in detail (Table 2). Even at the site sprayed on June 22, where the mean water temperature was 5.7°C, 100% larval mortality was observed after 48 hr. Here, and also at the site sprayed June 29, newly melted snow increased the size of the pool after spraying, resulting in the hatching of additional mosquito larvae. In all other cases, sites remained mosquito-free for the remainder of the study period. Pre-spray larval densities were highest early in the season (5.62 larvae per dip, June 15), and gradually became lower as the season progressed (1.25 larvae per dip, July 5, 0.55 larvae per dip, July 28).

The percentage of pupae present in samples taken from treated pools is shown in Fig. 2. Because of a difference in daily temperatures between 1982 and 1983, snow melting and larval development times were approximately 1 week later in 1982 than in 1983. In both years, however, over 50% of the pools contained some pupae by mid-July. In 1982, 50% of the sites and 61% of the water area treated had been treated by this time. In 1983, 68% of the sites and 61% of the water area treated had been treated by mid-July.

ADULT MOSQUITO POPULATION LEVELS. To determine whether or not populations of adult mosquitoes had been lowered substantially, routine adult sampling was done at two sites at Waldo Lake, Oregon within the treatment zone at Shadow Bay Campground and two sites in the North Waldo area as a control in the summers of both 1982 and 1983. A total of 1,156

Table 2. Efficacy of *B.t.i.* spraying at selected sites, Waldo Lake, Oregon, 1983.

Date sprayed	Area (meter²)	Temperature (°C) High	Low	Mean	Pretreatment density[a]	Percent. reduction 24-hr	48-hr	1 Week
15 June	900	13.0	5.5	9.5	5.62	95	—	100
21 June	840	11.5	8.0	10.0	5.97	35	80	100
22 June	240	9.0	3.7	5.7	0.85	85	100	29[b]
28 June	420	10.5	7.0	8.5	1.31	95	100	100
29 June	860	19.3	8.5	12.4	0.53	57	100	43[b]
5 July	418	20.0	11.5	14.9	1.25	100	100	100
6 July	836	15.3	6.5	10.2	2.12	98	100	100
12 July	575	22.3	10.8	16.2	2.20	67	95	100
13 July	750	21.0	10.0	14.3	0.36	100	100	100
20 July	480	20.0	13.5	16.7	0.44	91	100	100
21 July	300	12.3	12.0	15.4	0.26	—	—	100
28 July	198	21.5	10.0	14.7	0.55	—	—	100

[a] Mean number larvae per dip, all stages, 20 dips.
[b] Larvae present in portion of pool formed from snow melted since treatment.

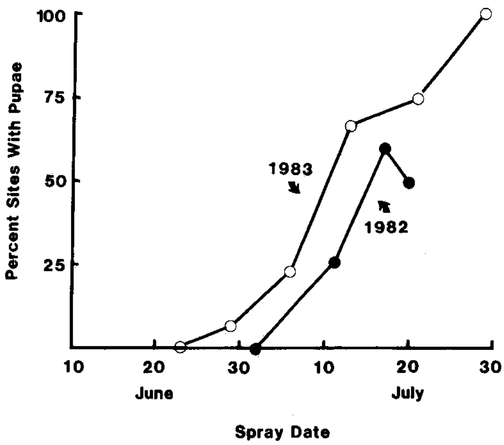

Fig. 2. Percent of sites sprayed having mosquito pupae present at time of initial spraying, 1982 and 1983, Waldo Lake.

female mosquitoes were collected in 1982, and they were not identified to species. In 1983, 8,139 female mosquitoes were collected and identified. Mosquitoes of the *Ae. communis* complex[3] were by far the most abundant group sampled (64% of all collections), *Aedes hexodontus* Dyar was the next most abundant (26.4%). In 1983 human bait and light trap collections (Table 3) indicated mosquito densities were higher in the Shadow Bay area for most of the season than were the densities at the North Waldo sites. Human bait collections, which parallel the light trap collection data closely, are not shown. Densities tended to be higher at the North Waldo sites earlier in the season because snow melt tends to take place a week or so earlier than at southern Waldo Lake sites. This trend continued until about July 20, and then a sudden surge in density at Shadow Bay caused total numbers there to far exceed those at the North Waldo sites. A similar pattern was observed in 1982, but the shift was reflected in the August 1 collections. Among the most common species sampled, the most dramatic increase was seen with *Ae. communis* complex. During the week of July 14, 1982, the mean density in light traps of this species was 14.3 females per trap night. The next week, however, the mean density was 362.0 per trap night. This increase in density coincided with the emergence of large numbers of *Ae. communis* complex at the South

[3] In the western United States, *Aedes communis* (de Geer) and *Ae. nevadensis* Chapman and Barr are virtually indistinguishable in the adult stage. In this paper, members of these species are referred to as the *Aedes communis* complex, although only *Ae. nevadensis* larvae were collected and identified in Oregon in connection with this study.

Table 3. Summary of light trap collections, Waldo Lake, Oregon, 1983.

Week of study	Date	Shadow Bay B-Loop	Shadow Bay F-Loop	Islet	North Waldo
1	15 June	—	—	—	—
3	28 June	8.5[a]	8.5	—	—
4	5 July	28.5	20.0	173.5	49.5
5	12 July	82.5	30.5	281.5	84.5
6	20 July	531.0	429.0	99.0	199.0
7	26 July	387.0	315.0	60.5	74.5
8	2 August	81.5	191.0	47.0	81.0
9	9 August	48.0	98.5	38.5	39.0
10	16 August	18.0	67.5	16.0	26.0
11	25 August	6.5	21.0	1.5	2.0
12	30 August	36.0	9.5	15.5	16.5

[a] Number of female mosquitoes per trap night.

Waldo Marsh. The previous week, an inspection of that area showed pupal densities well in excess of 100 per dip.

SNOW POOL *AEDES* FLIGHT STUDIES. Collections of adult female mosquitoes were made almost continuously on July 18 and 19, 1983 at Shadow Bay Campground at Waldo Lake. Adults were treated, counted, and marked as described earlier. Marked mosquitoes were released at noon on July 19 at a point on the southeast shore of Waldo Lake approximately 2 km from the Shadow Bay Campground and 0.5 km from the South Waldo Marsh (Fig. 1). A total of 3,054 mosquitoes were released. Sixty-three marked adults were recaptured within 72 hrs (Table 4), a recapture rate of 2.1%. Among those recaptured, 18 were *Ae. hexodontus,* 44 were *Ae. communis* complex. Recaptures indicated that marked females had dispersed at least toward the South Waldo Marsh and along the lake shore toward Shadow Bay Campground. No attempts were made to capture marked females which may have dispersed in other directions. Sampling at the release site on July 20 demonstrated that many of the marked females remained in that vicinity. Two successive days of collecting there resulted in declining numbers of recaptures. A recapture at F-Loop at Shadow Bay Campground represented a dispersal of 1.6 km within 40 hrs. Individual marked females were recaptured in Shadow Bay Campground on July 20, 21, 22 and 26. The recapture July 26 was at B-Loop, 2.0 km from the release site. In all, 10 collections of mosquitoes for the purpose of recapture of marked females were made between July 20 and July 26. The species identified were *Aedes communis* complex, *Ae. hexodontus,* and *Ae. fitchii* (Felt and Young) in a ratio of 100:21:1.

COST ESTIMATES FOR CONTROL. Based on 1982 data, we estimated that control of larval mosquitoes with *B.t.i.* at Waldo Lake would cost $14,000. The estimate was refined with data obtained during the 1983 studies. Using these data, we estimate that larviciding with *B.t.i.* can be done for less than $5,000 in a forested mountainous area of 500 ha ($10/ha). This assumes that conventional vehicles can be used to gain access to within 2-3 km of the area to be treated. This assumption was not met for Waldo Lake, and here costs would be higher most years. We estimate that alternate means of transportation (snowmobiles, helicopters, etc.) would add at least $1000 to the cost of treatment. However, this would depend upon factors too numerous to permit generalization.

The breakdown of estimated costs from the model is as follows:

Personnel	$2,448
Transportation	105
Insecticides	35
Equipment	600
Supplies	890
Miscellaneous	408
Total	$4,486

Table 4. Summary of marked mosquitoes recaptured, Waldo Lake, 1983.

Date of recapture	Number recaptured at distance from release site: 0.8–1.6 km	0.8 –1.6 km	1.6 km +
19 July	1	0	0
20 July	28	1	1
21 July	26	1	1
22 July	2	0	1
26 July	—	—	—
Totals	57	2	4

DISCUSSION

The experiments in California and Oregon demonstrated that *B.t.i.* wettable powders are extremely effective in controlling snow pool *Aedes* larvae, even at temperatures close to the freezing point of water. However, additional research on the effect of environmental temperature on efficacy of *B.t.i.* should be conducted. We saw no evidence of diminished efficacy at the temperatures we encountered in snow pools, even in those pools melting earliest in the season. The lowest temperatures we encounted was a mean of 5.7°C over a 48-hr period, and it is possible that snow pools with mean temperatures lower than that might be encountered. The opinion of Burges (1982) is that reports of diminished efficacy of *B.t.i.* in the literature are due to reduced feeding activity of the test insects. This may be true especially for laboratory testing at temperatures below those commonly encountered by the test species in nature, but the report of Lacey et al. (1978) would suggest that other factors are involved, at least for black flies.

Although the field tests reported here indicate that time of day is not a critical factor for application, seasonal timing appears to be very important, and the ability to reach breeding sites while larvae are in early developmental stages may be a limiting factor to the success of control programs. It is obvious that we failed to lower the density of adult mosquitoes substantially in the Shadow Bay Campground of Waldo Lake by larviciding. Several factors appear likely causes of this failure. Inspection of data for 1982 and 1983 suggests that thorough control of larvae in the treatment zone must be completed within 20 days of their first appearance, probably by July 10–15 most years at Waldo Lake. We did not treat all pools by this time and many mosquitoes emerged. Although we are confident that we reached and treated nearly all pools containing mosquitoes in the treatment zone, it is impossible to be certain that some pools went undetected. We used aerial photographs extensively in initial surveys, but 35% of the sites we eventually sprayed were invisible in these photographs, and another 24% were barely visible. The fact that little or no apparent reduction in the adult population was achieved suggests that dispersal of adults into the sampled area from outside of the treatment area also was a major contributing factor. Additional evidence of this is the mark-release-recapture study showing that *Ae. communis* complex females do fly at least 2 km, well within the range of a major breeding site which was not treated. This is further supported by the sharp increase in numbers of this species showing up in collections at Shadow Bay Campground which coincided closely with the appearance of heavy concentrations of pupae at the South Waldo Marsh. Dow et al. (1965) found that dispersal of *Culex tarsalis* adults into an area in California where intensive larval control had occurred reduced the effectiveness of the treatment.

In spite of our failure to demonstrate its effectiveness, we feel that larval control with *B.t.i.* may have promise as a practical and safe means of mosquito abatement in subalpine situations where high use or development justifies the costs involved. Additional studies are needed, and comprehensive local studies would have to precede any control programs. For treatment to be successful, seasonal timing must be carefully planned, and if necessry, special means of transportation must be utilized to reach treatment sites. Large breeding sites within the vicinity of areas to be protected must be treated if evidence indicates substantial migration of adult mosquitoes from such areas. These studies suggest that mosquito control in mountain environments is a very complex undertaking, and that an integrated pest management approach is the best means of achieving success.

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